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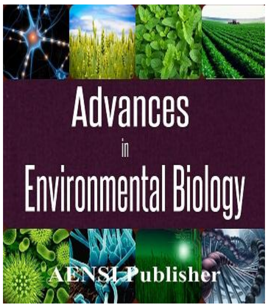

Investigating Dimensions of Chinks and Depth of Light Penetration in Relation to Heat Convenience of Local and Current Residential Buildings of Shiraz

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ABSTRACT

The present research aims at investigating location and dimensions of light–passing walls, windows and canopies to assess the depth of light penetration in key areas of the building, the amount of natural daylight received, the amount of heat energy of sun received through the windows and its influence on the internal temperature compared to convenient temperature in Shiraz. In local residential buildings' architecture, all the southern walls of key living spaces follow similar pattern in structure and the form of building. This often results in similar dimensions and sizes and consequently similar temporal situations in buildings, despite the fact than in current residential architecture, the form and structure of buildings is various. The question here is that if the size and dimensions of windows and consequently the depth of light penetration in old and current building had been efficient in achieving head convenience. According to the structure of the building, we used Daffy formulas to determine certain values and figures. We then will calculate the amount of light penetration in space in cm, and the amount of energy received in space in $Cal/min/cm^2$. In continue we will compare samples of current and old residential buildings and will determine optimum and responding samples to climate situation and some efficient points pertaining to window and canopy designing will be presented.

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INTRODUCTION

The mechanism of buildings can be resembled to human body system. Building material, like human skin, balances the internal and environmental temperature. Windows, like ears and eyes, enables the building to see and breathe. In Persian, terms "window" and "chink" are used rather similarly to refer to transparent and light – passing parts of a building. The word window, "Panjereh" in Persian is rooted in "Panjara" that means cage [10]. The window is used for receiving light, seeing out doors and air conditioning. The existence of light will influence the quality of internal space in two ways: first, changing the quality of vision [13] and second, the ability of indirect attraction, motivation, position, behavior and balance of human hormones [4]. The role of windows in air conditioning and receiving energy of sun for heating is one of their important features. In recent years, the world has faced so many problems such as deficit fossil energy and climate change as the result of using such energies [15]. Thus, accurate use of windows as an efficient local element is important. So we will assess the dimensions of space, walls and light – passing windows in order to investigate the depth of light penetration and amount of thermal energy of sun.

Methodology:

According to the topic and the points under the investigation, the present research is theoretical and functional in terms of aims. We will move toward the extension of science boarders and also will seek to present new functional – scientific patterns for current architectural usages. In this field, we will use deductive logic. To carry out the research, we chose current residential buildings and old residential buildings using conventional architectural patterns and sought to answer the question and realize the aim of the research. The initial data

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collection was done using survey method. According to the instruments and research method, the purposes of the present research are quantitative. The procedure of the study is presented as below:

- General characteristics of building were provided through interviews with residents and owners.
- Plans, dimensions and sizes related to windows and canopies were captured accompanied by professional planning team using Laika D510 Laser tape measure.
- The direction and the angle of the windows were calculated using Compass geographic navigation tool.
- The temperature in every space was determined in 21^{st} of Jun using Maximum- Minimum thermometer qualities – etzeusnis (T. F. A)
- In order to investigate the depth of light penetration, determining angels of sun in the sky was calculated using Sun Tools software and consequently the time of maximum and minimum altitude were chosen.
- The height of shadow in 21^{st} of December and Jun was determined using Kasmaei's formula for depth of light penetration.
- The shadows were drawn in AutoCAD software and the level of shadow and light receiving of every window were calculated.
- The amount of energy received on crossing surface to sunlight was calculated using Stevenson's formula.
- Then, the amount of energy received by the walls of building was calculated in every square centimeter in the position of buildings by Schbell formula.
- And then, according to the surface areas receiving thermal energy of sun in every window, the total amount of energy received by the space was calculated and then, the relation between the given elements was analyzed and compared in order to understand the effect of chink dimensions on the depth of light penetration in residential buildings and its relation with heat convenience in Shiraz.

Population of the study:

Shiraz is one of the biggest cities in south of Iran which has semi – arid climate with latitude of 52°33" and longitude of 29°33" and 1941m height from sea [3]. Shiraz with 1640665 residents in 2011 and 6049 km^2 of area is one of big and populated cities in Iran. This city is located in semi – arid area and has partial moisture level of 19 – 65 percent and average annual precipitation of 304.9mm (Iran's national statistics portal, 2014). This city, with its long history, has its own specified residential architecture during various historical eras. Climate based residential architecture is observed in the forms of central yards or granges surrounded with gardens. This pattern was built in crowded areas of the city in contemporary era. This might be the effect of commanding time and place dimensions on architecture identity in every era [14].

Samples:

The study samples in the present research are selected and categorized in two main groups. The first group studies the location and features of old buildings in Ghajar era as local residential building samples and the second group studies the current residential buildings. The samples of current residential buildings are selected based on their specific skeletal characteristics related to receiving light from light passing walls. Table2 shows the local building sample features and table 1 shows the current building sample features.

Position Of The Sun In The Sky:

Window is the most important element having role in letting light into the building. The major share of light and direct sunshine is received through chinks. The amount of light received in the buildings depends on different factors and situations. These factors can be categorized in three groups. The first group is related to the position of building on the earth, the second group is related to the location of building and the third is related to the type of windows and canopies. The affecting factors on the first group are latitude and height from sea level, for the second group: the direction of building and light passing walls and for the third group are the dimensions of window and canopy and the relation between these two elements. In order to analyze the amount of light penetration in the building we need to investigate the effects of all dependent variables simultaneously in all three groups. The motion of light photons is consisted with the movement of sunshine, so we can analyze the amount of light received by each space. Thus the position of sun in relation to the building is specifically important. The position of the sun in the sky can be determined by two angles. One is the angle of the altitude which shows the distance between a vertical line on viewer's eye and the sun which is presented with z. and the second is the azimuth which is presented by β. The position of the sun in the beginning of winter (21^{st} of December) is the lowest height and in the beginning of summer (21^{st} of Jun) is the highest position in the sky. So the position of the sun in both days is considered as the minimum and maximum of light penetration. Table3 shows the height angles and the direction of sunshine in 21^{st} of Jun when the sun is in the sky (from 5:32 to 18:32) and table4 shows the height angles and the direction of sunshine in 21^{st} of December when the sun is in the sky (from 6:48 to 16:55) in one-hour time span.

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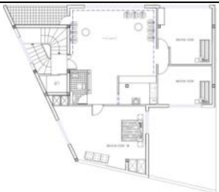
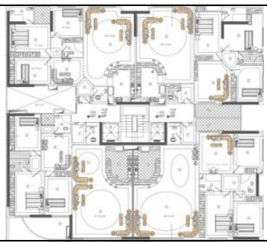
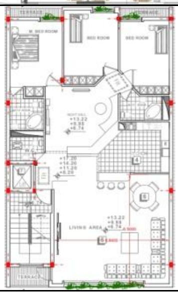
Table 1: The characteristics of the current residential building samples.

	Plan	Building name	Date of construction	Geographical position	Geographical direction	Selection criteria
1		Farhang – e - shahr	2011	Shahid Rajaei	South – north	Southern windows with small size dimensions
2		Alvand	2003	Maali abad	Northeast – southwest	The winner of energy oriented building design award
3		Heram – e – nour	2013	Maali abad	Southwest – northeast	Southern louver canopy
4		Nazar boland	2012	Maali abad	Southwest - northeast	Southern window with no canopy
5		Moshir – e – gharbi	201	Moshir – e – gharbi	Southwest – northeast	Window framework set as canopy

The position of canopy and window:

Regarding the position of current buildings in land separation, these buildings are surrounded by neighboring buildings from west and east, so they do not receive sun light from east, west and even north. Hence, the south face of the building is the most important face regarding light penetration into the building and receiving energy. In order to investigate the depth of light penetration in samples, the main spaces of each building were selected as living space or rooms. The dimensions of the window, the height of window from ceiling and floor and also the type and dimensions of canopy are the most important and effective on the depth of light penetration into the buildings. In addition to the dimensions and types of windows and canopies, the dimensions of building spaces are the most effective in relation to the windows. Table5 shows the characteristics and dimensions of each window in current buildings under the study and table 6 shows the characteristics and dimensions of window in traditional building samples.

Calculating The Height Of Shadow And The Depth Of Light Penetration:

In order to calculate the depth of canopy, we can use carious methods. Among those we can use Olgyay shadow mask drawing method which is determined according to need of light during all year [12]. Calculation method is another way. Formula1 is used to determine the depth of canopy with calculation method. In this formula D is the depth of canopy, H is the height of shadow which is formed on the window due to the depth of canopy, Z is the direction of light, N is the angle between vertical line on the window and real south and β is the height angle of light [9]. Because the canopies exist in the previous researches, we use canopy calculation method to obtain the amount of light passing from windows into the building. In the present study, in equation 1, the depth of canopy is considered as the active variable and the height of the shadow is the passive variable and we use equation1:

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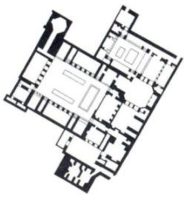
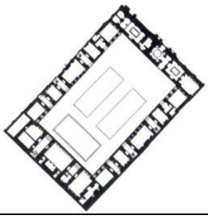
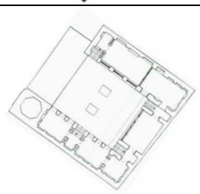
$$D = \frac{h\cos(z+N)}{\tan\beta} \quad (1)$$

$$h = \frac{D\tan\beta}{\cos(z+N)} \quad (2)$$

Table 2: The characteristics of local residential building samples.

	Plan	Building name	Date of construction	Geographical position	Geographical direction	Selection criteria
1		Zinat - al - molk	1911	Lotf ali khan zand	Northwest-southeast	Historical value, rich culture, static architecture techniques
2		Forough al molk	Late Ghajarian	Sange Siah region	Northwest - southeast	Historical value, rich culture, static architecture techniques
3		Haj mahya	Late Ghajarian	Sange siah region	Northwest - southeast	Historical value, rich culture, static architecture techniques
4		Khalili	Ghajarian	Gha'ani ave.	Northwest - southeast	Historical value, rich culture, static architecture techniques
5		Mohtasham	Late ghajarian	Shahpour ave.	Northeast-southwest	Historical value, rich culture, static architecture techniques

In order to calculate the depth of light penetration, we will extensively discuss the process of calculation in sample 1 of current residential buildings. First we calculated the height of shadow in 21st of December on 12 pm when the sun is at its highest point using the height angle and sunshine in winter and also the characteristics of the window through equation 2 as following. The height of shadow in this building in a winter noon was 25cm and in a summer noon was 305cm. we then determined the depth of light penetration in the noon of 21st of December in winter situation and in 21st of Jun in summer situation based of the depth of canopy and height of shadow formed as is shown in figure 1. In the analyzed building, at 12pm in summer day (21st of Jun) the light is banned from entering the building. In this situation the depth of light penetration is equal to 0. At 12pm in winter day (21st of December) the amount of shadow is at minimum and according to equation 3, the amount of light penetration in the space is 162.2 cm.

$$h = \frac{30\tan 84.1}{\cos(-174+23)} \qquad h=305$$

$$h = \frac{30\tan 37.2}{\cos(-177+23)} \qquad h=25$$

$$tanx = \frac{25}{30}$$

$$l = \frac{h}{\tan x} \qquad x=39.8 \text{ and } L= 162.5 \quad (3)$$

Table 3: The Altitude and the Azimuth in 21st of Jun.

21st of Jun Latitude 29.3° Longitude 52.3°	Sunrise: 05:01 Evening: 18:53	
Time	Altitude	Azimuth
6	11.7	69.6
8	37	81.5
10	63.1	95.7
12	84.1	-174.5
14	62	-94
16	36	-81
18	10.7	-69

Table 4: The Altitude and the azimuth in 21st of December.

21st of December Latitude29.3° Longitude 52.3°	Sunrise: 06:48 Evening: 16:55	
Time	Altitude	Azimuth
8	13.2	126.9
10	30.7	149.9
12	37.2	-177.8
14	28.9	-146.4
16	10.5	-124.6

Table 5: The characteristics and dimensions of light receiving spaces in current buildings.

	Space				Window					Canopy			
	Temperature	Length cm	Depth cm	Height cm	Direction degree	Length cm	Height cm	Distance from ceiling	Distance from floor	Type	Length cm	Width cm	Height cm
1	37°	37°	350	264	23 ° SE	150	150	17	100	Window frame	150	30	-
2	34°	34°	806	253	64° NE	260	226	27	0	Horizontal	250	185	253
3	36°	36°	990	252	30 ° SW	451	162	70	20	Louver	15	-	-
4	37.5°	37.5°	1000	270	35 ° SW	520	180	0	90	-	-	-	-
5	37°	37°	650	280	30 SW	460	170	0	110	Window frame	460	40	-

Table 6: The characteristics and dimensions of light receiving spaces in traditional buildings.

	Space				Window					Canopy			
	Temperature	Length cm	Depth cm	Height cm	Direction degree	Length cm	Height cm	Distance from ceiling	Distance from floor	Type	Length cm	Width cm	Height cm
1	34°	752	460	300	30° SW	94	250	50	0	Sun deck	750	290	300
2	34.5°	918	425	302	30° SW	120	290	12	0	Window frame	120	116	300
3	34°	560	380	298	43 ° SW	63	270	28	0	Window frame	63	60	270
4	33°	550	400	300	35 ° SW	120	280	20	0	Window frame	120	90	280
5	33°	470	330	300	30° SE	80	280	10	0	Window frame	80	80	290

According to the mentioned phases and using equations 1 to 3, the height of shadow is calculated regarding the position and the characteristics of canopies and windows in 10 sample buildings and is shown in table7. In the current residential buildings under the investigation, building no2 had no direct light in internal space in both winter and summer situation while the light direction in north; so, there is no light penetration. In building no3, louver canopy is used in southern face and the need of shadow on the window is met, but in this situation there is no possibility for light to penetrate into the building, because the building is faced to north. In the building no4, there is no shadow on the window because of no canopy and light penetration into the building is based on the angle of sun height. In buildings no 1 and 5, deep window frames served as a canopy for window and formed shadow on the window in the 21^{st} Jun at noon. In addition the possibility of light penetration in winter is much more. In all local building samples, windows are big and their height is as large as the space, all extending from floor to the ceiling. In this situation, not only the light penetration exists in both winter and summer, but also the required shadow is provided in summer. Table 7 shows the amount of light penetration and the amount of vein depth of natural light into the internal space of building according to the dimensions of the space in the noon of 21^{st} of December and Jun.

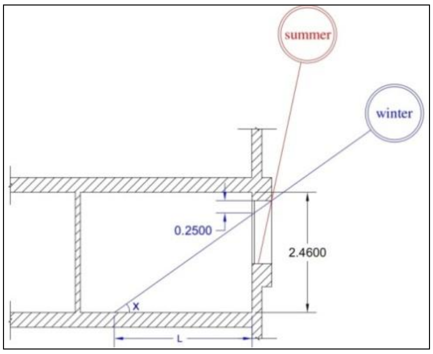


Fig. 1: The depth of light penetration in current building no1.

Table 7: Height of the shadow and depth of light penetration in the sample buildings, 12pm of 1^{st} day of Jun and December.

		12pm in 21^{st} of December			12pm in 21^{st} of Jun		
Current building	1	Height of shadow cm	Depth of light penetration cm	Depth of space cm	Height of shadow cm	Depth of light penetration cm	Depth of space cm
	2	25	162.5	3.50	305	0	305
	3	0	0	806	0	0	806
	4	15*11	0	909	15*178	0	909
	5	0	350	10.46	0	27	10.46
Local building	1	30	329	650	400	0	650
	2	215	403	290	302	35	290
	3	86	413	425	308	36	425
	4	48	362	380	270	32	380
	5	67	370	400	280	33	400

Calculating the amount of energy received in direct light receiving surfaces:

Formation of shadows on windows and glass surfaces impedes the entrance of direct light into the space. As a result, the heat beyond the glass, which is caused by sun light, decreases significantly. This amount of decrease depends on the place and amount of shadow. When it is formed on the external surface of the window, very few amount of energy is transferred beyond the glass, because the heat transfer is done via radiance and conductivity. Conductivity is rarely happened through glass and transparent surfaces like glass do not convey high frequency waves. Regarding the windows and canopies in sample buildings under investigation, receiving direct light in the first afternoon of December exists among all samples except for samples 2 and 3. The amount of received energy form windows differs by the position, dimension and amount of window surface which is imposed to sun light. In order to determine the amount of energy received from light receiving surfaces we use equation 4. In this equation In is the heat resulted from direct and vertical sunshine in $BTU/h/ft^2$, I is the constant sun figure (constant sun figure is that amount of radiance heat received by $1cm^2$ of surface vertical to the direction of sun light), α is darkness coefficient, and h is light angle which is equal to 4.429 $BTU/h/ft^2$ or 1.93 $Kcal/min/cm^2$.

$$In = I(-\propto \sin h) \quad (4)$$

According to the fact that vertical sunshine is just feasible in latitudes of 0 to +23.45 and 0 to -23.45 and samples under the investigation are located in latitude of 29° the amount of received energy in this condition is calculated using equation5. In this equation, *Is* the light shone on southern walls, *In* is the light shone on the surface vertical to the light, *h* is light angle, and *z* is light direction. Calculation of this equation is done per $1m^2$ of surface receiving direct light and the reflected energy is ignored. According to the fact that walls under the investigation are southeastern or southwestern, the effects of wall declination are used through equation6 for southeastern walls and equation 7 to calculate the energy in southwestern walls. In this equation θ is inclination angle of wall from south to east and west [5].

$$Is = In. \cos h \cos z \quad (5)$$

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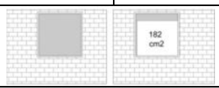
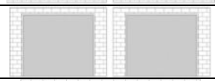
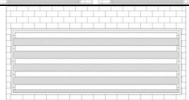
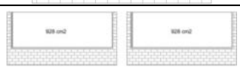
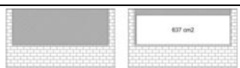
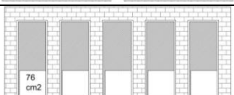
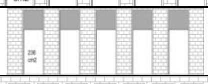
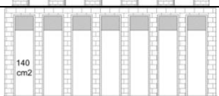
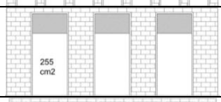
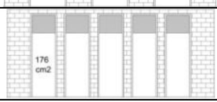
$$Ise = In.\cos h\ (\cos z + \sin z)\cos\theta \qquad (6)$$
$$Isw = In.\cos h\ (\cos z + \sin z)\cos\theta \qquad (7)$$

The results obtained from calculations, includes the amount of light receiving surfaces in the first noon of December and Jun, the amount of energy received from building walls in surface unit and also total amount of received energy from the surface of window which are shown in table 8. In this table, firstly we drew each shadow on windows according to the type of canopy in the noon of 21^{st} of December and Jun and next the light receiving surface was determined in every window. Then, according to the presented equations, we calculated the amount of light received on $1m^2$ of surface. Hence, the total amount of energy received from the surface of the window is calculated in summer and winter mid days. In the calculation table, the amount of thermal energy received in summer is shown by light color and that of winter is shown by dark color. According to the data in table 8, there is a direct relation between the depth of light penetration and receiving the energy of sun. In a way that in building no3, louver canopy provides the total required shadow in summer but the depth of light penetration and also the amount of thermal energy and sun light is equal to 0. In contrary, in sample4, the current building – without canopy- specifies major part of light penetration and sun energy to itself. In building 1 among local buildings, the amount of light penetration into the building is decreased due to the deep sundeck, and as a result, it has the lowest amount of thermal energy among local buildings. Finally, current buildings, in spite of various shapes and different patterns in designation and types and forms of windows in living spaces, lack natural day light or thermal energy of sun during winter. Also buildings which have no canopy, not only receive thermal energy during winter, but it receives some excess lights during summer. The depth of light penetration is among positive points of receiving light from windows due to the thermal energy and natural daylight received during winter. However, controlling the amount of direct light received through windows in summer is necessary to balance the temperature of internal space in the building.

Table 8: The amount of energy received from every light-crossing wall of Traditional and current buildings.

	Shadow and sunlight surfaces		The amount of energy received Cal/min/cm^2	Energy receiving surfaces cm^2	the amount of energy received
	1^{st} of Tir	1^{st} of Dey			
1 C			$1.93\times\cos 84.1\ (\cos -174.5+\sin -174.5)\cos 23 = 0.19$	-	-
			$1.93\times\cos 37.2\ (\cos -177.8+\sin -177.8)\cos 23 = 1.46$	182	265.7
2 C			$1.93\times\cos 84.1\ (\cos -174.5+\sin -174.5)\cos 64 = 0.09$	-	-
			$1.93\ \times\cos 37.2\ (\cos -177.8+\sin -177.8)\cos 64 = 0.70$	-	-
3 C			$1.93\times\cos 84.1\ (\cos -174.5+\sin -174.5)\cos 30 = 0.18$	-	-
			$1.93\times\cos 37.2\ (\cos -177.8+\sin -177.8)\cos 30 = 1.38$	-	-
4 C			$1.93\times\cos 84.1\ (\cos -174.5+\sin -174.5)\cos 35 = 0.17$	928	157.7
			$1.93\times\cos 37.2\ (\cos -177.8+\sin -177.8)\cos 35 = 1.31$	928	1215.6
5 C			$1.93\times\cos 84.1\ (\cos -174.5+\sin -174.5)\cos 30 = 0.18$	-	-
			$1.93\times\cos 37.2\ (\cos -177.8+\sin -177.8)\cos 30 = 1.38$	637	879
1 L			$1.93\times\cos 84.1\ (\cos -174.5+\sin -174.5)\cos 30 = 0.18$	-	-
			$1.93\times\cos 37.2\ (\cos -177.8+\sin -177.8)\cos 30 = 1.38$	380	524.4
2 L			$1.93\times\cos 84.1\ (\cos -174.5+\sin -174.5)\cos 30 = 0.18$	-	-
			$1.93\times\cos 37.2\ (\cos -177.8+\sin -177.8)\cos 30 = 1.38$	1180	1628
3 L			$1.93\times\cos 84.1\ (\cos -174.5+\sin -174.5)\cos 43 = 0.15$	-	-
			$1.93\times\cos 37.2\ (\cos -177.8+\sin -177.8)\cos 43 = 1.32$	98	129
4 L			$1.93\times\cos 84.1\ (\cos -174.5+\sin -174.5)\cos 35 = 0.17$	-	-
			$1.93\times\cos 37.2\ (\cos -177.8+\sin -177.8)\cos 35 = 1.31$	765	22.5
5 L			$1.93\times\cos 84.1\ (\cos -174.5+\sin -174.5)\cos 30 = 0.18$	-	-
			$1.93\times\cos 37.2\ (\cos -177.8+\sin -177.8)\cos 30 = 1.38$	880	27.36

Conclusion:

In the present research we investigated local and current residential building samples in terms of depth of shadow making and receiving natural daylight, dimensions of window and shadow making in summer and winder in order to understand the exact amount of energy and natural light received, the amount of energy received by windows and the depth of light penetration and also temperature situation in internal spaces by each residential building compared to convenience temperature. According to the results, the local building samples follow a specific pattern in the shape of windows and space designation and canopy. Following efficient and union pattern in local residential buildings results in forming acceptable and effective dimensions in space designation in order to receive thermal energy of sun, natural daylight and not receiving unnecessary light during hot days of year. However, in current buildings, the pattern and specific instructions is not observed in space, window and canopy designation and no attention is paid to climate design and receiving thermal energy of sun and light. Of course, it worth mentioning that, in current architecture, the direction of building depends on street networks and land separation. However, designers are able to use appropriate techniques to receive the energy of sun regarding the direction of the buildings.

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