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DAYLIGHT ANALYSIS IN TERMS OF BUILDING DIRECTION AND ONE-WAY ROOF

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Abstract: The location of the buildings in the residential area is very important in protecting or benefiting from sunlight. The dynamic structure of the sun, which constantly changes according to time and seasons, directly affects the building's architecture and urban formation. Ignoring the sun's use of the structures during the construction of the buildings can cause significant disturbances to the residents. Daylight strategies, which are also influenced by climate, depend on the availability of natural light, determined by the latitude of the building site and the instantaneous conditions around the building. High latitudes have different summer and winter conditions, with lower daylight levels in winter. At these latitudes, designers often aim to maximize daylight penetration in buildings. In the tropics, where daylight levels are high throughout the year, the design emphasis is often on preventing overheating by limiting the amount of sunlight entering the building. Daylight availability depends not only on latitude, but also on the orientation of a building, and each facade and material of the building requires a different design importance. Therefore, daylight and architectural design strategies are two inseparable phenomena. In this respect, examining traditional architecture and successful natural lighting designs in the past is very useful for understanding climate-balanced building design. For this purpose, determining the roof slope according to the sun angle in architectural structures by calculating according to the location provides efficiency in many issues from energy efficiency to human health.

Keywords: Daylight, Building Direction, Lighting, Efficiency

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1. Introduction

Daylight lighting design in architectural lighting is a design that aims to bring the light entering the building together, taking into account the regional climate, latitude, mass, and location of the architectural structure, other structures in the region, and all surfaces that can reflect. In natural lighting calculations, natural light does not only consist of rays from the sun. Daylight is the sum of sunlight and light from reflection. In this sense, the sum of the direct sunlight of the sun and the effect of the light reflected from the sky on the earth constitutes daylight. In natural lighting design, environmental, geographical, and atmospheric conditions should be examined first. Thus, by calculating the shadows that may fall on the building at different times of the day and year, it can be decided from where the building will receive the optimum daylight (Aykal et al. 2011: Baker and Steemers, 2014 Kaynaklı et al., 2016: Kim and Kim, 2010: Kurtay, 2002). After deciding on the location, form, and height of the building, the daylight entering the interiors is optimized. In this sense, the function of the building, its openings, and interior reflectors will determine the amount and direction of daylight that will enter the building. There are many reasons why a building is illuminated by daylight, both subjective and objective. While natural lighting creates a pleasant and inviting effect in spaces, when designed correctly, it can improve the visual environment by providing a dynamic and enjoyable environment, increasing user satisfaction, improving circadian rhythm, and reducing the load of artificial lighting, thus saving energy. Parameters related to the location, environment, and volume of the building are effective in benefiting from daylight in buildings (Brown and Dekay, 2001: Oakley et al., 2000) The parameters related to the location of the building can be listed as the natural and artificial obstacles around it, the heights of these obstacles, and their light reflection properties. Parameters related to the building's environment are related to the orientation, form, and dimensions of the building, while parameters related to the volume are related to the form and size of the space, the position of the ceiling, the wall, and the dimensions of the building. ground. materials and furniture used in the space and their surface properties. With the right lighting strategies, users in the space can perform their visual activities without difficulty, make optimum use of daylight, create better health conditions, and increase performance for efficiency (Demircan and Gültekin, 2017: Yüceer, 2010: Canan, 2008).

2. Materials and Methods

2.1. Direction of Architectural Design by Daylight

Orientation refers to how a building is positioned relative to its changing paths during different seasons, as well as to prevailing wind patterns. The most important factors to consider to obtain a good orientation include the climate of the building location, the choice of the south façade for the building (if in the northern hemisphere), the sun angles, and the climate zone (Özmen, 2010: Cengiz and Cengiz, 2018: Phillips, 2004: Cengiz et al., 2015). The effects of climate change should also be considered for optimum building design. Some climates require passive heating, while some climates require passive cooling as the case may be. To create an energy-efficient building, energy-saving projects must be implemented during the construction process with the help of simulations at the design stage. Energy-efficient solutions should be used to reduce the environmental and economic effects of excessive energy use and to provide maximum energy savings in the building. For example, the orientation of the building is the most important parameter. Because in terms of energy costs, building orientation provides great savings in energy consumption. Apart from this, energy-efficient systems such as natural ventilation, Low-e glass, hot water production from solar energy, heat recovery, 30% better heat transmission coefficient on the walls, and high-efficiency lighting fixtures offer useful solutions. Figure 1 shows the perspective view, features, and solar path of a building modeled in the northern hemisphere.

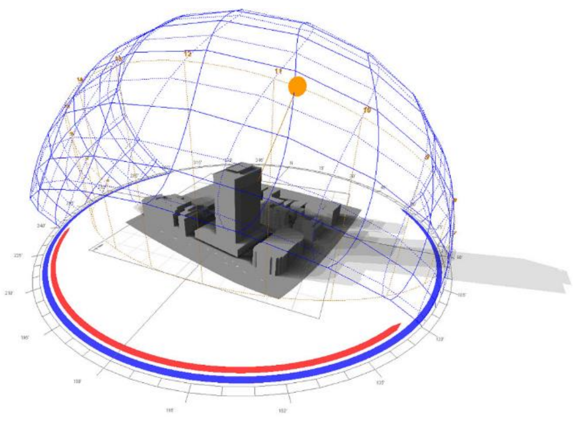

Figure 1. Perspective view, features, and solar path of a building modeled in the Northern Hemisphere (URL-1).

Suitable for passive heating is using the sun to heat a space in winter and keeping unwanted sun out in summer. Orientation for passive heating is best suited for places with a cold climate in winter. Passive heating of the one-way roof and south-facing window is shown in Figure 2.

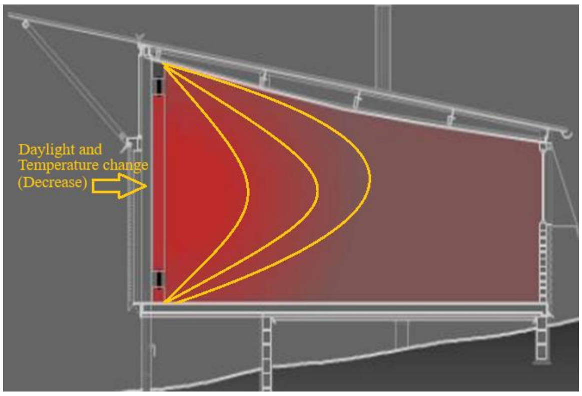

Figure 2. Passive heating of the one-way roof and south-facing window.

In a climate zone suitable for passive heating, living areas, and windows are placed on south-facing walls to let the low-angle (higher) winter sun in. Daylight efficiency is achieved by using horizontal shading devices to exclude the high-angle (lower) summer sun. Due to the movement of the earth, the sun moves from a low angle in summer to a high angle in winter. In terms of location, the best orientation for living spaces in Türkiye is south; however, directions up to 15° west of south and 25° east of south still allow good passive solar access.

2.2. Determination of Direction and Angle

2.2.1. Facade Direction and Sun Angles

The main sun access in Türkiye comes from the south side. In the passive house concept, when people talk about orientation, they mean how the house and especially the living spaces are oriented relative to the south. Solar south can differ significantly from magnetic south based on location. In addition, it will be necessary to determine the angle of the sun in different seasons for the region, because the position of the sun varies according to the regions. Knowing the angle of the sun at different times of the day and in different seasons causes the design of windows and shading elements to best capture or block the sunlight depending on the needs.

South-facing walls and windows receive more solar radiation in winter than in summer, as the sun is lower in the sky. East- and west-facing walls and windows get more sun in the early morning and late afternoon when the sun is lower in the sky in summer. The building design and south-facing walls will determine how much sun access the house will receive. Figure 3 shows the altitude positions of the sun in winter and summer.

The amount of solar access required varies by season and climate. Accordingly, if analysis is made for some climate scenarios; for a place with a hot humid (summer)-warm (winter), hot humid (summer)-temperate (winter), and hot dry (summer)-warm (winter) climate, the shading should be done on all fronts. Shading is a must to minimize direct sunlight. In a place where summer is hot and dry and winter is cold, the aim is to provide a balance of winter sun and summer shade for a place with a mild climate in all seasons. The south aspect of their habitat is preferred because the sun's position in the sky allows for full sun access in winter. In these climates, the south facades can be easily shaded with simple horizontal arrangements such as eaves in summer. In places like Bitlis, which have a cold climate in winter and a temperate climate in summer, the aim is to maximize the use of the sun. The south aspect of the living spaces requires making the most of solar access to heat the home, along with appropriate glazing and thermal mass. Solar access to south façades should be increased in regions with cooling breezes or high-altitude climates.

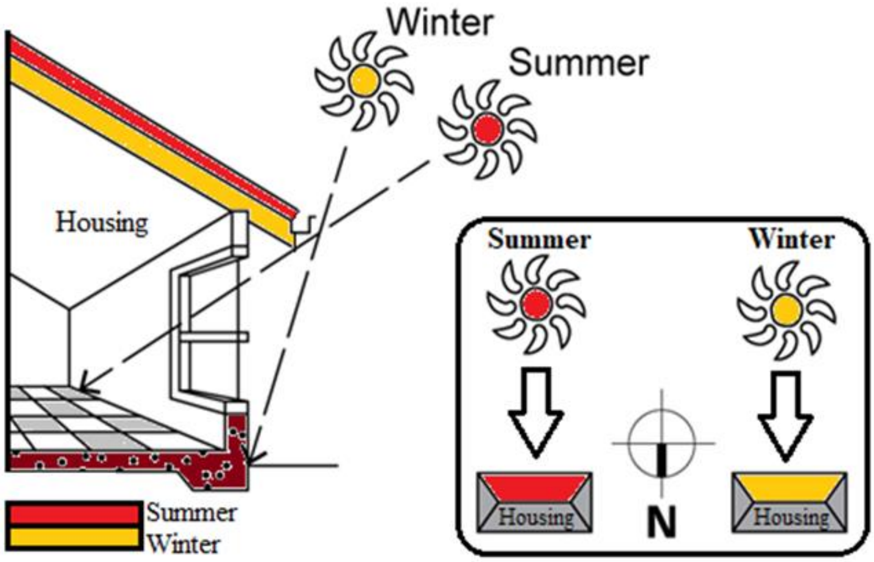

Figure3. Elevation positions of the sun in winter and summer.

2.2.2. Position Effect

When constructing a building, it is necessary to know the direction of the building. The orientation of the building will receive the sun at its highest efficiency when oriented fully towards the sun. Although it seems like a simple idea to make a building by directing the direction of the building to the sun; The sun is in different positions at different times of the year. It constantly changes during the day. Therefore, an optimal direction must be chosen (Costanzo et al. 2017: Efe and Varhan, 2020: Guzowski, 2000). For a country in the northern hemisphere, a south-facing setup provides optimal efficiency. The direction of the building is determined by the location of the place where it will be installed. In countries located in the northern hemisphere such as Türkiye, the direction of the Building is directed to the south. In countries located in the southern hemisphere, it is oriented to the north. For example, applications where the direction of the building is oriented east or west are wrong. In every city in Türkiye, the direction of the Building should face south.

The latitude value of the Building Location can be converted to the required tilt angle with the help of various formulas (Alshami et al. 2015: Bekkering et al., 2021: Beşiroğlu and Özmen, 2022). When the direction of the building is chosen optimally, it is ensured that it can benefit from the sun at the maximum level throughout the day. If the roof of the building will be used as a living space or if the light will enter the interior from the roof of the building, the slope angle of the building roof is calculated with the help of the latitude value. This angle is calculated by multiplying by 0.87 if the latitude value is less than 25. If the latitude value is between 25 and 50, multiply by 0.87 and add 3.1 degrees to the result. Since Türkiye is located between 36-42 degrees latitude, this calculation method should be used for all installations in our country. To be used in all cities in Türkiye, Equation 1 can be used for the slope angle calculation of the roof of the building.

$$\text{Optimum Roof Slope} = (\text{Latitude} \times 0.87 + 3.1) \quad (1)$$

The angle of inclination to be found with the help of calculation expresses the angle between the roof of the building and the ground. In other words, a zero-degree slope means full horizontal positioning, 90-degree building roof full vertical positioning. If a calculation is made for the location of Bitlis, which is the subject of this study; The latitude value is 38.39379 and the longitude value is 42.12318. Accordingly, the calculation is done as in Equation 2.

$$\text{Optimum Roof Slope} = 38.3 \times 0.87 + 3.1 = 36.42 \quad (2)$$

As a result of this calculation, for a building in Bitlis province, its fixed direction should be directed to the south and the slope of the roof of this building should be directed at an angle of 36.42 degrees. In this way, energy savings are achieved both in the south and in the optimum roof slope. The optimum angle of 36.42 degrees should be used since the roof on the building that transfers the daylight to the interior is fixed. Since Türkiye is located in the Northern hemisphere, one-way roofs for daylight are directed toward the South. Figure 4 shows a one-way roof.

Figure 4. One-way roof.

3. Results and Discussion

Differences in east and west orientation can have advantages. For example, in cold climates, orienting a space slightly west or south increases afternoon sun gains that are most desirable for evening comfort. But the southeast can warm the home's living areas more in the morning and increase daytime comfort. If it is accepted that the world will warm up more due to climate change, in warmer climates, directing the space to catch local breezes will increase comfort. The breezes may vary from region to region, depending on the local topography and climate zone. Poor orientation and lack of proper shading can prevent the winter sun from getting into the space. Or, as a result of the low-angle east/west sun hitting the glass surfaces at steeper angles, it can increase the sunshine duration and cause overheating in the summer. South-facing slopes may be better suited to moderate density if design strategies are used to overcome the effects of shading. For example, side walls can be designed to provide thermal buffers and smaller floor areas can be solar heated with carefully designed and shaded east or west-facing windows using the right type of glass. For passive heating, the ideal orientation for living spaces is 15° west and 20° east of true or solar south. Standard eaves overhangs will allow the winter sun to warm the building and let the occupants out of the summer sun without any effort or additional cost. Poor orientation can block out the winter sun and allow low-angle east or west sun to hit glass surfaces, causing overheating in the summer. Orientation for passive cooling keeps out unwanted sun and hot winds while providing access to cooling breezes. Some passive cooling is required in most hot climates. In hot, humid climates where the winters are not cool, orientation should often maximize access to cooling breezes while keeping out direct sunlight and radiant heat from nearby structures at all times of the year.

4. Conclusions

Orientation in architecture is the position of a space or house relative to the path of the sun and the prevailing wind in your area. Since the direction of the sun in Türkiye is in the south, the orientation is generally related to the living areas of the house facing south. This is because south-facing rooms get the longest amount of sun in winter and are easily shaded by roof eaves in summer. Optimum orientation significantly increases ambient comfort. It also contributes to energy efficiency and reduces the need for heating and cooling. The best orientation for a building is one suitable for the climate zone.

The routing requirement for a building's passive heating, passive cooling, or both should be selected according to the climate zone. The passive heating orientation maximizes the south exposure of walls and windows to prevent overheating during the summer months. However, it aims to keep the east and west fronts to a minimum. The orientation towards passive cooling aims to eliminate sun access and maximize access to cooling breezes with proper shading (particularly east and west). Orientation for heating in the winter and cooling in the summer should aim to maximize the southward exposure of walls and windows but block sun access in summer with suitable eaves and other shading. With careful design, good orientation can be achieved even in almost any structure. Good orientation is best achieved when purchasing or building a structure, but some improvements can also be made through renovation.

The warming of the earth's climate must be taken into account when deciding on the best orientation for a structure. Considering that extreme temperatures will be seen more and hot summers will be experienced more frequently, planning in this direction is essential. Passive heating is still highly desirable in most climate zones, but passive cooling is becoming more and more important.

Extra consideration should be given to exposing windows and walls (especially west-facing) to shading, wind directions, and other forms of natural cooling.

Author Contributions

The percentage of the author contributions is presented below. The author reviewed and approved the final version of the manuscript.

	M.S.C.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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