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Energy Efficiency and Thermal Comfort Analysis of Traditional Diyarbakır Inn

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Abstract—The traditional structures of Diyarbakır is reflect centuries of Mesopotamian culture interms of planning. Beside the walls of Diyarbakır, many buildings and traditional houseswere built with the most suitable materials and components depending on the climaticcharacteristics. It is easy to recycle to the environment because it is made of naturalmaterials and the design in which it conforms to the climatic and geographical structureof the environment in which it is located. In addition, it accommodates ecological andsustainable design criteria with its structure providing comfortable indoor environmentsthat can heat and cool without requiring additional measures. Nowadays, energy efficiencyand thermal comfort analyzes of these designs have been made with the engineeringsimulation program Autodesk Ecotect Analysis. In this study, thermal analysis and solarintensity of Sülüklü Han which was built in 1680 in different days, months and seasonswere investigated. National (BEPY) and international (ASHRAE) standards were evaluatedand simulated as a result of the simulations. Because fossil fuels have come to the end.With this study, energy efficiency of traditional buildings will be examined and energyefficiency will be provided for new buildings. Thus, maximum utilization of solar energy willbe achieved and energy saving will be achieved. title.

Index Terms—Traditional inn, thermal comfort, thermal analysis.

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1 INTRODUCTION

Building simulation has been an essential point within the energy research community of the 1970s [1]. Building simulation can be applied in a life cycle analysis of a building including design, construction, management, maintenance, and management. Today it is possible to create sustainable and ecological constructions by effective using of energy by means of specific standards. LEED takes the lead in related standards as well as it is a certification system that provides green buildings to be graded. Building simulations have played a unique role in predicting, evaluating and confirming the factors which affect the building about complication and interactions of components [2]. Literature has studies in this field. Ossen et.al (2008) reviewed thermal comfort conditions for constructions in tropical climates; they also explained design principles by analyzing passive cooling function via Ecotect program [3].

Sargentis (2009) et.al, compared ferroconcrete and soil material by single-story prototype model; energy consumption was evaluated in term of sustainability by using Ecotect simulation [4]. Rashwan (2013) et.al, analyzed energy gain and loss of arising from covering traditional construction in Egypt by nano thermal model (NTM) by benefiting from Ecotect program. It was found at the end of the analyses that there is an energy gain by 72% in comparison to the traditional construction [5]. The purpose of this study was to determine the energy consumption of Sülüklü Inn (in Diyarbakır Province) in basalt via building simulation program; evaluating the energy consumption within the context of sustainability was the other goal.

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2 MATERIAL AND METHOD

2.1 Basalt Stone Properties

The basic equipment in structures of constructions in Mesopotamia is the stone material that can be affluently seen in the region. The stone that has been used in Anatolian architecture and Diyarbakır as from ancient periods in priority position of architecture almost in all the periods. Other materials (brick, marble, wood, plaster, and tile) vary by function, importance and century of the building [6].

Original basalt stone is used in the structure-specific heat capacity; 1013 (J/kgK), thermal conductivity; 1.325 (W / mK) [7]. Basalt is the leading material that is used almost in all the building types without noticing function and size due to the geological structure of the region. This stone forms by hardening fluid and basic lavas in the shape of five and six-sided columns as perpendicular to the cooling surface. Related stones have colors which varying between dark grey and black. Basalt proofs water, acids, rustiness, frost, shocks, and frictions. It does not change color and has no extremely glassy characteristic. Therefore, there is not seen stain and hair crack a long time. This stone has been frequently used in buildings such as the walls with a length of 5.5 km, mosques, inns, bathhouses, madrasahs, houses and roads. Figure 1 shows the processing process of related stone.

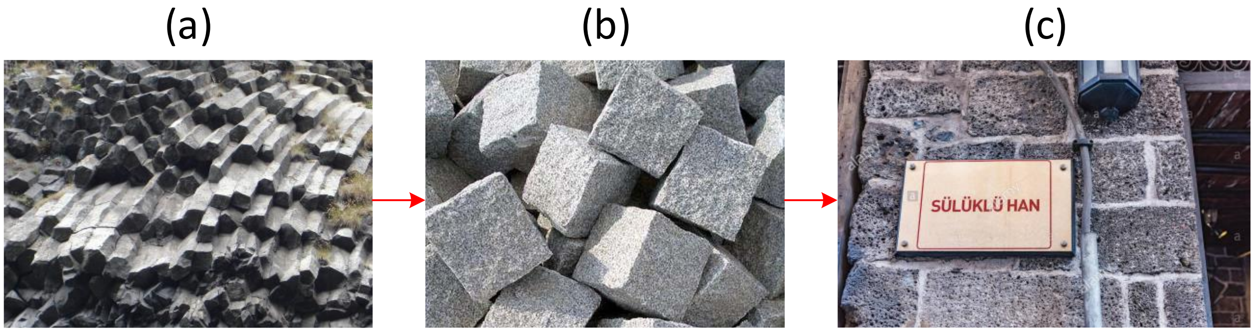

Figure 1. Basalt stone production process a) Basalt stone ore b) Stone cutting c) Constructional use.

2.2 Object of Experiment (Suluklu Inn)

Suluklu Inn was built by HanilioğluMahmutÇelebi and his sister, AtikeHatun in 1683. Sülüklü Inn with threefold where had 18 rooms on each floor and whose first floor was a cowhouse is single-layered now. The related inn was built in accordance with its period by using basalt just as many buildings within the wall [8]. A part of the building is functioned as a cafe after restoration. Entrance to the inn is provided by the large and big gate opens from the north. There can be passed to the garden via arced hallways. Rectangle garden is an area behind flat-arched porticos. The upper part of these places is covered by a ceiling joist. The ground is covered by basalt. There is a basement with a flat-arched gate at the north and south of the hallway that opens toward the garden. Basement at the north covers the building shaped like ‘’L’’. The inner part of the basement with tunnel vault is divided into two parts with arches. The basement at the south has the same characteristics with the other basement; there are three window openings toward the garden. Figure 2 shows the location of Sülüklü Inn within the wall (37°54'41.7"N 40°14’14.5"E).

Figure 2. Suluklu inn location in Diyarbakır.

2.3 Simulation Software (Ecotect Analysis)

There are several different ways to measure key performance. Thermal analysis shows the usage profile of thermal profile and calculation via data obtained from inner and outer parts of the building. Internal and external loads are required for providing sufficient information for thermal calculation in a construction. External load is obtained by air and climate; therefore, while weather condition data is statistically used in energy performance simulation, the internal loads come from people, lights and equipment in an area. Internal loads are substantially based on the actual use of an area at the same time [9].

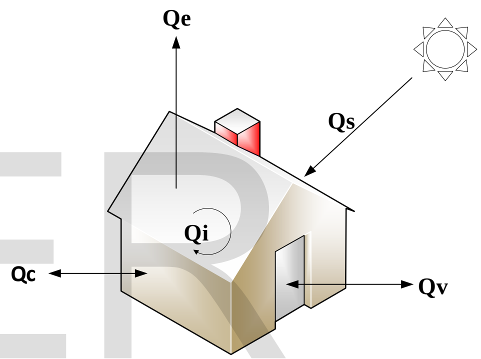

Figure 3. Thermal behavior of buildings.

Energy gain and losses are the factors which affect heat interchange. These losses are shown in Figure 3 and Equation 1 for a sample house. Hereby, Qi shows internal heat gain; Qc shows conduction heat gain or loss; Qs represents solar heat gain; Qv is ventilation heat gain or loss; Qe is evaporative heat gain or loss [10]

$$Qi + Qc + Qs + Qv + Qe = \Delta S \qquad (1)$$

ΔS in Equation 1 is the amount of heat balance stored. ΔS equals to 0 (ΔS=0) if there is a heat interchange. If ΔS>0, there is heating; if ΔS<0, there is cooling. The crucial energy gain in passive constructions in Equation 1 occurs by solar energy (Qs).

Title of ASHRAE Standard 55 – 2004 is determined as “Thermal Environmental Conditions for Human Occupancy”. These standard lays bare that people in a specific environment find related environment as thermal. There can be specified a comfort range for values of damp, airspeed, metabolic ate and garment insulation parameters. This comfort range can be determined in operative temperature that can provide acceptable thermal environment conditions [11].

Ecotect Analysis requires 3D graphic modeling of the project toward actualizing performance analysis. 3D model of Sülüklü Inn is obtained by relief drawings in Figure 4 to perform this modeling. Besides 3d modeling; there is a need for place zoning, material information, and climate data for thermal simulation of building [12].

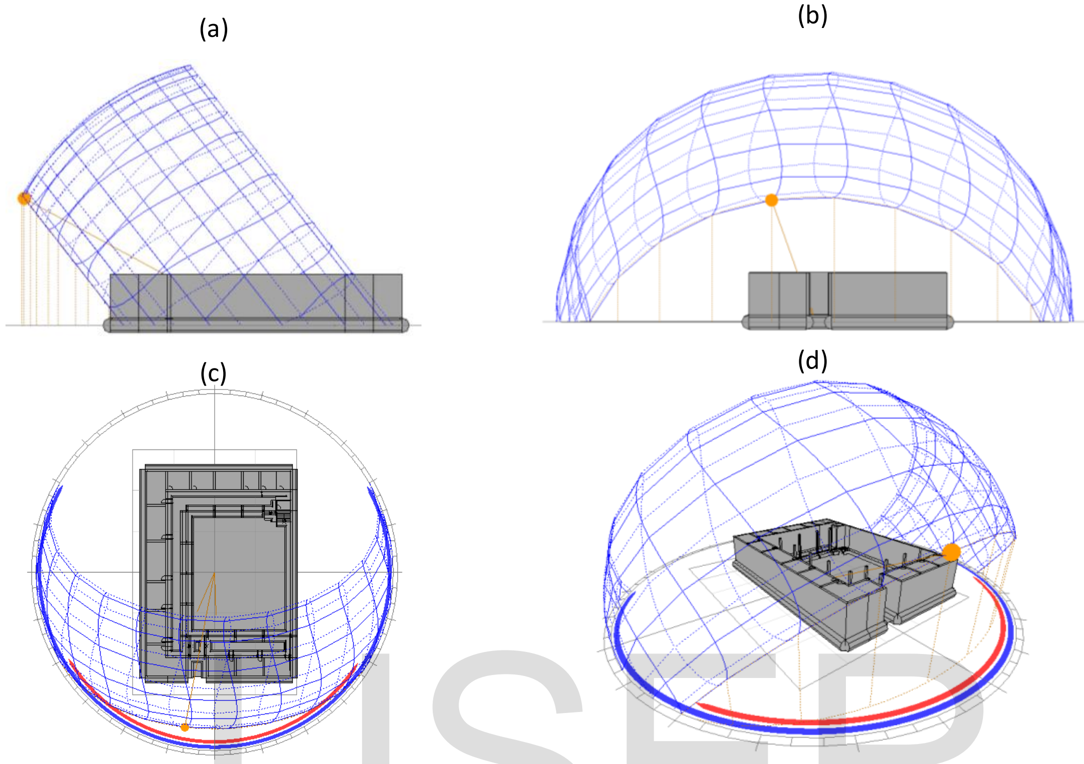

Figure 4.Suluklu Inn architectural drawing 31 December 12:00 Sun Path

a) Front b) Side c) Top d) Perspective

3 RESULTS

Realistic geometric plan of Historic Sülüklü Inn was analyzed in the simulation program. At the end of the analyses, the effect of the location of the inn and the material type in building on climatic characteristics of Mesopotamia.Figure 5 and Table 1 show energy gain/loss of Sülüklü Inn for a year from 1st January to 31st December. The maximum losses in the related process are the ventilation and conduction. So, ventilation losses are about 48.3%; they arising from wooden door and windows. Conduction losses are about 51.7%; they arising from thermal bridges, floors, roof, and wall. Heat gains which disrupt comfort in summer months are about 16.5% because of conduction; 16.2% because of ventilation. Passive solar radiation gains which affect the architecture of the building are about 36.1% for a year.

Temperature analysis of the construction in certain days was conducted; related analysis can be observed in Figure 6 and Figure 7. The red line indicates the hourly internal temperature change of the inn. The blue line indicates the outdoor temperature change. The green line represents wind speed within a day. The yellow lines show both diffuse solar radiation and beam solar radiation. Currently, the temperature change inside the inn remains within ASHRAE standards (18 C^0 – 26 C^0) without being affected by the external environment. This circumstance confirms that the related building is in proper comfort range without heating or cooling within a day

TABLE 1
GAINS BREAKDOWN - SULUKLU HAN

Category	Losses	Gains
Fabric	51.7%	16.5%
Sol-air	0.0%	36.1%
Solar	0.0%	6.4%
Ventilation	48.3%	16.2%
Internal	0.0%	24.8%
Inter-Zonal	0.0%	0.0%

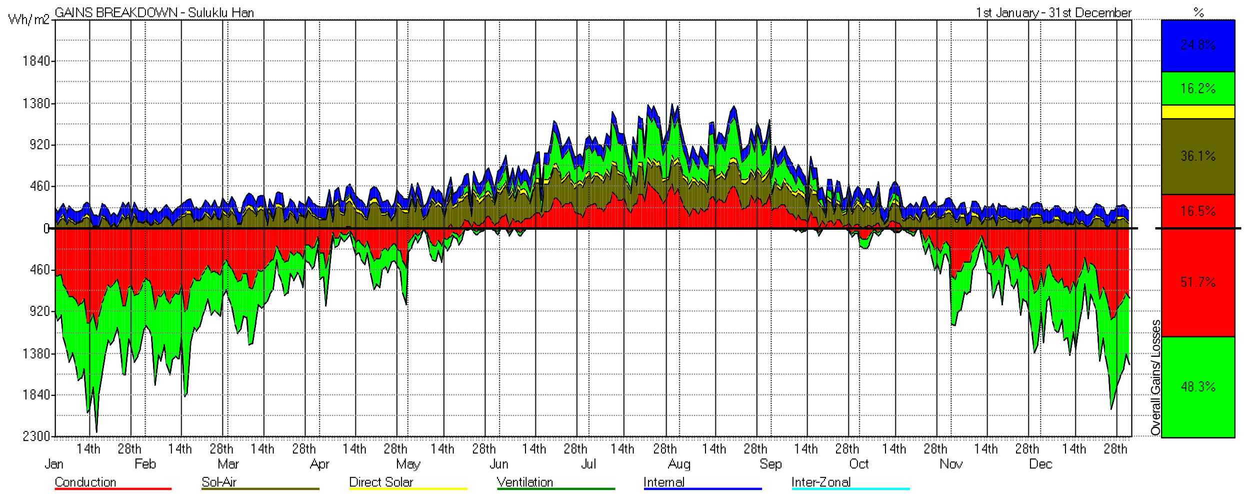

Figure 5. Thermal performance for Suluklu inn.

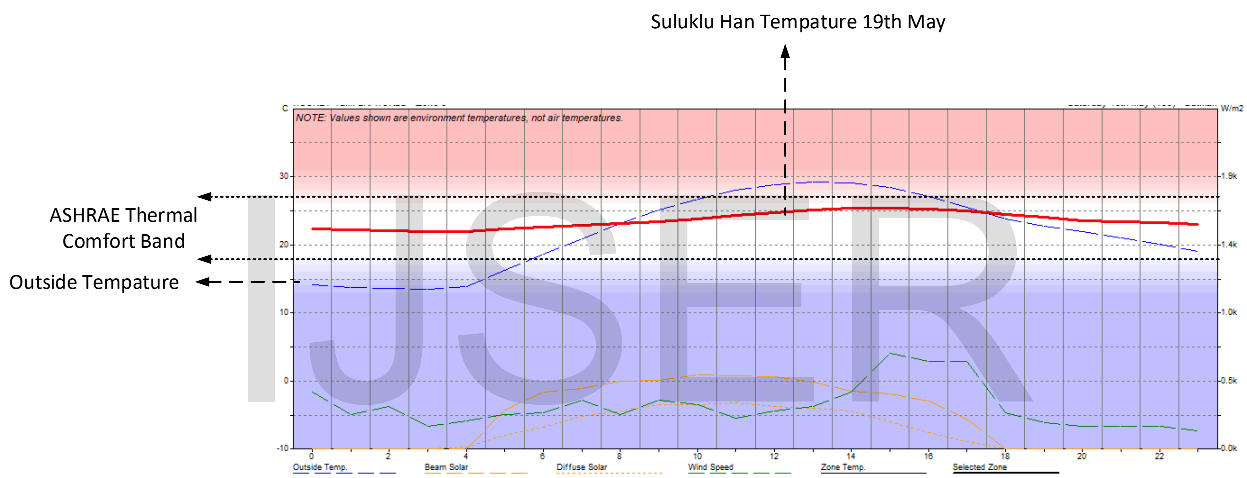

Figure 6. Hourly tempature (19th May).

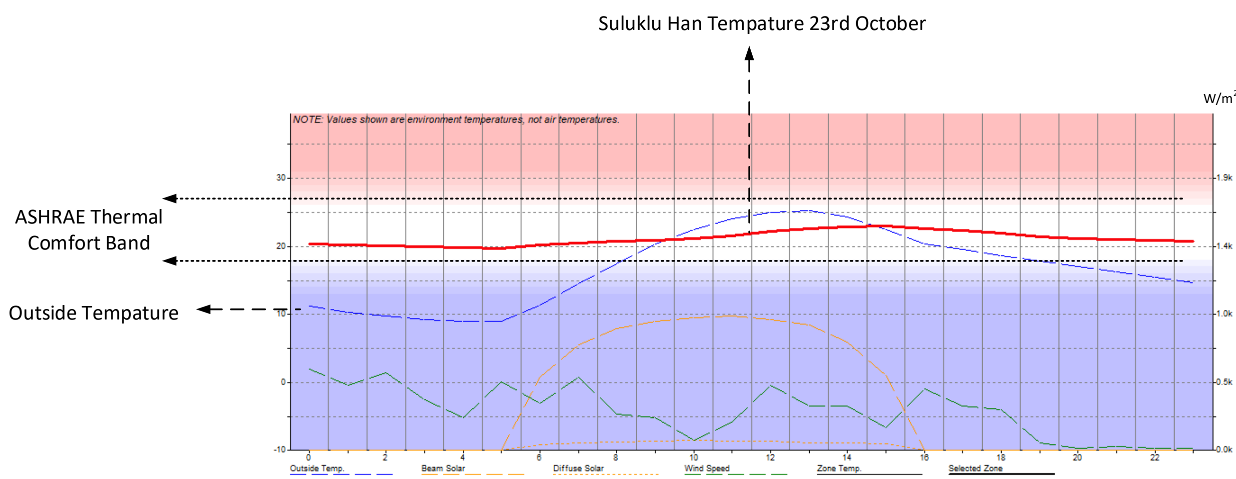

Figure 7. Hourly tempature (23rd October).

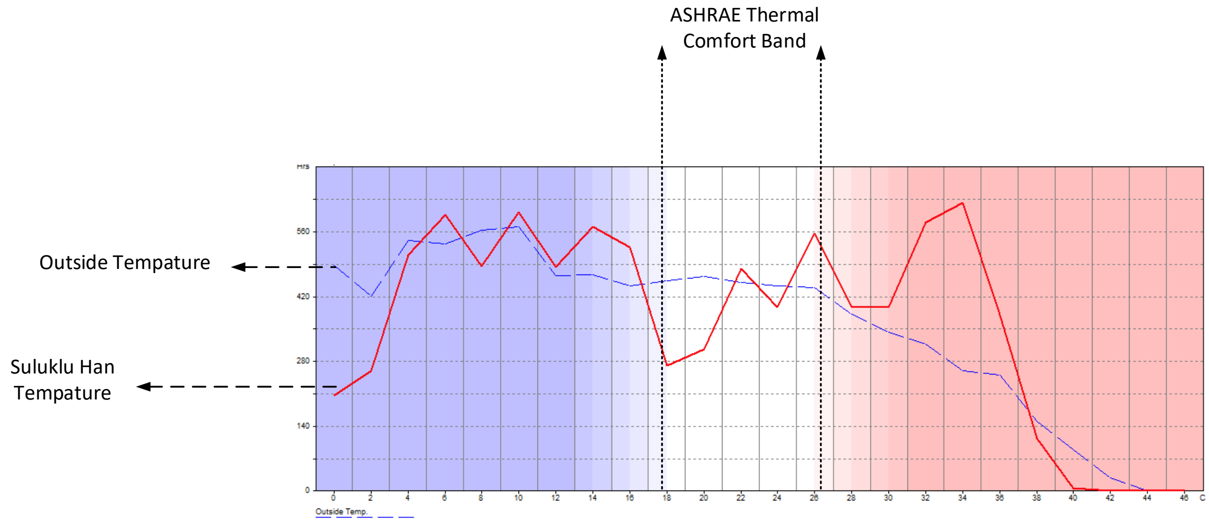

Figure 8. Annual temperature distribution.

Figure 8 shows the annual temperature profile of Sülüklü Inn between 18 C0 and 26 C0 comfort zone. The time within comfort bans has 2012 hours and 23% share in a year. Under these circumstances, there can be provided temperature values that are determined by standards without needing any heating or cooling.

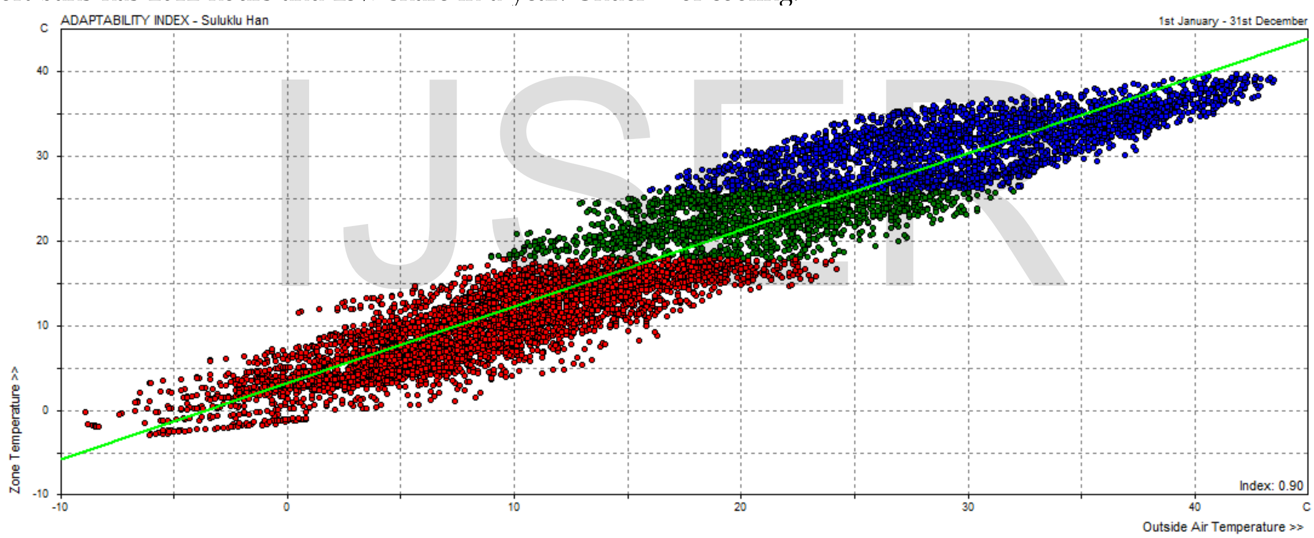

Figure 9. Passive adaptivity index.

The colors were used to plot the relationship between the Sülüklü Han temperature zone and outside temperature. Green represents times when both the zone/outside temperature fall within the defined thermal comfort band. Blue represents times when the temperatures are above the thermal comfort band (indicating a cooling load is required) While red represents times when the temperatures are below the thermal comfort band (indicating a heating load is required). Figure 9 shows Passive adaptivity index graphics. This value becomes 0.90 for the inn. Converging this value towards zero shows us there is no necessity for an extra effort for heating or cooling.

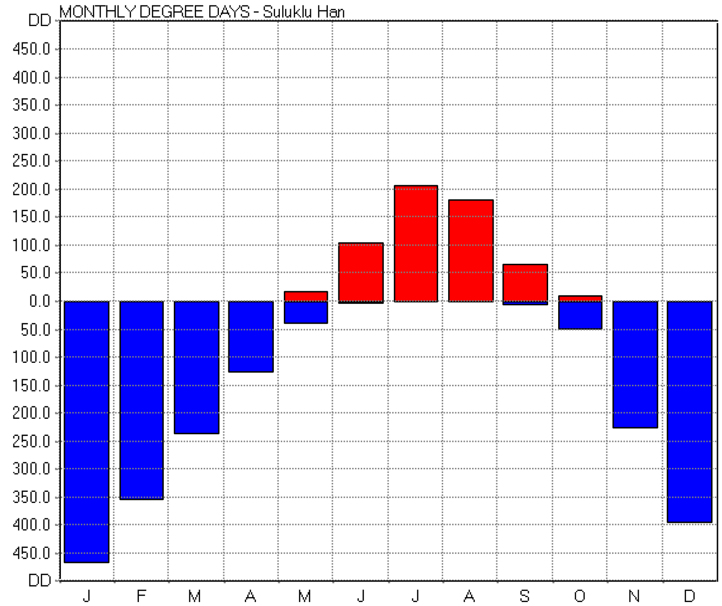

Figure 10. monthly degree days-Suluklu Han.

TABLE 2
MONTHLY DEGREE DAYS

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heat	466.7	352.8	235.5	126.5	39.4	3.1	0.0	0.0	4.7	48.9	225.7	394.0
Cold	0.0	0.0	0.0	1.0	18.5	105.0	206.4	181.9	67.3	11.0	0.0	0.0

Annual required heating and cooling loads are seen in Figure 10 and Table 2. With reference to calculations, there is a need for heating when it is under 18 C^0 ; there is a need for cooling when it is over 26 C^0. Blue columns in the figure show the time zone for heating; red columns show the time zone for cooling.

4 Conclusion

- This experiment examined the temperature characteristics sulukluhan through three types of indicators: Monthly Temperature Profile, Passive Gains Breakdown, and Passive Adaptivity Index.
- The Monthly Temperature Profile shows that, in winter and summer temperature in the sulukluhan is usually under and above the limit of the comfort band.
- While the temperature in spring and autumn the sulukluhan always equal the limit of the comfort band.
- This experiment shows the use in simulating interoperable digital mock-up to investigate indoor thermal efficiency.
- It provides an alternative on the evaluation of the indoor thermal simulation method based on energy determination especially for antics building.

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