Solar Radiation Gain in Modern House in Tripoli

Feeras Shawesh

online.feeras@gmail

Department of Engineering and Technology, Faculty of Architecture and planning, University of Aljfara, Al Swani Ben Adam, Libya

الملخص

المعترف به على نطاق واسع أن نهج التصميم المستدام هو وسيلة مهمة للتعامل مع التصميم المعماري بشكل عام .مع استمرار الأدوات التكنولوجية في التقدم والتطور، يعد مجال الهندسة المعمارية أيضًا جزءًا من هذا التطور المستمر. تهدف هذه الورقة إلى استكشاف التأثير المادي ومنهج التصميم المستخدم في تصميم منزل عائلي في طرابلس ليبيا .بالإضافة إلى ذلك، فإنه سيتم التحقيق في كيفية استخدام أدوات البرمجيات البيئية لتحليل البيانات التي تم إنشاؤها بواسطة هذه البرامج .ومن أجل ضمان دقة إدخال البيانات، من الضروري جمع معلومات حول موقع المشروع . يتم الحصول على البيانات المستخدمة في دراسة هذا المشروع محليًا. تتكون طبقات البناء من الطلاء الأبيض والجص والكتل الخرسانية والخرسانة المسلحة .المبنى نفسه عبارة عن هيكل مكون من طابق واحد، ويتكون من فراغات متعددة، لكل منها استخدام خاص به .يتم أيضًا أخذ عدد الأفراد والأنشطة داخل كل فراغ في الاعتبار عند تحليل بيانات في برنامج. سوف تعكس نتائج هذه الدراسة كيفية تصميم المبنى. كما سيكون التأثير كبيرًا على طريقة التصميم المستدام. البيانات التي يتم جمعها هي بيانات بيئة مثل والمواد والأنشطة داخل كل فراغ .في حالة استخدام نفس البيانات في هذه الورقة، فإن أفضل ممارسة لاستخدام التهوية الطبيعية المنزل هي بين الساعة 20:00 إلى 00:00 في فصل الصيف.

الكلمات المفتاحية: الإشعاع الشمسي: الكسب الشمسي، الإشعاع الشمسي المباشر، الإشعاع الشمسي غير المباشر، الكسب بين المناطق، مناخ طرابلس.

ABSTRACT

The sustainable design approach is widely recognized as an important method for approaching architectural design in a general. As technological tools continue to progress and evolve, the field of architecture is also a part of this ongoing development. This paper aims to explore the material impact and design approach employed in the design of a family house in Tripoli, Libya. Additionally, it will investigate how environmental software tools can be utilized to analyze the data generated by such software. In order to ensure accurate data input, it is necessary to gather information about the location of the case study. The materials used in this particular case study are sourced locally, and the building layers consist of white paint, plaster, concrete block, and reinforced concrete. The building itself is a single-story structure, comprised of multiple zones, each with its own distinct spatial use. The number of individuals and activities within each zone are also taken into account when analyzing the outcome data. The findings of this study will reflect how to design building. Also the impact will be great on design approach, such data collected from software environment data such as building design, materials, and the activities within each zone. In case of using the same data in this paper, best practice for using natural ventilation is between 20:00 to 00:00 in summer time.

Keywords: solar radiation: Solar gain, Direct solar radiation, Indirect solar radiation, Inter zonal gains, Tripoli climate.

1. Introduction

The discussion of sustainable architecture in contemporary times offers hope for the improvement of community life and is of great importance. It is crucial to acknowledge that the rise in temperature each year is a result of environmental changes. Architecture plays a significant role in shaping the behavior of individuals within their communities. The use of sustainable approaches in architectural design can have a positive impact on energy consumption and efficiency. The heating and cooling of buildings are responsible for the majority of environmental pollution, which is greater than that caused by cars [1]. Therefore, adopting sustainable architectural design at the beginning of the design process is essential. Architects are now using real-life data from the environment to simulate the design process for more sustainable outcomes. Tools are employed to gather data on wind, rainfall, solar radiation, relative humidity, and other environmental factors. This data is then imported into analysis software that simulates actual real-life data, providing valuable output data that shows the potential impact of specific building designs. The case study presented in this paper simulates real-life data to demonstrate how the right combination of materials, building orientation, and design approach can make buildings more sustainable. This paper's contribution is particularly valuable for architects designing in hot climate zones, where building material type and finishes are as important as shading devices. During the summer season, energy demands are higher than in winter, and ventilation plays a crucial role in reducing building and space temperatures.

2. Materials and Methods

The present study adopts a research approach that utilizes authentic data collected over the course of a year, 24 hours a day, in the city of Tripoli, Libya. The software simulation employed in this study is using energy software. The methodology employed is straightforward, involving the collection of total solar radiation gained by the model (house) surface. The study is divided into three parts, namely the hottest day, the hottest month, and the entire year. The peak of the hottest day is observed on the 3rd of July, with an available amount of 1485279.4 km/h in July [2].

2.1 Climate and electricity consumption in Libya

According to the Köppen-Trewartha climate classification, Libya is BW and BS climate zone, Tripoli considered as hot semi-arid (steppe) climate, BS climate zone type [3][4]. According to Renewable energy authority. Electricity consumption in libya in 2021 is 8.816 GW average growth rate of 9% [5].

2.2 Study Site

The study was at a site location in Janzur Tripoli district, it's a semi plane site, geographical coordination as the following: 32°50'4.07"N, 12°59'48.14"E, and elevation is 11.27 meter.

2.3 Building materials

This experimental modern model house will be using generic building material consist of concrete cinder for walls, plaster cement 0.01m finish for interior, and 0.01 for the exterior. For more specific numeral data about the wall, see the bellow tables.

Table 1: *Wall materials*

#	Layer name	Width	Density ($Kg/m^{3)}$	Conduct. (W/m.k)
1	Light Paint	0.002 m	914.0	0.200
2	Plaster Interior	0.010 m	1250.0	0.431
3	Concrete Cinder	0.200 m	1600.0	0.335
4	Plaster Exterior	0.015 m	1250.0	0.431
5	Light Paint	0.002 m	914.0	0.200

Table 2: *Roof materials*

#	Layer name	Width	Density ($Kg/m^{3)}$	Conduct. (W/m.k)
1	Concrete Light Weight	0.20 m	950.0	0.209
2	Plaster Interior	0.01 m	1250.0	0.431

Table 3: *Glass material*

#	Layer name	Width	Density ($Kg/m^{3)}$	Conduct. (W/m.k)
2	Glass Standard	0.20 m	2300.0	1.046

Table 4: *Floor materials*

#	Layer name	Width	Density (Kg/m3)	Conduct. (W/m.k)
1	Concrete	0.10 m	3800.0	0.753
2	Soil	1.50 m	1300	0.837

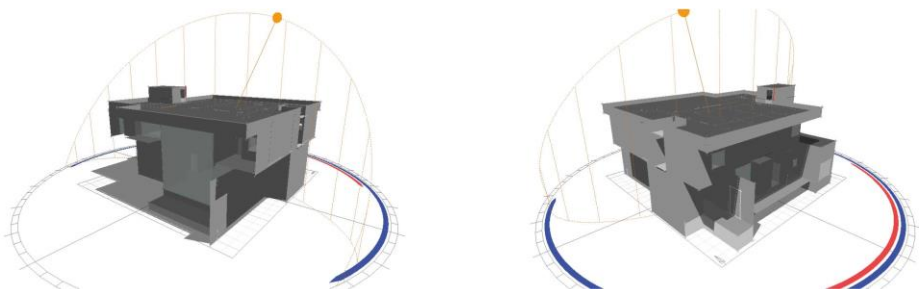


Figure 1: The model house, two perspective view showing details, using (energy software).

The model is made of 22 zones, each zone considered a closed space. The ground floor consists of a guest room, kitchen, garage, 2 restrooms, dining room, and living room. The second floor is made up of a studying room, 4 bedrooms, and 3 bathrooms.

Data of occupancy and operation also was considered in all zones, internal gains and infiltration rate also considered. A general design approach is maximizing the opening in the north and minimizing in east and west.

3. Theory and Calculation

The aim of this study is to investigate the solar radiation gain on both vertical and horizontal surfaces in the North African climate, with a specific focus on Tripoli. Various models were employed to quantify the amount of energy gained by horizontal surfaces from solar radiation, with particular emphasis on the month of July [6]. Weather data was obtained from the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), and was collected on a daily basis over the course of one year. The collected weather data was then converted from energy plus weather data format to weather files. The minimum requirement for these weather files, in order to conduct a site analysis and pre-design analysis, is as follows:

- Dry-Bulb Temperature
- Relative Humidity
- Solar Radiation
- Wind Speed

- Wind Direction
- Cloud Cover
- Rainfall

3.1 Mathematical Expressions and Symbols

An equation used in the purpose of this research is as follow:

- Conduction Gain: $Qc = U.A.\Delta T$ (1) [7]
- Solar Gain: $Qs = G.A.Sgf$ (2) [7]
- Indirect Gain: $Qs = U.A\ (G.Abs.Rso)$ (3) [7]
- Ventilation Gain: $QV = 0.33\ N.V.\Delta T$ (4) [7]
- Thermal Resistance: $Q = \frac{A.\Delta T}{R}$ (5) [7]
- the total resistance for composite building materials as follow:

$$R_T = R_{SO} + \sum R_n + R_{si} \quad (6)\ [7]$$

4. Results and Discussion

4.1 Area and Volume

Table show the total area and volume of the house, divided to floor, surface and window. The total exposed planar surface include windows is 1,125.292m2. Table 5 shows detailed data.

Table 5: *Area and volume*

	Floor	Surface	Exposed	Window	Volume
Ground Floor	219.393	724.878	558.536	44.168	779.018
First Floor	352.303	615.249	461.387	61.201	705.771
External Shading	0.000	593.557	593.557	0.000	0.000
TOTAL	571.695	1340.127	1019.923	105.369	1484.789

4.2 Solar Gain Analysis

Analysis is not date or time dependant - they represent worst-case design condition based on average cloud or uniform sky. Natural light levels, this method also used considered the transparency and refractive index of windows glazing and actual surface reluctances and external obstructions instead of standard value. Calculates daylight factors using the sky, external and internally reflected components along with the design sky illuminance, sky condition: CIE Overcast Sky - 8555lux.

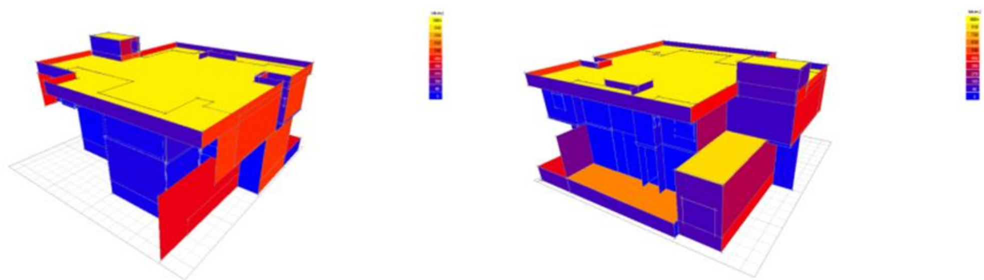
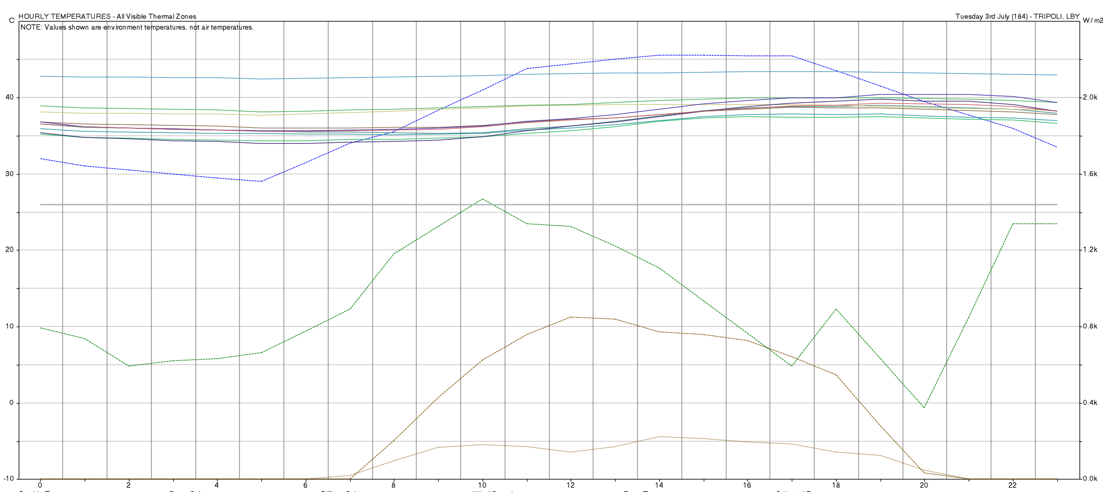


Figure 2. *Direct solar Gains to all surfaces, using (energy software)*

The amount of wh/m2 each surface receives depends on its position and material property as show in colors. The range is 0 wh/m^2 in blue to 900+ wh/m^2 in yellow. The direct solar gain in all zones ranges from 0 watts to 11,000 watts, for more detailed data see graph 4.1.3. For the indirect solar in all zones.

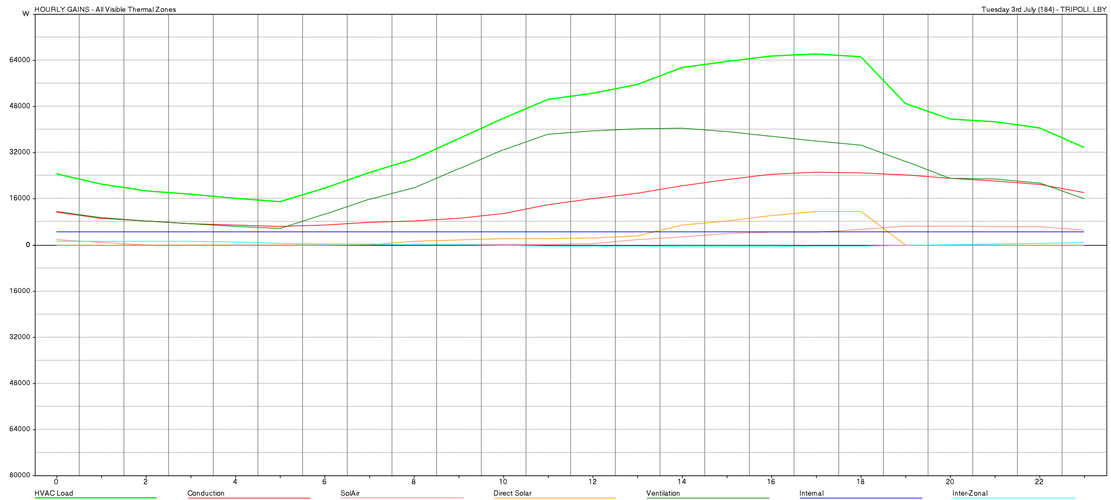
All surface and material properties, calculating the total transmitted radiation. This is only for planar surfaces. For specified period January to December from 8:00 to 20:00.



Graph 3: *Hourly Temperatures in all zones in 3rd of July hottest day, using (energy software)*

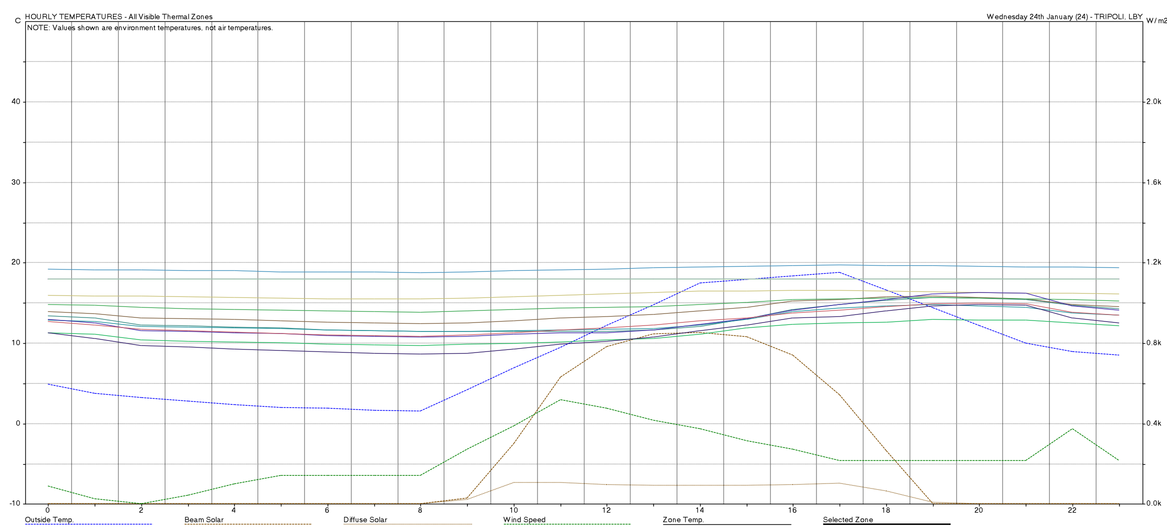
On the hottest day of the year the 3rd of July we can see the temperature getting higher in all zone starting 10:30 until it reach its peak at 20:15. Temperature ranges from 32

Degree to 39 degree. Outside temperature less stable, and reach its peak from 10:30 to 14:30. Diffuse solar radiation is direct start from 6:30 until 20:30.



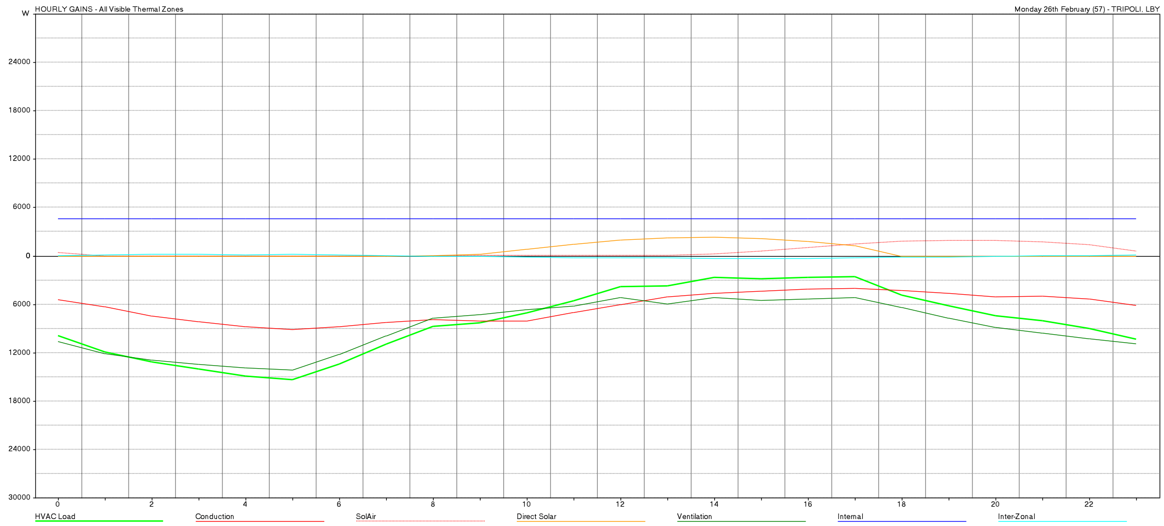
Graph 4: *Hourly gains in all zones in 3rd of July hottest day. using (energy software)*

This graph shows HVAC load in the hottest day of the year, amount of watt used to cool all zones is more than 6400 watt. Conduction is higher starts at 7:30 throughout the day and night, it reach its peak between 16:00 to 20:00.



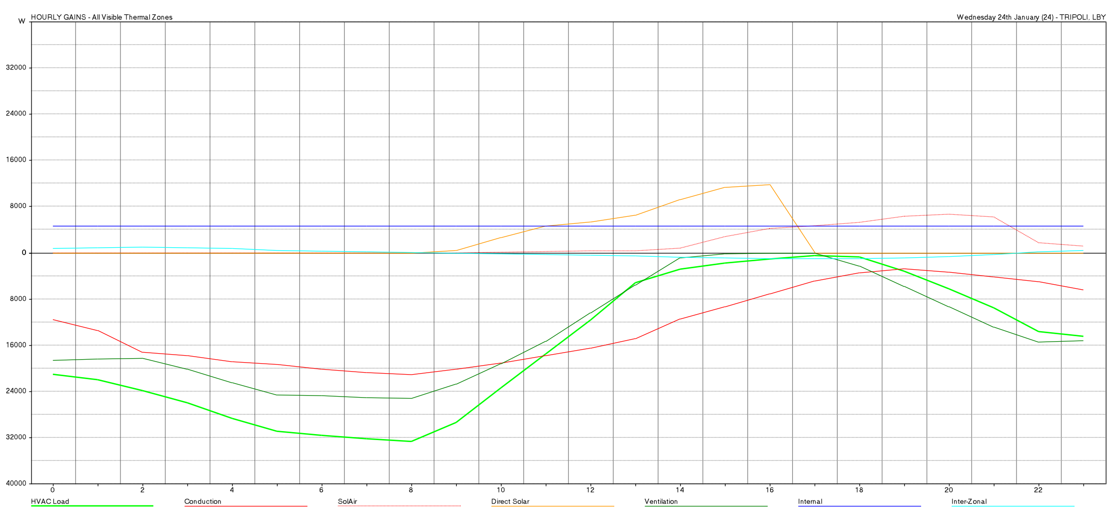
Graph 5: *Hourly Temperatures in all zones in 24th of January coldest day, using (energy software)*

Coldest day of year in 24th of January, we can see the temperature getting colder in all zone starting 14:30 until it reach its peak at 21:00. Temperature ranges from 9 degree to 11 degree. Outside temperature less stable, and reach its peak at 08:00.direct solar radiation is unavailable.



Graph 6: *Hourly gains in all zones in 24th of January coldest day, using (energy software)*

This graph show the HVAC load in the coldest day of the year, watt used to neutralize temperature in all zones is higher at night and morning, between 00:00 to 10:00. Conducation follows similler as HVAC load pattern, it reach its peak between 01:00 to 11:00.



Graph 7: *Hourly gains in all zones in 26th of February coldest day, using (energy software)*

This graph show the HVAC load in the coldest day of the year, watt used to neutralize temperature in all zones is higher at night and morning, between 00:00 to 10:00. Conducation follows similler as HVAC load pattern, it reach its peak between 01:00 to11:00.

5. Conclusion

- Conductivity of all zones follows similar pattern, because of the same building material used.
- In case of using the same building material in this paper, best practice for household is to use natural ventilation between 20:00 to 00:00 in summer time.
- The model is capable of determining the degree of solar exposure to high, medium, and low.
- The HAVC load is higher in summer time than winter.

References

[1]. Aisha A. Almansuri, Steve Curwell and David Dowdle, Designing a Dwelling Unit in Tripoli – Libya by Using Sustainable Architectural Principles, Sustainable Architecture and Urban Development conference at Amman, Jordan, pp 3. 2010

[2]. Hifa Salah Embirsh and Yousuf Almukhtar Ikshadah, Future of Solar Energy in Libya, International Journal of Science and Research Publication, Volume 7, Issue 10, October, pp 34. 2017

[3]. Attia Mahmoud El-Tantawi, Climate Change in Libya and Desertification of Jifara Plain, pp. 37, 2005

[4]. Michal Belda, Eva Holtanova, Tomas Halenka, and Jaroslava Kalvova, Climate Classification revisited: from Koppen to Trewartha, Inter-Research Science, Volume 59, pp 08. 2014

[5]. Ali O. Maka, Salem Salem and Mubbashar Mehmood, Solar photovoltaic (PV) applications in Libya: Challenges, potential,
opportunities and future perspectives, Cleaner Engineering and Technology 5 (2021) 100267, pp2. 2021

[6]. Ali. S. Al-Nuaimi and Tariq Elmabrouk, Estimating global , direct , diffuse and reflected solar radiation on horizontal and tilted surfaces in Tripoli , Libya, the University of Asmarya for human and applied science journal, pp 94. 2017

[7]. Ecotect Resources Community WIKI, http://wiki.naturalfrequency.com/