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MODELING AND OPTIMIZATION OF INCIDENT SOLAR RADIATION ON AN INCLINED ROOF OF A HABITAT FOR A TYPICAL CLIMATE OF GUINEA

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ABSTRACT

The aim of this work is to develop a mathematical model of the solar radiation incident on the walls of an inclined roof habitat for a typical climate of Guinea and to highlight the influence of the variation in the angle of inclination of the roof. Thereafter, we set up a program for the determination of all its parameters under the Fortran Language and plot our curves through the Origin software. This work allowed us to know, the amount of solar flux that each wall of a habitat receives, the importance of the orientation of the main facade of the habitat to the south, how often the roof is exposed to radiation solar and the influence of the variation of the angle of inclination of the roof compared to the horizontal. For example, for an angle of 15 ° the maximum value of the solar flux received is 547 W / m^2 and for that of 75 ° is 995 W / m^2. Thus, the optimal angle obtained from analyzes of the variation of solar radiation with respect to the inclination of the roof through Figure 7 is 60°.

KEYWORDS: Modeling, optimization, incident solar radiation, climate.

1. INTRODUCTION

The problem of knowing, collecting and processing solar data (solar radiation) is very difficult for a country like Guinea, belonging to a humid tropical zone, for passive air conditioning and the production of solar energy. This is the purpose of this study on: modeling and optimization of incident solar radiation on a pitched roof of a habitat for a typical climate of Guinea.

Solar energy is clean, abundant, renewable and a sustainable energy resource from the sun which reaches the earth in the form of light and heat.[1,2,3] In developing countries, data on solar radiation is not easy to obtain due to the lack of data measurement equipment and the techniques involved.[4-6] Solar radiation is rapidly becoming an alternative to other conventional energy sources. Most variable types of clean and energetic bases, solar energy seems to be the most favored option because of its infinite and non-polluting natur.[7-14]

Radiation is the oldest source of energy; it is the basic element for almost all fossil and renewable types. Solar energy is available free of charge and could easily be harnessed to reduce our dependence on hydrocarbons.[15-17] Solar energy is also the most dominant of all renewable energies, it is the source of almost all energy sources used by humans.[18,19,20] It is the most basic renewable energy source on the earth's surface, and global solar radiation (Rs) plays an important role in a wide range of applications in fields such as meteorology and hydrology.[21,22]

The measurement of solar radiation is always a necessary basis for the design of any solar energy conversion device and for a feasibility study of the possible use of solar energy. However, the low presence of radiometric stations leads to an insufficient database for a global study of the components of solar radiation.[23] The measured data is the best, but may not always be available.[24-27] Knowledge of total solar radiation data is essential for research and the basics of the economic viability of systems that use solar energy.[28] The data of total solar radiation are important for the use of solar energy which are in the form of diurnal variation, of daily average monthly values, of frequency distribution of the number of constant consecutive days in certain month, with insolation less than a certain threshold and the frequency distribution of monthly average values and annual average values.[29-32]

The use of solar energy in sunny countries is an effective tool to compensate for the lack of energy. The interest of such energy is not only economic but also environmental because pollution has become a major problem to which solutions must be found.[33,34]

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Presentation of the study area

Guinea is a country in West Africa, it is bounded to the north by Senegal, to the northeast by Mali, to the northwest by Guinea Bissau, to the west by the Atlantic Ocean, to the south by Sierra Leone and Liberia, to the east by the Ivory Coast and part of Mali (Figure 1). It has an area of 245,857 km2.[35,36]

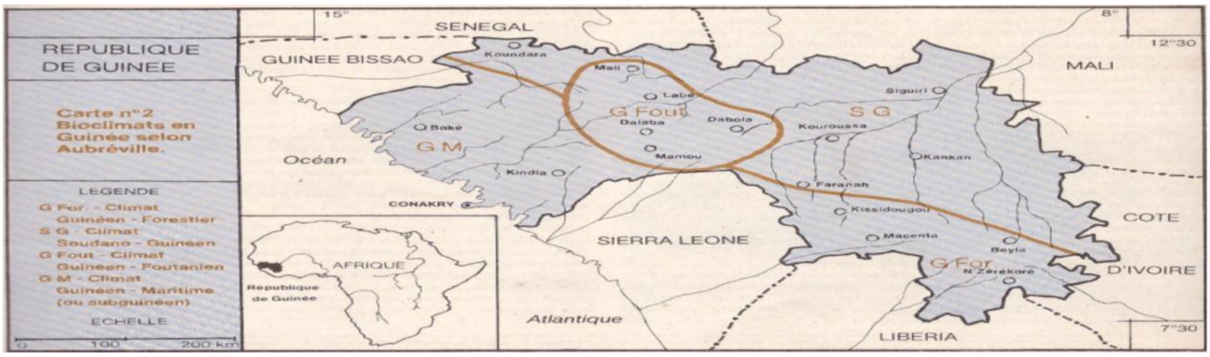

Figure 1: Climate map of the Republic of Guinea.[35]

2.1.2. Tools

The tools we used for this research are the climatic data for the typical day of March with a maximum global radiation of 1000 W / m^2, a minimum and maximum temperature of 25 ° C and 35 ° C respectively. These data allow us to find the hourly variations in ambient temperature and solar flux by considering a sinusoidal variation (Figure 2), the programming language is Fortran and the Origin software to plot the curves. Figure 2 represents the evolution of the global solar radiation on a horizontal plane (RGH) and the ambient air temperature (TEMP) for a typical day in March. Indeed, March is an extreme period of the year for Guinea. We therefore choose the climatic data for this typical day as input to our program because they make it possible to analyze the thermal behavior of the habitat for extreme climatic conditions.

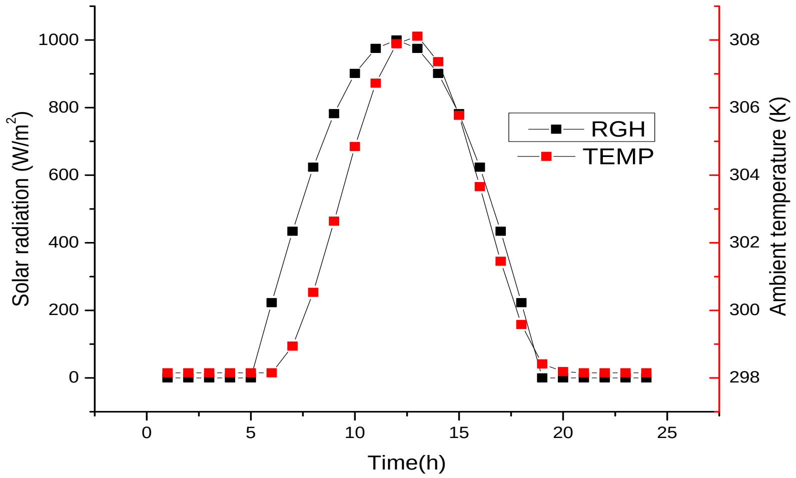

Figure 2: Global radiation and ambient temperature for the typical day in March.

2.2. Methods

We proceeded to the modeling of the parameters of the lighting in the first place and that of the global radiation and incidents on the walls of a roof habitat inclined by an angle of 30 ° in the second step.

2.2.1. Mathematical models of the lighting parameters

The astronomical formulas established for modeling solar radiation are as follows:

Declination, δ

$$\delta = 23.45 Sin\left[360.\frac{(284+n)}{365}\right] \quad \text{(Eq.1)}$$

Where n: is the number of days

Hour angle of the sun, ω_{rd}

$$\omega_{rd} = (TSV - 12).\frac{\pi}{12} \quad \text{(Eq.2)}$$

True solar time, TSV

$$TSV = TL - N + ET + \left(\frac{LG}{15}\right) \quad \text{(Eq.3)}$$

With:

TL: temps local en heure;

N: time difference, equal to 0 for Guinea;

ET: equation of time;

LG: longitude of the place

Equation of time, ET

$$ET = 9.87xSin\left[720.\left(\frac{J-81}{365}\right)\right] - 7.53xCos\left[720.\left(\frac{J-81}{365}\right)\right] - 1.5xSin\left[360.\left(\frac{J-81}{365}\right)\right] \quad \text{(Eq.4)}$$

Sun height, α_s

$$Sin(\alpha_s) = Cos(\varphi)Cos(\delta)Cos(\omega) + Sin(\varphi)Sin(\delta) \quad \text{(Eq.5)}$$

Sun azimuth, γ_s

$$Sin(\gamma_s) = \frac{Cos(\delta)Sin(\omega)}{Cos(\alpha_s)} \quad \text{(Eq.6)}$$

2.2.2. Mathematical models of solar radiation

Incident solar radiation on any plane

$$\begin{aligned} Cos(\theta) &= Sin\delta Sin\varphi Cos\beta \\ &- Sin\delta Cos\varphi Sin\beta Cos\gamma + Cos\delta Cos\varphi Cos\beta Cos\omega \\ &+ Cos\delta Sin\varphi Sin\beta Cos\gamma Cos\omega + Cos\delta Sin\beta Sin\gamma Sin\omega \end{aligned} \quad \text{(Eq.7)}$$

For a horizontal plane, (β =0), Eq.7 becomes:

$$Cos\theta = Cos\varphi Cos\delta Cos\omega + Sin\varphi Sin\delta \quad \text{(Eq.8)}$$

Global solar radiation on a horizontal plane

$$R^*_{GH} = R^*_{DIRH} + R^*_{DIFH} \quad \text{(Eq.9)}$$

If the global horizontal radiation is measured, in this case the horizontal direct radiation is worth:

$$R^*_{DIRH} = R^*_{GH} - R^*_{DIFH} \quad \text{(Eq.10)}$$

Diffuse radiation on a horizontal plane

$$R^{*}_{DIFH} = 120x\Gamma xExp\left(\frac{-1}{0.4511+Sin(h)}\right) \quad \text{(Eq.11)}$$

Where Γ : is the cloud factor of the sky, it is expressed by the relation:

$$\Gamma = 0.796 - 0.01xSin\left[\frac{360}{365}x(n+284)\right] \quad \text{(Eq.12)}$$

Direct solar radiation on an inclined plane

$$R_{DIRI} = R^{*}_{DIRH} xR_b \quad \text{(Eq.13)}$$

With R_b : the geometric factor and $R_b \geq 0$

$$R_b = \frac{Cos(\theta)}{Cos(\theta_Z)} = \frac{Cos(\theta)}{Sin(h)} = \frac{Sin\delta Sin(\Phi-\beta)+Cos\delta Cos(\Phi-\beta)+Cos\omega}{Sin\Phi Sin\delta + Cos\Phi Cos\delta Cos\omega} \quad \text{(Eq.14)}$$

Diffuse solar radiation

$$R_{DIFI} = R_{DIFH}\frac{1+Cos\beta}{2} \quad \text{(Eq.15)}$$

Solar radiation reflected from the ground

$$R_{RIFL} = R_{GH} x\rho x\frac{1-Cos\beta}{2} \quad \text{(Eq.16)}$$

Where ρ : is the coefficient of reflection of the ground or albedo and whose average value is 0.25

Global solar radiation on an inclined plane

$$R_{GI} = [R_{DIRJH} xR_b] + \left[R_{DIFH} x\frac{1+Cos\beta}{2}\right] + \left[R_{GH} x\rho x\frac{1-Cos\beta}{2}\right] \quad \text{(Eq.17)}$$

3. RESULTS AND DISCUSSION

Figure 3 illustrates the graphical representation of global solar radiation (RGH), direct solar radiation (RDIRH) and diffuse solar radiation on a horizontal plane (RDIFH). In this figure, we note that the global solar radiation is the sum of the other two radiations as stated in the literature at the level of formula 13. The maximum values of these radiations are observed at 12 o'clock and are respectively 1000 W/m^2, of 950 W / m2 and 50 W/m^2.

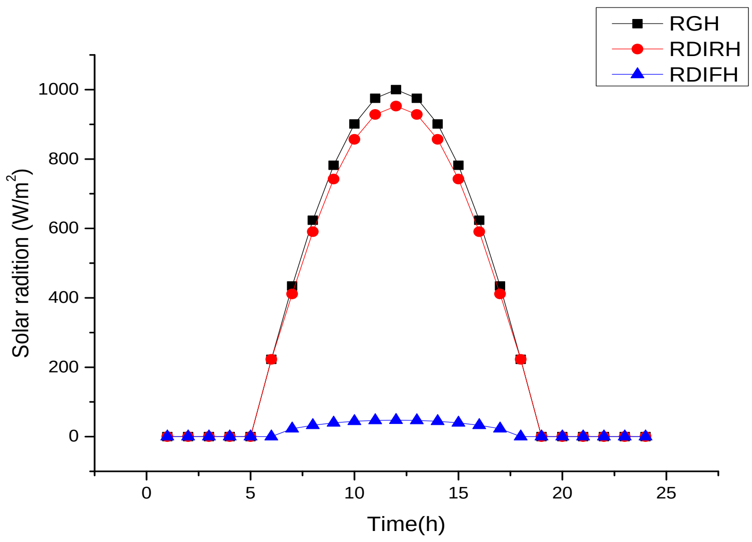

Figure 3: Global solar radiation.

Figure. 4 represents the profile of global solar radiation on the horizontal plane (RGH) and of the global solar radiation incident on the roof (RGIT). In this figure, we notice that the value of the global solar radiation incident on the roof is very close to that of the global solar radiation on the horizontal plane. This shows that the roof is the component of the habitat that receives a very large amount of solar flux compared to the other components.

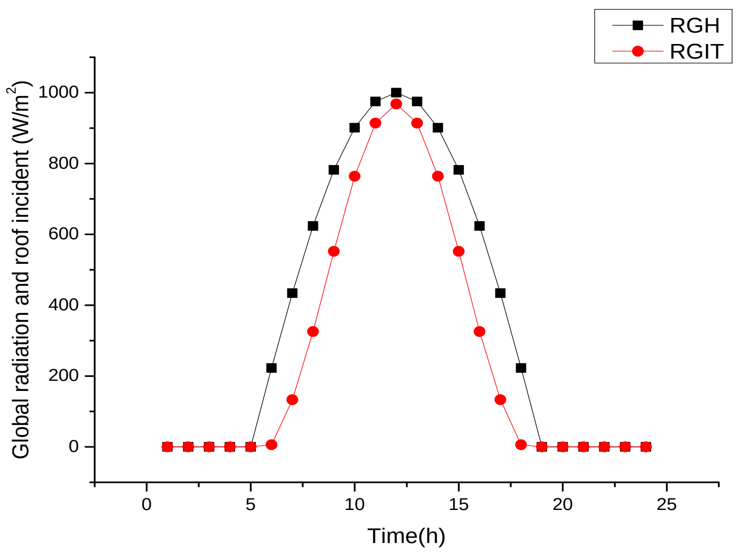

Figure 4: Global solar radiation and roof incident.

Figure 5 represents the graph of variation of the incident solar radiation on the east (RGIE) and west (RGIW) walls of our habitat. In this figure, we see that the two profiles are symmetrical from midday and the maximum value of the radiation is observed at 9 a.m. for the west wall and at 3 p.m. for the east wall, which are 620 W/m^2 and 625 W/m^2. respectively. This shows that the sun rises in the west and sets in the east.

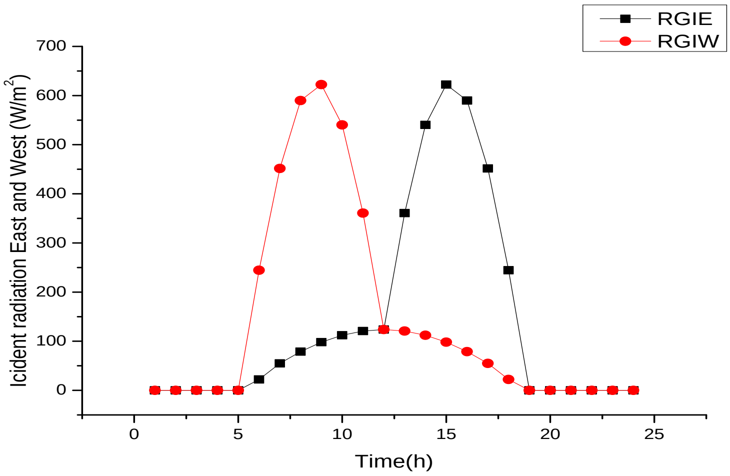

Figure 5: Incident solar radiation east and west wall of the habitat.

Figure 6 illustrates the solar radiation profile incident on the south (RGIS) and north (RGIN) wall of the habitat. In this figure, we note that apart from the north wall, it is the south wall which receives the minimum solar flux more than the other components of the habitat. This shows that for a construction, you must always orient the building to the south. The maximum values of these two profiles are observed at midday and are respectively 335 W/m^2 and 121 W/m^2.

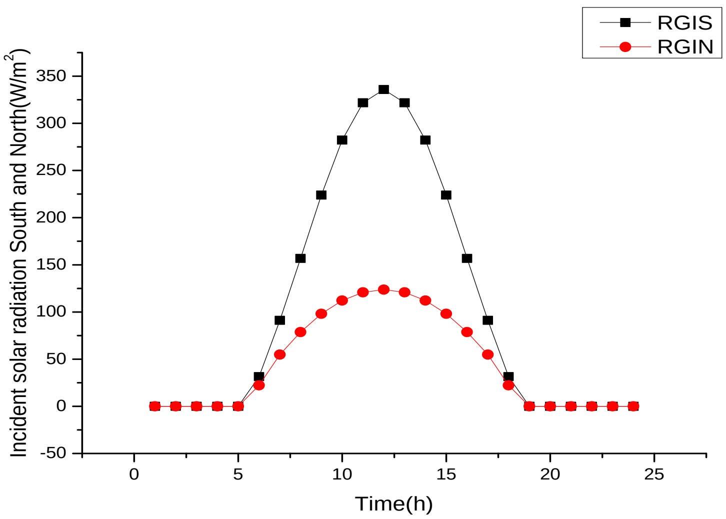

Figure 6: Incident solar radiation south and north wall of the habitat.

Figure 7 shows the influence of the variation in the angle of inclination of the roof relative to the horizontal. In this figure, we see that the more the angle of inclination of the roof relative to the horizontal varies, the more the roof receives less solar flux. For example in this figure, we notice that the maximum value of the solar radiation incident on the roof for an angle of 15 ° is 995 W/m^2 and that of 75 ° is 545 W/m^2. This variation in the inclination of the roof relative to the horizontal allowed us to choose an optimal angle of 60 ° to attenuate the maximum heat penetrating inside the habitats in Guinea whose maximum value of solar radiation received is from 730 W/m^2.

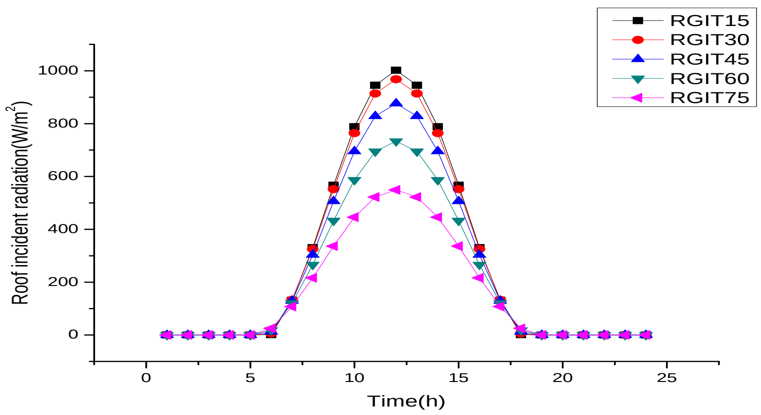

Figure 7: Influence of the angle of inclination of the roof for optimizing the incident solar flux.

4. CONCLUSION

During this work, we presented a numerical modeling of the essential parameters of the illumination, of the global horizontal radiation, direct horizontal, horizontal diffuse and global incident on the different walls of the habitat.

Thus, we analyzed the evolution of the profiles of incident solar radiation with respect to time on each wall of the building and the influence of the variation in the angle of inclination of the roof relative to the horizontal, which is considered like the false ceiling of the habitat. This variation in the inclination of the roof relative to the horizontal allowed us to choose an optimal angle of 60 ° to attenuate the maximum heat penetrating inside habitats in Guinea whose maximum value of solar radiation received is of 730 W/m^2 against 1000 W/m^2 which is the global solar radiation (RGH).

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