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Influence of Envelope Colour on Energy Saving in Different Climate Zones in an Emergency House

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Abstract

The VEM project (Emergency house project) aims a series of objectives based on energy efficiency through the study of basic parameters, by natural systems, to reach climatic comfort: the influence of the form factor in the climatic performance, the orientation, ventilation, and an adequate performance towards the temperature and humidity conditions that the different climate zones offer. From the resulting data, the validity in the performance of the VEM project's constructive system is verified based on its energy simulation.
The study begins with the energy simulation of the project with the Ecotect Analysis program, in five locations: continental Mediterranean climate (Madrid), monsoon climate (New Delhi), tropical climate (Brasilia), continental humid climate (Montreal), and semiarid climate (Karachi); considering its constructive system, materials, orientation, ventilation, incident solar radiation, environmental conditions (temperature, wind, rainfall), generating a study on technical control

and the degree of environmental influence on the project. In every location, the behavior is simulated for both a cold and a warm day, recollecting data on Wh (energy gains and losses) and interior temperature, considering the variations throughout the day.
The second part of the study goes beyond the simulation, with the aim to improve the first results and delve more deeply into the materials of the envelope, the color and the material's reflection, studying the effects produced on the interior temperature, taking into account the region and climate of the simulation. It also addresses the positive effect produced by the form factor applied in the VEM project, its advantages compared to other designs with different form factors; all to amend possible thermal tolerances and allow comfort in the interior of the living space.

Keywords: Sustainability, emergency house, green building, sustainable building, energy saving, solar reflection index, green engineering

1 Introduction

It is expected that by 2050 the world's energy consumption will be doubled. A large part of the annual energy consumption is based on fossil fuels, which causes an increase in CO2 emissions, therefore causing global warming. The activity generated by the building sector, including its associated industry, is the largest consumer of natural resources, consuming 50% of the world's resources and being responsible for 50% of the CO2 emissions[1],[2]
This structural behavior has been analyzed in an emergency house prototype developed by Rebirth INhabit research group, within VEM project (Reference Oracle MEADSAIR), sponsored by Airbus Defence and Space. This is a patent prototype with the reference ES2488790A1 Modular Adaptable Housing Architecture, with the international extension WIPO/PTC WO 2014/114836 A1. The VEM project consists of the development of an innovative project which relates emergency aid with the industrial applicability. It gives a rapid response to shelter necessity in case of disaster. The VEM project centers its interest in the research on models of basic habitability standards, and the implementation of architectural solutions adaptable in situations of risk, emergency and vulnerability of human settlements due to forced causes, with the main goal of making the social regeneration of the habitat possible [3],[4],[5].
The research developed in the VEM project opens a line of major architectural interest: the technical control and degree of environmental influence of the materials [6],[7],[8], and its incorporation to housing typologies with a social emergency interest. Three parameters have been identified as influential in the thermal behavior of the model. The first is the form factor of the living space, which must correspond and 9be coherent with the level of response needed in each situation or local requirement. [9],[10],[11],[12]. The second is the influence of color in the envelope, allowing to optimize the energy efficiency of the living space to its most. Lastly, the constructive system is studied in order to achieve

thermal comfort throughout the year in the different locations where it is established. [13], [14].

The aim of this article is:

- To understand its performance in different locations, orientations, and its response to environmental conditions; studying its constructive systems and being aware of the specific conditions for thermal comfort in each climate, favors the design of more energy-efficient buildings, by working on the project under the temperature and humidity conditions of the location in which it is established, easing the path to achieve comfort conditions through passive strategies for the environmental conditioning of the space [15],[16],[17],[18].

- To analyze the materials' performance in average, maximum and minimum temperatures that may occur in the location where it is established; focusing on the study of the exterior color of the envelope, studying the thermal change produced by each color [19],[20],[21],[22],[23]. The influence over certain solar factors and quantifying the influence in terms of climate comfort in the interior living space, how by means of a broad study on the color of the material in contact with the exterior environment the energy efficiency can be optimized. [24],[25].

- To amend possible thermal tolerances referred to materials or constructive systems of the project, with an efficient use of energy resources to guarantee the climatic comfort by means of a sustainable system. [26],[27],[28].

Figure 1. Representation of the model VEM

2 Methodology

The initial conditions of the VEM project and the parameters . with which it is subjected to study are:

Systems and ventilation flows. Standard criteria and conditions have been considered, as shown in UNE-EN ISO 5912-2012 [29]; the ventilation surface must be of 2x0.01m2/person; with a 70x10cm surface of ventilation. [30]. A ventilated chamber is needed, both in the winter and in the summer, to avoid condensations and to cushion the temperatures in the different seasons of the year. The thickness of the air chamber considered is 7cm.

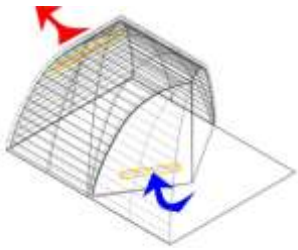

Figure 2. Ventilation scheme of the VEM model

Orientation. Due to the existence of an exterior covered space in the VEM model, the importance of the orientation for the climatic conditions of the interior space is taken into account. **Climatic areas considered in the study**. The following regions have been chosen: continental Mediterranean climate (Madrid), monsoon climate (New Delhi), tropical climate (Brasilia), continental humid climate (Montreal), and semiarid climate (Karachi).

Figure 3. Orientation of the VEM model

The constructive system is based on a double layer with a 7cm-thick air chamber.

	Exterior envelope	Air chamber	Interior envelope	Floor
Material	Polyester with PVC coating	Ventilated air chamber	Short- fibre polyester	Polyester with fibreglass coating
Thickness	0.002m	0.07m	0.002m	0.04m
Density	1400 kg/m3	1.3kg/m3	1400 kg/m3	1200 kg/m3
Thermal conductivity	0.19 W/m°k		0.19 W/m°k	0.4W/m°k
Specific heat	1200J/Kg°K		1200J/Kg°K	1000J/kg°K

Table 1. Materials used in numerical simulation

a) S=43,61m2; V=35,97m3; f=1,21 b) S=93,52 m2; V=56 m3; f=1,67 c) S=7,52 m2; V=48 m3; f=1,49

Figure 4. Comparison of the form factor of the section of the VEM model with a square section: f= S/V,

For the floor material, the following data has been considered: U= 3.5 W/m2 k, weight = 5 kg/m2, thermal coefficient of exposure = 12 * 10K, special thermal capacity = 1 KJ/kgK and a water absorption percentage = 0.15 %.
The form factor is decisive in terms of the module's climatic utilization and its relation with the surrounding. It is defined by two characteristics: the envelope's surface and the volume it occupies [31]. Envelope's surface: 43.61 m2 : Volume it occupies: 35.97 m3: Form factor: 1.212
The advantages of the VEM Project's form factor are studied and compared with other alternatives, obtaining more efficient results with a form factor of 1,21 The optimum form factor of 1,16 is obtained with a semispherical surface, which for the volume considered would have a surface of 41,82 m2. In the VEM Project, with an interior volume of 35,97m2 and a surface of 43,61m2, the form factor results in 1,212. The form of the VEM Project provides better results from the bioclimatic point of view, since reducing the exterior skin's surface reduces the energy losses throughout the constructive elements. The more compact, the less contact with the exterior climatic conditions and less energy losses, however also decreasing the possibilities of ventilation and solar radiation uptake. [32],[33].

3 Results

3.1 Comparison between energy losses and gains depending on the form factor.

The VEM Project simulation is carried out for three different designs, with different form factors. Annual graphs for gains and losses are obtained for each of the three prototypes, drawing conclusions and advantages of the design with the optimum form factor. The location chosen has been the city of Madrid.
Graph of Energy losses (Wh): The graph shows how, with the same exterior climatic conditions (in the city of Madrid), important changes can be observed in terms of energy losses in the VEM Project, obtaining energy losses of 11.095.500Wh with the form factor f=1,67 in the month of January, compared to

2.197.916Wh with a form factor f=1.49 in the same month, and to 1.241.366Wh when the form factor is f=1.212.
This data shows that the VEM Project's form factor (f=1.212) involves an energy saving of 88% when compared to the design with a cube's form factor

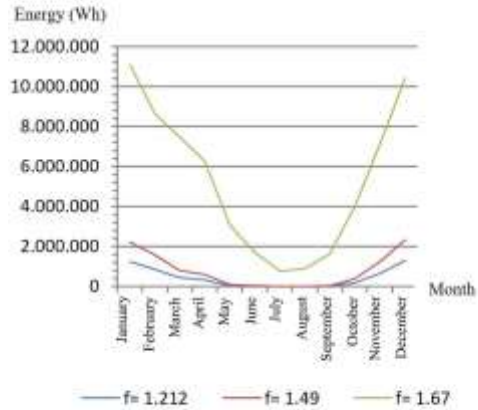

Figure 5. Energy losses (different form factors)

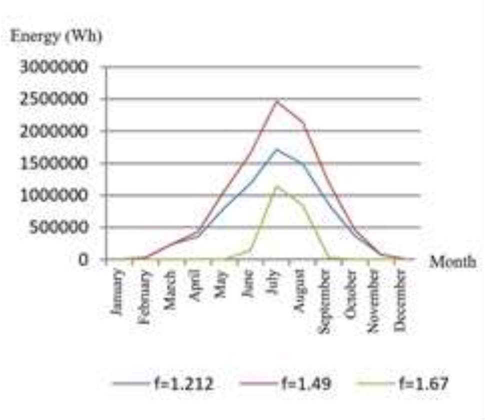

Figure 6. Energy gains (different form factors)

In the simulation of energy gains with different form factors, the graph shows how, with the same exterior climatic conditions (in the city of Madrid), important changes can again be observed, obtaining energy gains of 1.147.200Wh with the form factor f=1,67 in the month of July, compared to 1.711.586Wh when the form factor is f=1.212 in the same month of July.
This data shows that the VEM Project's form factor (f=1.212) involves energy gains of 150% compared to a design with a cube's form factor.
From these simulations, it is established that the optimum form factor is 1.212.

3.2 Modification of the exterior color.
The study of the exterior envelope's performance in terms of climatic comfort, taking into account its color and its reflection, as well as the influence of the emissivity and roughness in the interior temperature of the living space. Another material for the envelope, with neutral characteristics, has also been considered. The solar factors considered in the simulation go from 0.2 (white color) to 0.9 (black color), flowing through two intermediate colors with solar factors of 0.43 and 0.67. Two days have been considered for the simulation, the first with cold temperatures (January 23rd), and the second with warm temperatures (July 23rd).
Solar factor 0.2 (white color in the exterior), January 23 in different climates.
The thermal study shows two types of graphs: Brasilia and New Delhi, since being in the summer, reach maximum heat gains of 2179Wh and 1769Wh respectively, which override the losses produced in New Delhi during the night, with a peak of -1649Wh. In Montreal, during the winter, the exterior temperatures are very low, therefore needing to extract much more heat, never less than 4000Wh, reaching peaks of -4895Wh. The graphs for Madrid and Karachi show similarity in their need for energy support, maintaining the same tendency of

losses with minimum values of necessity equivalent to 1000Wh during the day, and maximums of -4000Wh.

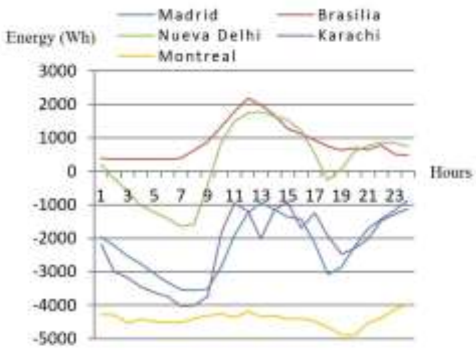

Figure 7. Energy demand (January 23. SF 0,2)

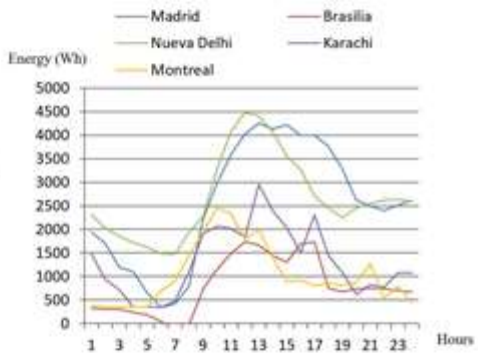

Figure 8. Energy demand (July 23., SF 0,2)

Solar factor 0.2 (white color in the exterior), July 23 in different climates. In this temperature graph, we can observe how all the climate zones remain in positive energy values, highlighting maximums in Madrid and New Delhi of 4256Wh and 4472Wh respectively, both locations reaching energy minimums of 341Wh and 1476Wh.

In the graphs for Karachi, Montreal and Brasilia, the peaks are similar (a maximum of 2951Wh in Karachi, 2455Wh in Montreal, 1743Wh in Brasilia), remaining in a range between 1000Wh and 2000Wh, highlighting a negative minimum of -159Wh in Brasilia when there is not yet solar radiation.

Solar factor 0.43, January 23 in different climates. The same dynamic is shown for Brasilia and New Delhi, since they are in the summer, with maximums in Brasilia of 2179Wh at 11AM and remaining around 1000Wh during the rest of the day, without losing the positive markers. In New Delhi, during the night, minimum values occur down to -1648Wh. Madrid and Karachi, with similar data, are in winter conditions showing maximum values of -3549Wh and -4019Wh, and minimum values of -938Wh and -641 respectively.

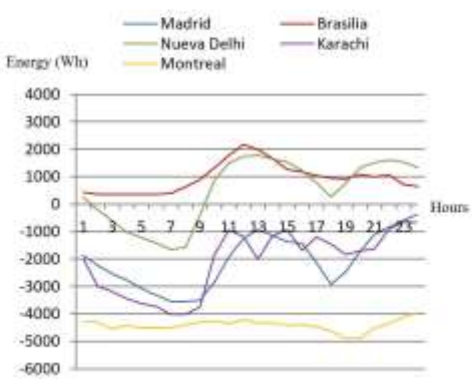

Figure 9. Energy demand (January 23.SF 0,43)

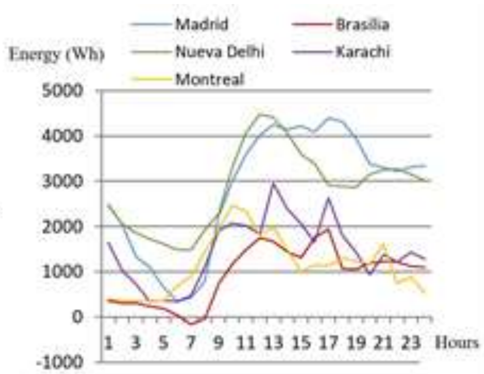

Figure 10. Energy demand (July 23.SF 0,43)

Solar factor 0.43, July 23 in different climates All the climate zones remain in positive energy values, highlighting maximums in Madrid and New Delhi of 4391Wh and 4472Wh respectively, both locations reaching energy minimums of 343Wh and 1477Wh. In Kerachi, Montreal and Brasilia, the peaks are similar (a maximum of 2951wh in Kerachi, 2455Wh in Montreal, 1935Wh in Brasilia), remain in a range between 1000Wh and 2000Wh, highlighting a negative minimum of -15Wh in Brasilia when there is not yet solar radiation.

Solar factor 0.67 (color in the exterior), January 23 in different climates. The graphs for Brasilia and New Delhi, since being in the summer, show an area of positive values with maximums of 2179Wh and 2396Wh respectively, highlighting negative values in New Delhi with minimums of -1646Wh during the night. Kerachi and Madrid show negative data, with peaks of -4018Wh and -3547wh respectively. In Montreal, since the exterior temperatures are very low, there is a higher need to extract energy; an average of -4000Wh, with peaks of -4873Wh. Brasilia and New Delhi show an average of 1000Wh, Brasilia with positive values and New Delhi with a minimum of -1720Wh.

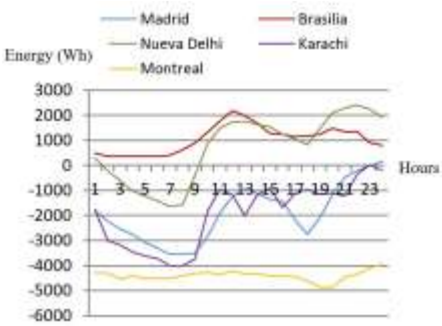

Figure 11. Energy demand (January 23.SF. 0,67)

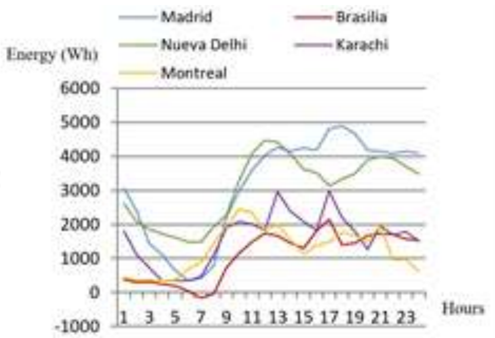

Figure 12. Energy demand (July 23.SF 0,67)

Solar factor 0.67 (color in the exterior), July 23 in different climates. Madrid shows a maximum of 4898Wh and a minimum of 345Wh. It is similar for New Delhi, with a maximum of 4472Wh and a minimum of 1478Wh. Brasilia shows maximums of 2153Wh and a minimum of -157wh. Montreal and Kerachi show similarities, with maximums of 2455Wh and 2979Wh respectively, and minimums of 566Wh and 346Wh.

Solar factor 0.9 (black color in the exterior), January 23 in different climates. The graphs for Brasilia and New Delhi, since being in the summer, show an area of positive values with maximums of 2179Wh and 3142Wh respectively, highlighting negative values in New Delhi with a minimum during the night of -1644Wh. Kerachi and Madrid show similar graphs, with maximum peaks of -4016 and -3546Wh. In Montreal, since the exterior temperatures and very low, there is a higher need to extract energy; never less than 4000Wh, reaching peaks of -4863Wh.

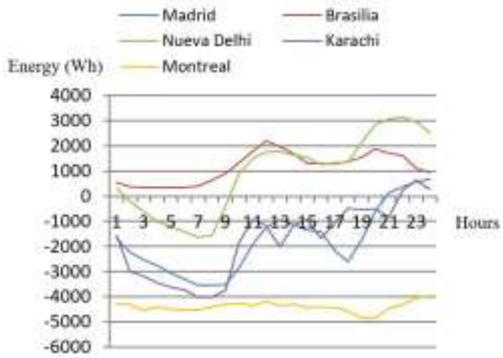

Figure 11. Energy demand (January 23.SF. 0,90)

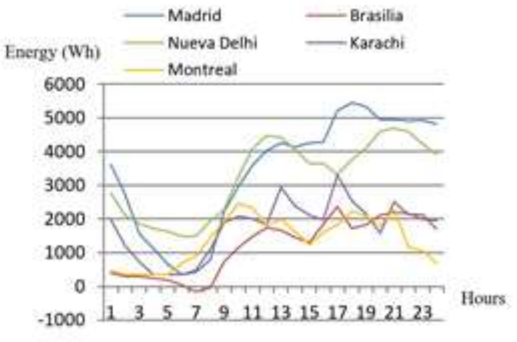

Figure 12. Energy demand (July 23.SF 0,90)

Solar factor 0.9 (black color in the exterior), January 23rd in different climates In the temperature graph, we can observe how all the climate zones remain in positive values, Madrid having a maximum of 5454Wh at 5PM and a minimum of 346Wh during the night. The graph of New Delhi is similar, with a maximum of 4472 Wh and a minimum of 1478wh. The graph of Brasilia shows a maximum of 2153Wh and a negative minimum at 4PM of -157wh. Montreal and Kerachi show similar curves, with maximums of 2455Wh and 2979Wh respectively, with minimums of 566Wh and 346Wh.

3.3 Study of the temperature gradient ΔT.

A part of the study is dedicated to the expression through graphs of the temperature gradient (expressed as ΔT) and its variation throughout the day in the different locations studied and, as in the previous case, for a cold day (January 23) and a warm day (July 23).

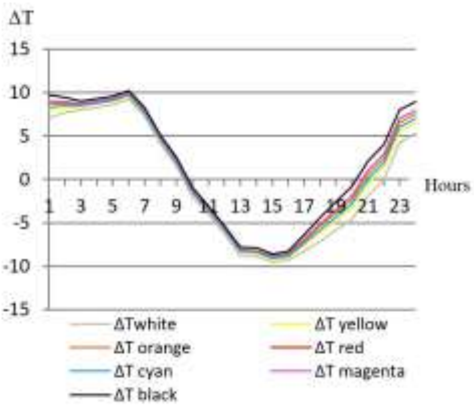

Figure 15. ΔT in Madrid 23 of January.

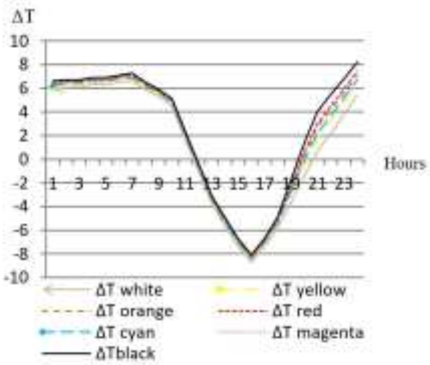

Figure 16. ΔT in Madrid 23 of July

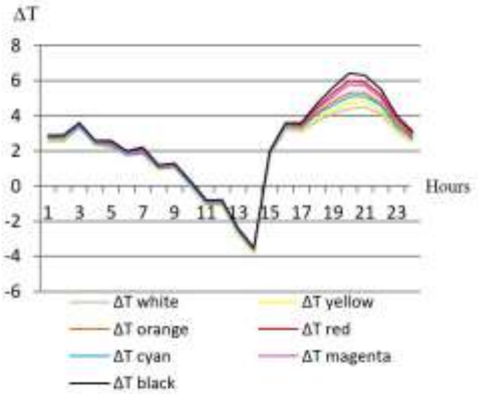

Figure 17. ΔT in Brasilia 23 of January.

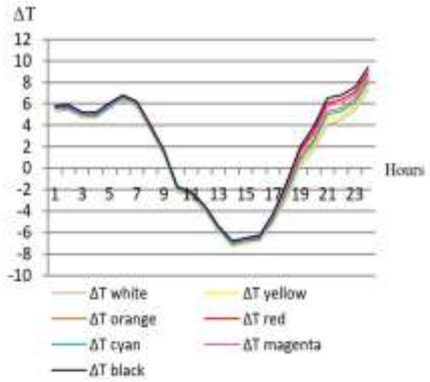

Figure 18. ΔT in Brasilia 23 of July.

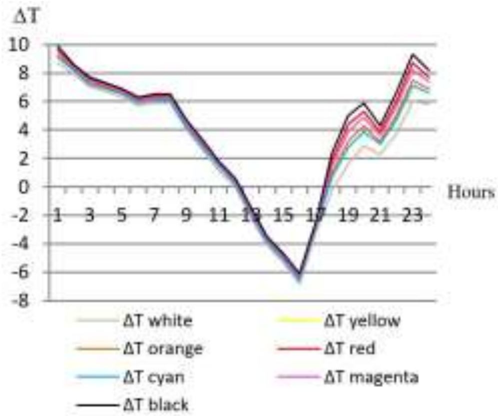

Figure 19. ΔT in Karachi 23 of January.

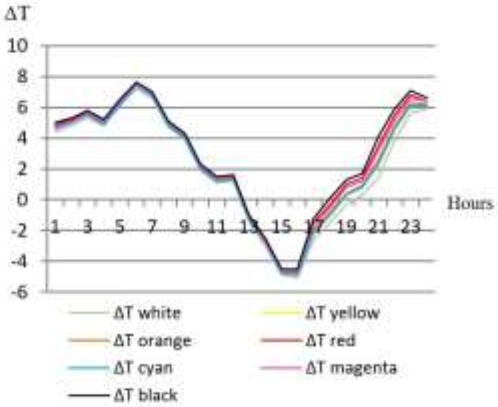

Figure 20. ΔT in Karachi 23 of July.

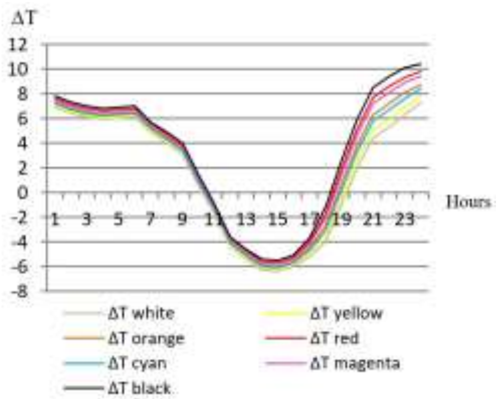

Figure 21. ΔT in Nueva Delhi 23 ofJanuary..

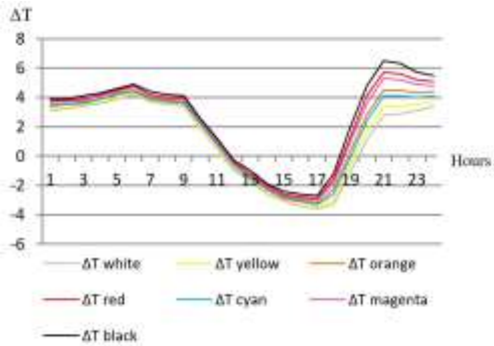

Figure 22. ΔT in Nueva Delhi 23 of January

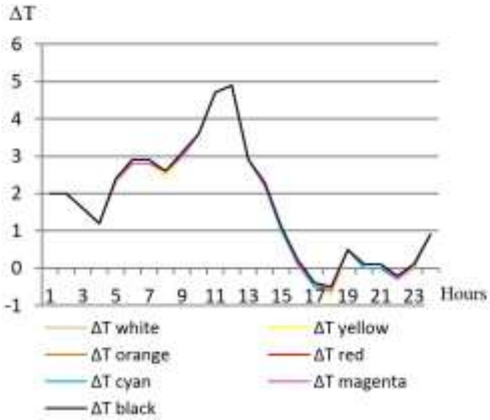

Figure 23. ΔT in Montreal 23 of January.

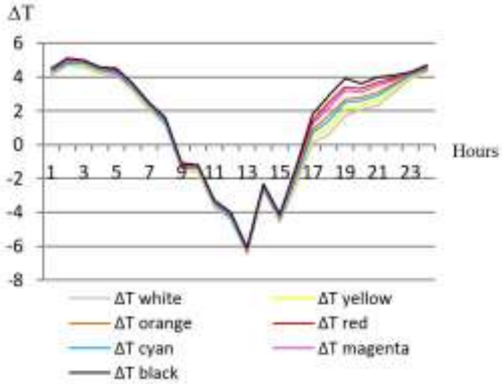

Figure 24. ΔT in Montreal 23 of January

-In Madrid, on a cold day, there is a difference in temperature of 3º at most, using the envelope in a black color in comparison with using the white color, which means a 33% of savings in the requirements of energy consumption. In a warm day, the difference in temperature gradient is of 4º, which means 55% of energy improvement.

- In Brasilia, on a cold day, there is a difference in temperature of 2.1º at most, using the envelope in a black color in comparison with using the white color, which means a 20% of savings in the requirements of energy consumption. In a warm day, the difference in temperature gradient is of 3º, which means 45% of energy improvement.

- In New Delhi, on a cold day, there is a difference in temperature of 3.3º at most, using the envelope in a black color in comparison with using the white color, which means a 45% of savings in the requirements of energy consumption. In a warm day, the difference in temperature gradient is of 3º, which means 50% of energy improvement.

- In Karachi, on a cold day, there is a difference in temperature of 2º at most, using the envelope in a black color in comparison with using the white color, which means a 33% of savings in the requirements of energy consumption. In a warm day, the difference in temperature gradient is of 2.2º, which means 50% of energy improvement.

- In Montreal, on a warm day, there is a difference in temperature gradient of 2º, which means 50% of energy improvement.

4 Discussion

4.1 Summary of the behavior in Madrid, regarding the solar factor.

A cold day, January 23rd: The graph shows similar data during the day. Significant changes occur during the night, with a maximum with 0.9 solar factor (black color in the exterior) of 688Wh. For a 0.67 solar factor we obtain 173Wh, -

364Wh when the solar factor is 0.43, and -879Wh when the solar factor is 0.2, which is white color in the exterior. Therefore, there is a significant difference of 1567Wh at the end of the day, depending on solar factor of the color used in the exterior.

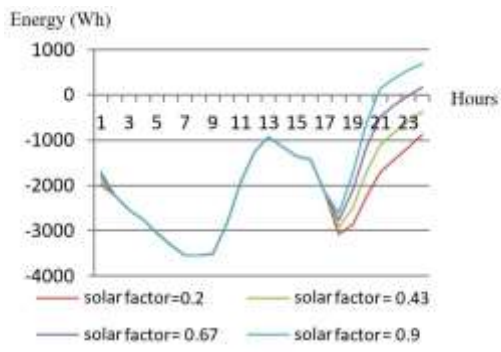

Figure 25. A cold day in Madrid.

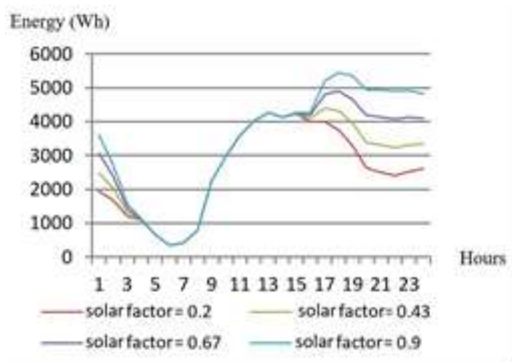

Figure 26.A warm day in Madrid

A warm day, July 23rd: Maximums show during the afternoon: with a solar factor of 0.9 the value is 5432Wh, 5000Wh for a solar factor of 0.67, 4255Wh for the solar factor of 0.43, and 4000Wh then the solar factor is 0.2. A certain tendency with similar values is maintained during the day, showing perceptible differences of 1664Wh at 3AM and of 3050Wh at 8PM. It reaches 3502Wh with a solar factor of 0.9, and 1938Wh when the solar factor of 0.2, which corresponds to the white color in the exterior.

4.2 Summary of the behavior in Brasilia, regarding the solar factor.

A cold day, January 23rd: The graph shows similar data during the day. At 2AM an insignificant change of 100Wh occurs, however from 5PM onwards deviations are produced, reaching 1870Wh then the solar factor is 0.9, 1481Wh with a solar factor of 0.67, 1076Wh with a solar factor of 0.43, and 687Wh with a solar factor of 0.2. In consequence, a difference of 1183Wh is produced depending on the solar factor of the color applied on the exterior.

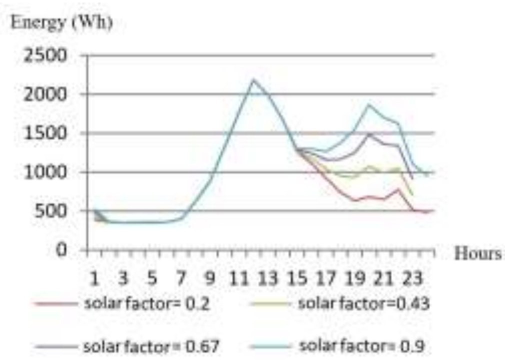

Figure 27. A cold day in Brasilia.

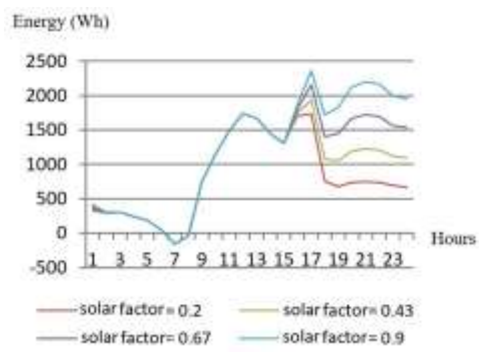

Figure 28. A warm day in Brasilia.

A warm day, July 23rd: The graph shows similar data during the day. At 2AM an insignificant change occurs, however from 5PM onwards deviations are produced, reaching at the end of the day: 1955Wh when the solar factor is 0.9, 1532Wh with a solar factor of 0.67, 1091Wh with a solar factor of 0.43, and 669Wh with a solar factor of 0.2. In consequence, a difference of 1286Wh is produced depending on the solar factor of the color applied on the exterior.

4.3 Summary of the behavior in New Delhi, regarding the solar factor.

A cold day, January 23rd: The graph shows similar data throughout the day, with variations occurring in the afternoon reaching maximums of 3142Wh at 10PM when the solar factor is 0.9, 2396Wh when the solar factor is 0.67, 1616Wh with a solar factor of 0.43, and 869wh with a solar factor of 0.2. In consequence, a difference of 2273Wh is produced depending on the solar factor applied on the exterior.

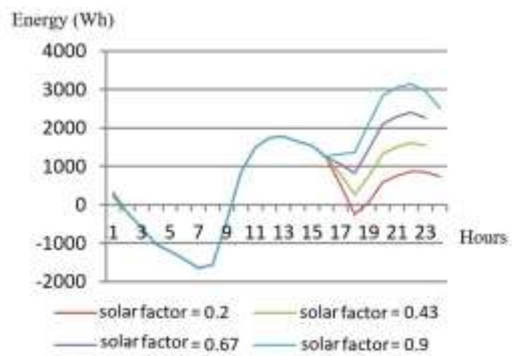

Figure 29. A cold day in New Delhi

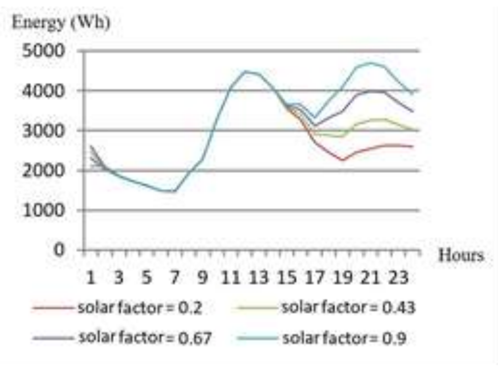

Figure 30. A warm day in New Delhi

A warm day, July 23rd: The graph shows similar data throughout the day. At 2AM a slight change of 500Wh occurs, however from 5PM onwards deviations are produced and progressively increase, reaching its highest value at the end of the day: 3916Wh when the solar factor is 0.9, 3481Wh when the solar factor is 0.67, 3026Wh with a solar factor of 0.43, and 2591Wh with a solar factor of 0.2. In consequence, a difference of 1325Wh is produced depending on the solar factor applied on the exterior.

4.4 Summary of the behavior in Karachi, regarding the solar factor.

A cold day, January 23rd: The graph shows the importance of negative values practically throughout the whole day, with significant differences during the afternoon, with values of 634Wh with a solar factor of 0.9, 14Wh when the solar factor is 0.67, -641Wh with a solar factor of 0.43, and -1270Wh when the solar factor is 0.2. Having a total difference of 1904Wh depending on the solar factor applied on the exterior.

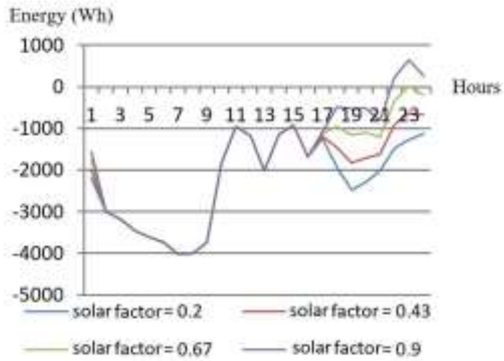

Figure 31. A cold day in Karachi.

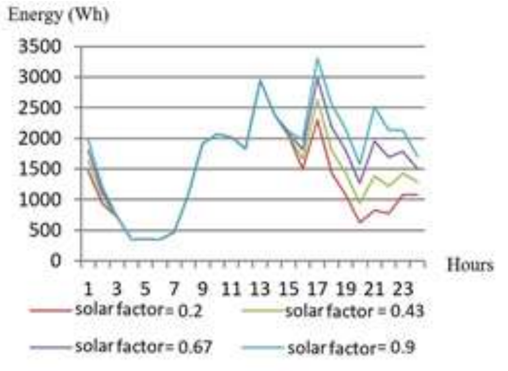

Figure 32. A warm day in Karachi

A warm day, July 23rd: The graph shows similar data throughout the day. At 2AM a slight change of 500Wh occurs, however from 5PM onwards deviations are produced: 3309Wh when the solar factor is 0.9, 2979Wh when the solar factor is 0.67, 2633Wh with a solar factor of 0.43, and 2303Wh with a solar factor of 0.2. In consequence, a difference of 1006Wh is produced depending on the solar factor applied on the exterior.

4.5 Summary of the behavior in Montreal, regarding the solar factor.

A cold day, January 23rd: In Montreal, in the date given, the graphs appear similar, with the results from the change in color of the exterior not being significant. The exterior temperatures are very low; therefore no energy consumption improvement is made.

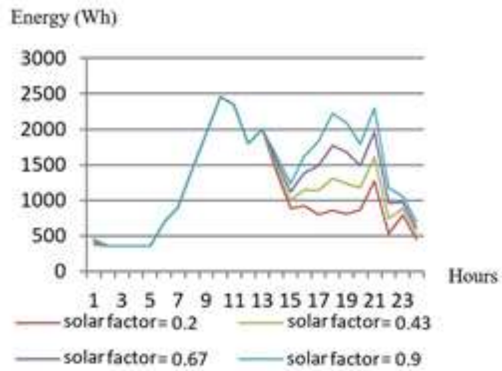

Figure 33. A cold day in Montreal

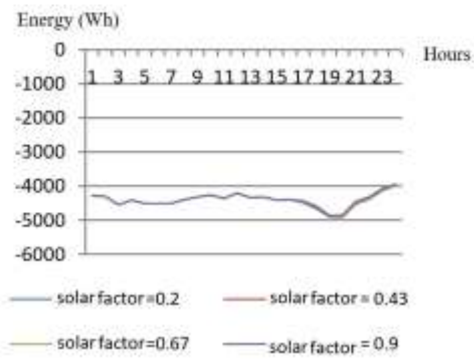

Figure 34. A warm day in Montreal.

A warm day, July 23rd: The graph shows similar data throughout the day. At 2AM a slight and insignificant change, however from 3PM onwards deviations are produced: 2295Wh when the solar factor is 0.9, 1997Wh when the solar factor is 0.67, 1633Wh with a solar factor of 0.43, and 1250Wh with a solar factor of 0.2. In consequence, a difference of 1006Wh is produced depending on the solar factor applied on the exterior.

5 Conclusion

The thermal simulations carried out confirm that the form factor of the VEM project affects the results of thermal performance in a more favorable way than with another geometry. In the study squared surfaces, the resulting form factor would be 1.67 while in the case of this project the form factor obtained is 1.2, being a lower form factor more energy efficient to adapt better to the conditions of use of solar radiation, ventilation and air renewal, due to the study of energy gains and losses (pg.5), in the energy losses graph: it shows that with a form factor of f=1,67 in the month of January the energy losses are 11.095.500Wh, compared to 2.197.916Wh with a form factor of f=1.49 in the same month of January, and to 1.241.366Wh when the form factor is f=1.212. This data proves that the form factor of the VEM project (f=1.212) represents an energy saving of 88% compared to the design with a cube form factor.

In the graph of energy gains, important changes appear again, showing that with a form factor of 1,67 in the month of July, the energy gains are 1.147.200Wh, compared to 1.711.586Wh with a form factor of f=1.212 in the same month of July. This data proves that the form factor of the VEM project (f=1.212) represents an energy gain of 150% compared to the design with a cube form factor. After these simulations, it is established that the most optimum form factor is 1.212. The results on the study of the energy support needed in different regions by modifying the exterior color show significant data on cold days, from which the following conclusions are drawn:

- In Madrid, with a continental Mediterranean climate, the color study shows maximum results of 688Wh in energy losses if the color of the exterior envelope was to be black (with a solar factor of 0.9), and losses of -879Wh if the color was to be white (with a solar factor of 0.2). The energy improvement according to the color of the exterior envelope is of 1567Wh on a cold day.
- In Brasilia, with a tropical climate, the color study shows maximum results of 1780Wh in energy losses if the color of the exterior envelope was to be black (with a solar factor of 0.9), and losses of -687Wh if the color was to be white (with a solar factor of 0.2). The energy improvement according to the color of the exterior envelope is of 1183Wh on a cold day.
- In New Delhi, with a monsoon climate, the color study shows maximum results of 3142Wh in energy losses if the color of the exterior envelope was to be black (with a solar factor of 0.9), and losses of 869Wh if the color was to be white (with a solar factor of 0.2). The energy improvement according to the color of the exterior envelope is of 2273Wh on a cold day.
- In Karachi, with a semiarid climate, the color study shows maximum results of 634Wh in energy losses if the color of the exterior envelope was to be black (with a solar factor of 0.9), and losses of -1270Wh if the color was to be white (with a solar factor of 0.2). The energy improvement according to the color of the exterior envelope is of 1904Wh on a cold day.

The results on the study of the energy support needed in different regions by modifying the exterior color show significant data on warm days, from which the following conclusions are drawn:
- In Madrid, with a continental Mediterranean climate, the color study shows maximum results of 5432Wh in energy losses if the color of the exterior envelope was to be black (with a solar factor of 0.9), and losses of 4000Wh if the color was to be white (with a solar factor of 0.2). The energy improvement according to the color of the exterior envelope is of 1432Wh on a warm day.
- In Brasilia, with a tropical climate, the color study shows maximum results of 1955Wh in energy losses if the color of the exterior envelope was to be black (with a solar factor of 0.9), and losses of 669Wh if the color was to be white (with a solar factor of 0.2). The energy improvement according to the color of the exterior envelope is of 1286Wh on a warm day.
- In New Delhi, with a monsoon climate, the color study shows maximum results of 3916Wh in energy losses if the color of the exterior envelope was to be black (with a solar factor of 0.9), and losses of 2591Wh if the color was to be white (with a solar factor of 0.2). The energy improvement according to the color of the exterior envelope is of 1325Wh on a warm day.
- In Karachi, with a semiarid climate, the color study shows maximum results of 3309Wh in energy losses if the color of the exterior envelope was to be black (with a solar factor of 0.9), and losses of 2303Wh if the color was to be white (with a solar factor of 0.2). The energy improvement according to the color of the exterior envelope is of 1006Wh on a warm day.
- In Montreal, with a continental humid climate, the color study shows maximum results of 2295Wh in energy losses if the color of the exterior envelope was to be black (with a solar factor of 0.9), and losses of 1250Wh if the color was to be white (with a solar factor of 0.2). The energy improvement according to the color of the exterior envelope is of 1045Wh on a warm day.

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