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# Assessment of the temperature comfort of a model house

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**Graphical Abstract**

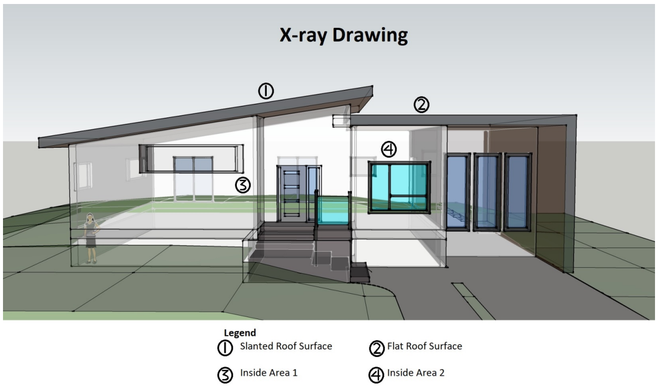


**Fig. 1**: Model house designed with AutoCAD. The geometry facilitate circulation and cooling

**Abstract.**
The growing concerns about global climate changes and mitigation strategies constitute a technical challenge for civil engineers and architects altogether. In this project, a model house was designed appealing to AutoCAD, and a scaled version was assembled using low cost materials. The model design pretends to enhance cooling within the house taking advantage of the geometry of it and the circulation pattern around it. Measurements of the thermal load were done with a Thermal Infrared Camera and a set of sensors located within the model house. The temperature distribution was compared with the one obtained from solving the heat equation with Wolfram Mathematica. Recommendations for homebuilders are presented.

## 1. Introduction

Urban developments nowadays demand from civil engineers and architects creativity. Megacities are suffering from large urban heat island effect (UHI). It is defined as the rise of temperatures in any man-made area, resulting in a change of urban temperature profiles, wind and rain patterns when these parameters are contrasted with those from rural areas [1]. Changes in albedo that are associated with UHI yield to changes in transport of energy and mass within urban areas which combined with particular geometry of urban canyons will produce specific spatio-temporal patterns of pollution dispersal too [2]. A further exacerbation of UHI effect is coming from global climate changes. Variations in weather conditions around urban areas are sensible to further amplification effects when they are contrasted to similar variations in rural environments. These changes might impact the ecology of cities and stimulate the proliferation of vector-borne diseases in addition to the thermal loads already associated with climate changes [3]. Altogether, they tend to increase the demand on energy in order to cool houses and other facilities and maintain a level of acceptable comfort. In these circumstances, the consideration of geometries that facilitate the air circulation might lead to an effective cooling and therefore to energy saving while maintaining the comfort standards.

This project is aimed at designing and testing a model house for insulation. It is combining design with educated choice of materials and geometries, as well as the internal layout of the house.

## 2. Materials and Methods

**Fig. 2**: Model house and the collection of spotlights simulating the sunlight. The emitted power from the lamps was about

A model is created using AutoCAD (see Fig. 1) and then created to scale using thermo-insulating materials such as: insulating polystyrene foam, acrylic, silicon sealer, and Masonite hardboard (see Fig. 2). This model will be tested by exposing it to a radiating source of heat, which follows a temporal pattern similar to that exhibited by the sun in that it raises from the east and sets on the west. We will measure the temperature at different regions of the house using a laser sensor as stated in the X-ray Drawings (see Fig. 1). By comparing the outside and inside temperatures after the model has been exposed to the heat source for 1 hour, the efficiency of the insulation can be assessed. In order to estimate how much heat is capable to enter the house for a given radiating source output, the Fourier law of thermal conduction [4] will be used and it can be cast into:

$$\frac{dQ}{dt} = \frac{kA}{L}(T_H - T_E)$$

where L is the width of the wall, A is the surface area of the wall, k is the coefficient of thermal conductivity, $T_H$ is the temperature at the interior of the house, while $T_E$ is the value outside of it. In Table 1, the values for the physical parameters are summarized.

| Description | Values | Unit Conversion | Conversion Factor | Values in SI Units |
|---|---|---|---|---|
| Themal conductivity of polystyrene | 0.027 W/(m*K) | - | - | 0.027 W/(m*K) |
| Cross-Sectional Area | 372 in^2 | sq inches to sqmeter | 1 in^2 = 0.000645 m^2 | 0.24 m^2 |
| Thickness of Wall | 1.25 in | inches to meter | 1 inch = 0.0254 m | 0.03 m |
| Temperature of Interior | 20°C | Celsius to Kelvin | T(°C)+273.15 | 293.15 K |
| Temperature of Exterior | 23°C | Celsius to Kelvin | T(°C)+273.15 | 296.15 K |
| Time elapsed | 1h | Hours to seconds | 1 h = 3600 s | 3600 s |

**Table 1**: Values of the physical parameters used to estimate the heat transfer across the model house and following the Fourier law of thermal conduction.

## 3. Results and Discussion

The first round of measurements focused on the outside distribution of temperatures while moving the radiating source following a sun-like pattern. It is noteworthy that environmental (background) temperature at the Physics Laboratory was around 69 F (20.56 C or 293.71 K) for most part of the day. It conditioned the time interval required to observe significant changes while heating the model house (see Fig. 3).


**Fig. 3**: Thermal distribution obtained from the Thermal Infrared Camera for different positions of the source of heat (spotlight emitting about 500W of power). Left-most panel corresponds to the source located to the eats, the central panel corresponds the source located at a center, while the right-most pane corresponds to the source located westward.

Once the outside part was characterized, measurements at the inside locations were performed with a infrared diode laser thermometer. The obtained results were included in Table 2.

| Temperature at Different Regions (East) | | | |
|---|---|---|---|
| | | Temperature (°C) | |
| | | Min | Max |
| Exterior | Slanted Roof | 20 | 22 |
| | Flat Roof | 21 | 24 |
| Interior | Inside Area 1 | 20 | 21 |
| | Inside Area 2 | 20 | 21 |

| Temperature at Different Regions (Center) | | | |
|---|---|---|---|
| | | Temperature (°C) | |
| | | Min | Max |
| Exterior | Slanted Roof | 20 | 23 |
| | Flat Roof | 21 | 23 |
| Interior | Inside Area 1 | 19 | 20 |
| | Inside Area 2 | 20 | 21 |

| Temperature at Different Regions (Center) | | | |
|---|---|---|---|
| | | Temperature (°C) | |
| | | Min | Max |
| Exterior | Slanted Roof | 20 | 23 |
| | Flat Roof | 21 | 23 |
| Interior | Inside Area 1 | 19 | 20 |
| | Inside Area 2 | 20 | 21 |

**Table 2**: Temperature measurements for different geometries and comparison of in and out values.

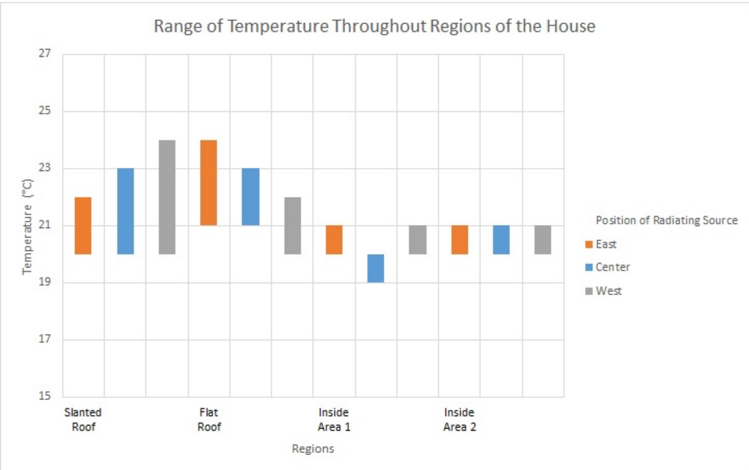


**Fig. 4**: Summary of the range of temperature variations in different parts of the model house.

Taking into account all measurements together, a summary of the temperature ranges in different parts of the model house can be seen in Fig. 4. It is clear from this picture that the largest range is observed in the junction of the flat roof and slanted roof (see Fig. 1).

According to the results, we can say that our insulation system is very reliable for small projects like this. These materials may not be optimal for real-life construction, yet the polystyrene insulation works very well to insulate thermal transmission through the conduction method, which makes it optimal to place along masonry units. Other small size applications of this experiment include cool (cold) boxes, packaging delicate electronics, and flooring. From our experiment we can see that not even a thermostat will be needed to prevent the interior of the house from heating up. However, real life always has more variables that implicate the results of experiments. A legitimate, not model, house under changing environment conditions will release or absorb heat; in which case, there are many other methods that reduce this leak or absorbance of heat like manipulating air flow through vents or using specialized panels that have high thermal resistance $R = L/k$ ratings.

## 4. Conclusions

The joint effort of civil engineers, architects and applied physicists might help to find optimal solutions in the construction industry. The thermal and fluid environment may be characterized nowadays much better than it happened years before, thus, physics-comfort-oriented designs might become a reality, saving energy and resources, and transforming construction industry into a smart and sustainable one.

## Acknowledgments

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