Design parameter guidelines for purely passive cooling buildings in Tropical regions

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by

to obtain the degree of Master of Science
at the Delft University of Technology,
to be defended publicly on ... 2019

Student number:	4744896
Project duration:	November 1, 2018 – November 1, 2019
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1 Reflection

1.1. Objective of the research

The objective of this research is to investigate whether it is possible or not to design a purely passive building in tropical climate and to draw a guideline for architects and engineers to achieve this goal as conclusion. Through the computational optimization of the design of a building case study it was possible to observe the impact of the envelope and indoor comfort parameters to decrease the energy consumption of an office high rise in a tropical region. In particular, the methodology implemented is based on the following steps:

- research question
- background research
- literature review of the state-of-the-art
- energy simulation in Grasshopper+Honeybee
- optimization in ModeFrontier
- exploration of the design solutions
- conclusions

1.2. Process

The first phase of this research consists on the literature review of the state-of-the-art of the passive cooling strategies and of the principles of the bioclimatic architecture applied in tropical regions. Also, other two important topics to research are the Zero Energy Building's in tropical regions and the benchmark applied in the location of the case study. Finally, the application of adaptive comfort models was investigated.

The second part of this research consists on the research through design. In particular, starting from a case study it was researched how to achieve a purely passive building through a building performance simulation (BPS) and building performance optimization (BPO) process. The set-up of the simulation process was done through Rhino and Grasshopper (GH) for the construction of the parametric model and through the plug-ins Honeybee and Ladybug for the performance evaluation of the tested designs. This first phase consisted of the construction of the model and the set-up of all the parameters that influence the energy performance of the building, meaning envelope parameters, parameters related to the internal loads and schedule and the definition of the HVAC system implemented in the current case study. It is important to specify that many information related to the systems implemented in the case study were not found, thus assumptions were made, such as the type of HVAC system, the air infiltration rate or the lighting density. Also, another aspect to highlight is the reliability of the results of the tools used. Grasshopper, Ladybug and Honeybee are tools in constant development, thus limitations and restrictions were faced during this face. However, an evaluation of the results of the simulations was done by testing the performance of the design also in another reliable software, which is Design Builder.

Then, the building performance optimization was carried on Modefrontier, by linking the Grasshopper script with the optimization software. ModeFrontier is a tool used mostly in the engineering design process rather than in the architectural design process. Thus, this study helps to experiment the application of this tool in this field. Because of the lack of other studies based on the application of this software, this last phase of this research turned out to be slower than expected. In particular, different complications were found during the connection of the Grasshopper script with the optimization script. It was learned to test the optimization software by testing the simulation file in different stages, by enhancing gradually the details of the script and by adding slowly the variables to be combined by the algorithm. Also, it is important to check the time needed for each simulation during the testing phase of the software and to simplify the grasshopper script in order to run a considerable amount of simulations and to approach to the optimal solution. However, once obtained the results of the optimization phase, it was easier to read and understand the outcomes of the research thanks to the advanced tools for data analysis and visualization. The post processing phase of the results in ModeFrontier turned out to be an interesting feature of this software simplifying the decision making phase. With this study hopefully it will easier to implement this optimization tool in the architecture design process to achieve easily the design objectives fixed.

1.3. Impact on the academic and professional field

During the background research it appeared the lack of research about the computational optimization of the design of passive buildings in tropical countries, thus the outcome of this study could be useful for future research on the development of zero energy buildings in tropical climates. In fact, this study establish not only the impact of the envelope properties on the energy performance of a building but also the impact of indoor comfort strategies, such as internal loads and schedules or the introduction of cross ventilation.

Also, this research contains a guideline to design a high rise office building in a tropical region following three criteria: architectural constraints, indoor comfort parameters and finally the energy performance of the building. All the design proposal take into account the energy consumption of the building, in order to allow to the designers, architect or engineer to be aware of the impact of the choices made on the energy performance of the design chosen. Finally, as stated previously this research can be useful for a further development, by taking into account other parameters such as a dynamic shading system or the HVAC system parameters.

1.4. Societal impact

Regarding the impact on the the society or the users, it is interesting to observe how active users could have a high impact on the energy consumption of a building. In particular, by implementing the adaptive comfort standards and at the same time by acting on the indoor comfort parameters, namely internal loads and schedule. This parameters were tested by calculating the user's comfort implementing the adaptive comfort model. The latter, differently from other comfort models, allows higher ranges of temperatures thanks to the adaptability of the users. Also, the use of Adaptive Comfort Standards can increase design flexibility, reduce the capacity of installed plant for cooling purposes and save energy consumption, without affecting enormously user's satisfaction

As noticed by the results of the second optimization, all the solutions simulated reach the total percentage of comfort time although the high indoor operative temperature reached. Thus, this study shows that it is still possible to increase the cooling set point temperature and achieving the highest thermal comfort levels, especially in tropical regions.

Also, as stated by Francois Garde ”The last most important key feature are the occupants of the building because the success of the process is to get active people in a passive building instead of passive people in active buildings. To do this, people need to be educated and to adapt their behavior.” (Francois Garde, 2012 Integrated Building Design In Tropical Climates: Lessons Learned from the ENERPOS Net Zero Energy Building).

The challenge to the related architects/designers/researchers is to come out with effective strategies to overcome the state of discomfort with minimum energy utilization.

Finally, I can conclude that in order to achieve a nearly passive building architects, designers and engineers must come out with a design proposal, not driven anymore by architectural design, but driven by comfort and energy performance in order to guarantee acceptable comfort levels with minimum energy consumption. It is thus necessary to make certain design compromises in order to reduce the harmful impact of the building industry on the environment.