Reflection

Integrating Natural Ventilation within an optimization process of energy performance in the early design stage

Antonio D’Aquilio – 4328116
Mentors: Dr. MSc Arch. Michela Turrin
Dr. Regina M. J. Bokel
Dr. Craig L. Martin

The aim of this research is to show that the implementation of natural ventilation strategies can contribute to a multi-objective optimization process, in order to achieve a better performing design for office buildings located in temperate or hot climates. Passive aspects and strategies play a key role for the future efficiency of buildings, and they must be planned and optimized early in the design process.

The research done within this thesis was divided into 5 steps:

1. Background research.
2. Assembly and validation of tools for the calculation of Natural Ventilation and Heating/Cooling need.
3. Assembly of an integrated optimization process.
4. Application of the proposed process on a case study of office building.
5. Comparison of results and final discussion.

The first two points can be identified as the planning of the whole research, where important background literature on design strategies, computational techniques, evaluation methods was analysed. Also the evaluation tools needed for the proposed process were developed in this phase. The rest of the research was the practical and theoretical development of a computational framework that is eventually tested on a case study for an office building.

Planning

1. Background research
The background research comprises a Literature review and an Interview to architects/engineers.

1.a Literature review
The review done on previous studies of energy performance optimization of buildings was fundamental in order to critically understand and start working on the current limits of optimization processes studied within the academic field. Also, a literature research was done on the environmental problems related to buildings, on the potentials of designing following sustainability criteria related to energy and on the current Building Performance Simulation (BPS) techniques.

1.b Questionnaire
Next to this, a questionnaire was delivered to a number of Architects and Engineers of top-level studios and consultancy firms, in order to assess the current situation of building optimization in real practice. The objective was to retrieve information on the potential of such a process and on the feasibility of being embedded into the early stage of a design. This step was important to understand what are the limits of optimization in real practice, and spot in which way, such an optimization process can have a wider application on average level building designs.

2. Tools development
The next step was to build the tools that were needed in order to test an integrated approach for optimization. In this phase, the development of a Natural Ventilation solver and a Heating & Cooling calculation tool were computationally developed. In this phase, research was also done on the calculations to be used. Finally, the Natural Ventilation tool was tested and compared with a software (CoolVent) that natural ventilation for cooling.

**Process**

3. Integrated optimization process
Once the needed tools were ready to be used, the integrated optimization process was assembled. In this phase, design parameters, constraints, evaluation criteria, objective functions, evaluation tools, optimization algorithm and specific passive strategies were investigated and selected. A distinction was made between a hypothetical process and a practical one, which are slightly different. The reason is because the practical process (to be applied to a case study) needed to overcome time issues. The goal of the proposed hypothetical process is to create a computational framework for the holistic optimization of selected objective functions (and related evaluation criteria) for early stages of a design process. The applied process will slightly differ in the selection of design variables, objective functions and level of detail of specific evaluations.

4. Case study
An application of the assembled optimization process is performed on a case study of an existing office building comprising Atria, in order to visualize its potentials and to assess its results. A first analysis of the existing building revealed problems and room for improvement of the original design. Then, a parameterization of its shape and layout following a specific design strategy, together with other aspects related to its envelope, was done. The application of the computational process was done at different levels. First, the application was made without comprising natural ventilation as strategy for passive cooling. Second, natural ventilation was assessed and optimized together with other passive aspects. The third application dealt with a more holistic approach, comprising both aspects related to the geometry of the building and its basic envelope parameters. The three results come along with a base case analysis, which will serve as final comparison to assess the potential of the investigated process.

5. Comparison of results
Finally, the results retrieved from the analysis and optimizations were compared and discussed, in order to coherently answer the research questions.

**Product**

The main product of this research is a computational optimization process and the demonstration (through practical application) that an integrated approach leads to better performance for the design of office buildings. Specifically, the objective of this research can be better explained by answering the proposed research questions.

**Research question**

*To what extent natural ventilation strategies can improve energy performance and thermal comfort of a design for an office building?*

According to the comparison of the performance of an optimized office building and its base case (surrogate design of the case study), it is clear that a design optimized by using an integrated approach in its early stages has greater chances for energy savings. Moreover, this comparison shows
the potential of applying such a concept early in the design process, where important decisions that will affect the future performance of the building are taken. As previously observed, the strict constraints selected for this specific case study have eventually confined the optimization potential. Therefore, it is important to underline that both design variables and design constraints play a key role for optimization potential. Since these parameters are dependent on a number of design aspects and issues specific for a project, they cannot be categorized and either their effect on building performance can be predicted with absolute certainty.

Sub-questions

To what extent embedding natural ventilation strategies into an optimization process affects its final outputs in terms of building performance and layout?

A comparison between an optimized design embedding the assessment of natural ventilation and its cooling potential with a design not optimized with the same objective functions was done in chapter 6. The results show that the design of this case study can have different performance and layouts if the optimization process embeds or not natural ventilation. Moreover, the overall performances of the building are higher in the integrated approach than in the one that is not integrated. This leads to the conclusions that the early stages of a design comprises a high number of variables that affect each other and for which there should be found a balance in order to achieve better performing solutions. It is important to underline that this balance cannot be easily achieved by splitting the problems and that an integrated approach leads to greater improvements.

To what extent a holistic approach can be beneficial for an optimization process of energy performance in the early stages of a design?

This question finds its answer in the second comparison of the results retrieved by the performed analysis. From this, it appears clear that there is an overall improvement of energy, thermal comfort and daylight performance when these three aspects are considered altogether and when the design variable regard elements of both building geometry and envelope characteristics. Considering the highly constrained search space of the case study and related results, the overall potential appears to be high. Specifically, saving potentials are always dependent on the design quality, defined parameters and constraints.
Finally, constraining aspects related to envelope design have effects on the saving potential of such a process. Even though in the early stages it is not always common to have specific material choices, a holistic approach should always comprise basic envelope strategies.

Comments

My thesis started by having as a goal the making of a computational process by using existing evaluation tools. However, as I discovered along the way, there was the need of making specific tools for evaluation of building performance. Even though the initial research part helped in the clarification of this point, the original plan was eventually changed and only after P2 a clear path to follow was found. By having more time for the making of the evaluation tools, I could have spent more time in the application of the integrated optimization process. Even though I managed to retrieve the information I needed in order to answer the originally proposed research questions, by having more time I could have retrieved more information and data from the practical application.
The choice for the case study came along the research made on office building design and on the way optimization is (or is not) done in real practice. Eventually, this building resulted to be a good case study, because of its overall current performances, and served as good basis for design improvements.