

Reflection

This master thesis aimed to optimize the assessment of hygrothermal safety of wooden beam ends that are embedded in solid brick masonry and internal capillary active insulation is applied. Primarily focussing on the key input material properties that have the highest effect on decay of the wooden beam and the visualisation of those results in order to create a better visual understanding of the effect of input changes on hygrothermal safety. However, initially the scope of the project and objective I wanted to reach was broader. Starting from P2 it was my goal to create a comprehensive, quick and accurate method to simulate the hygrothermal performance of the interior insulation around the wooden beam ends. But this quickly seemed to be a step to far. Because, before creating the best method for simulating and assessing the simulation, results when varying the simulation programs input should be research. How does the geometry and possible changes in settings, both material and program, affect the hygrothermal performance of a construction. And thus, finding what is important to get right in order to receive accurate results from the simulation, eventually resulting in being able to give a more accurate advise to clients.

In order to reach this objective I had to gain more theoretical knowledge. Dive deeper into the settings of Delphin, find what input was used in the calculations and make decisions how I could research the input effects on hygrothermal performance. I started with simple simulations, changing settings as wind driven rain, solar radiation and detail of geometry but quickly realized that a comprehensive and accurate analysis of the software needed a more complete method. With the knowledge from the first simulations: the fact that the application of WDR and SR have significant influence on the simulation results and should thus be included in future simulations, highest moisture loads were found on south and west orientated facades and the detail of the geometry does not have a big influence on the simulation results, I explored other possible high influential settings that could influence the results. From the literature study and during talks with my mentors it became clear that material properties would have big effects on the simulation results.

I determined at P3 that 10 material properties would be research on sensitivity on the simulation results with the Sobol sensitivity analysis and the moisture dose component as result value used in the

sensitivity analysis. For this I needed to learn Python programming from the basics, and how to control the Delphin software with the programmed scripts. Tasks sometimes seemingly impossible but in the end being moments where you just have to divide the problem in to multiple smaller steps in order to reach these bigger end goals. With the guidance of mentors, and colleagues at ABT I eventually solved the problems, always taking longer than anticipated. While gaining more theoretical knowledge the number of variable material parameters decreased to 5 and became more complex. It made myself familiar with new hygrothermal functions and integrated these in the scripts. All in order to find more accurate results.

Looking back at the plans I had for this master thesis at P2 and P3, I hoped to be a bit further in my research at this point. Possibly it's the feeling that I've put in a lot of research and programming time, but results are not really as I would have expected. Both in quality and quantity. On the contrary, the thoroughness of the research conducted is increased significantly, maybe even more important than result alone.

Evaluating at P4, I had an enormous list of possible additions to the research. For example: researching wood an-isotropic behaviour, location, orientation, and weather influences. Adding more variables, creating better visualisations, changing geometries and improve the analysis of result. Available time was, when looking back, not sufficient for all these changes and new research opportunities. But eventually at P5, I implemented all these changes and have succeeded in making a master thesis where I'm extremely satisfied about.

I'm proud that I've learned so much. Theoretical knowledge about all topics that can be associated with hygrothermal performance of building components, and learned a lot of new skills. For example, software skills but also skill to do literature research more efficiently. I still find it hard to motivate myself and work efficiently every day, but think I did a quite adequate job during this master thesis. I've found that discussing problems, really helped solving them. New insights, opinions and knowledge really helped to reach a higher level, and people really would like to help if you ask them. All beneficial to reaching this master thesis objective.

1. What is the relation between your graduation project topic, your master track (A, U, BT, LA, MBE), and your master programme (MSc AUBS)?

The total building sector is going through an enormous transformation towards sustainability. Architecture, construction and consultancy companies are all searching for ways to reduce the use of finite materials and energy and to reuse materials and energy in order to contribute to Dutch, European and global environmental goals. This thesis, where the use of internal, capillary active insulation around wooden beam ends in solid brick masonry is researched, contributes to those challenges.

With the reuse of buildings, there is a decrease in need for new buildings and thus the need for new materials and corresponding CO₂ emissions. Buildings are more energy efficient and can be given other functions. Biobased materials minimize CO₂ emissions, while the application of indoor insulation preserves their aesthetical, historical and cultural value. Additionally, new innovative materials, like capillary active insulation, are researched and tested and integrated into current building standards. Bridging the gap between the architectural design and engineering and improving the implementation of innovations. Both can be seen as principles of the master track Building Technology and the master of Architecture, Urbanism and Building Sciences. Where we have set ourself the goal to integrate new knowledge and skills into design practices to create sustainable development.

2. How did your research influence your design/recommendations and how did the design/recommendations influence your research?

This research primarily focussed on providing recommendations when simulating building components in Delphin hygrothermal simulation software, especially when focussed on embedded wooden beam in solid brick masonry facades. Finding key parameters that affect wood decay. The findings of this research can be used in future hygrothermal simulations, by giving an indication of parameters that have an high influence on the simulation results and can be taken into account when giving advice to clients in similar practical situations. Wood decay assessment can be used in all kinds of situations, assessing design options and hygrothermal safety in all kinds of locations, orientations and weather types worldwide.

3. How do you assess the value of your way of working (your approach, your used methods, used methodology)?

I think, when looking back to the start of this master thesis, that I gained an substantial amount of (theoretical) knowledge. I learned from scratch how to use new software programs like Delphin hygrothermal simulation software and programming in Python and learned a lot on material properties and their behaviour, especially when looking at moisture and heat properties.

When assessing my approach, used methods and methodology from this starting point I'm really satisfied with the completed work. Continuously adaption to new insights, new skills and knowledge to lift this master thesis to a higher level. But, I'm also very aware that I could have reach a higher research level if could have started with this all knowledge that I have gathered to this point. I would have made different choices, included more important research in order to create a more complete study and could have done work so much more efficient. Knowing that this is part of learning and only that I can see this because of the fact I learned so much. I'm therefore definitely satisfied with the approach and think the used methods positively impacted the value of the final result.

4. How do you assess the academic and societal value, scope and implication of your graduation project, including ethical aspects?

With the renovation of monumental buildings, aesthetic, cultural and historical value is preserved. Internal insulation ensure that the outside of the building stays the same, keeping their character and cultural and historic features. Secondly, hygrothermal performance of building facades have a significant positive effect on the users of the building. Creating a safe and comfortable indoor environment.

But societal impact is not only made on the users or cultural aspects of the building. Building construction companies, architects and consultant companies are in need for quick, correct and more accurate ways to simulate the hygrothermal effects of interior insulation. The results of this thesis can be used in future research and to develop the best possible solution for insulation around embedded wooden beams in practice. Resulting in an increase in monumental buildings that can be renovated. Contributing to the needed increase in deep building renovations to reduce material use, conserve energy and minimise CO₂ emissions eventually aiding in reaching the UN Paris Agreement goals.

Finally academic relevance and value. Standard insulation has been tested and applied, but new, biobased and capillary active materials that can reduce humidity levels in building envelopes have to be researched and developed further. More knowledge has to be gathered on the storage, transport and absorption and desorption of the capillary active materials around wooden beam ends, simultaneously verifying simulation models. Applied to transport moisture back to the indoor side of the insulation layer to minimize moisture induced damages, while still preserving their functions as insulation material. Contributing to finding design solutions that can be used within the building sector.

5. How do you assess the value of the transferability of your project results

During the entire master thesis period, I've focussed on the fact that I would like my research to be used in practice. From the start I've tried to make my research to be as transparent as possible. Within my report there is a chapter on the inputs and choices made in the material parameter study, that could be used when others want to use my results. For example in other sensitivity analysis or to extend this specific analysis with the recommendations from this study.

Besides the sensitivity analysis results, the wood decay assessments are made to be used by others. To make the wood decay risks more visual and understanding, even for people without the knowledge on the subject. With the python script that is used to make the visualisations, standardly divided into different parts and parts of text added to create a better understanding of the specific task of the scripted part. In addition to the script, extra information is written within the thesis report for more clarification and transferability of the project and corresponding results.

6. What is the practical value of the innovative capillary active materials from this master thesis?

The use of capillary active materials for interior insulation is quite new in current building construction, precise effect on building hygrothermal performance is still unknown and the application of this new material when transforming or renovating buildings is often complicated. The material and its important real life application rules, such as the need for direct contact with the old wall and the installation without air gaps, is not yet common and therefor an risk on performance when installed in projects.

This research adds to the knowledge needed for the real life application of these new innovative materials, probably used by consultancy companies in the first place but eventually leading to new, and hopefully standard building practices in the future. Making the renovation of old buildings with more (biobased) capillary active materials possible and reducing environmental impact.

7. How did the graduation internship at ABT influence your master thesis?

During this master thesis, I had the opportunity to do a graduation internship at ABT in Delft. A consultancy company part of the Oosterhof group. ABT provided me with all resources I needed to do my research, both practical and knowledge wise. When asked, I received all the help I needed, for example with Python programming questions, or missing theoretical knowledge. All crucially important for the progress of this research and definitely one of the reasons that I reached the research level to the point where I'm right now.

The fact that I had my own place to work and the structural motivation to work at least those 8 hours every day helped me a lot. I'm confident this had a tremendous positive effect on the total amount of hours and work that went into this thesis, motivating me every day to start and keep improving my work. I'm therefor very grateful for this opportunity and appreciate this immensely.