Reflection

The main objective of the master thesis is the investigation of potentials in cellular structures that are generated with Additive manufacturing production methods and more specific the thermal performance. The results from the investigation would give the new functions in order to produce the final product of the thesis which is an integrated facade panel. The cellular structures were designed, produced with Fused Deposition Method and tested for the thermal performance and more specific for thermal insulation. The results that were obtained from this part of the thesis was the input for designing the building envelope.

The methodology that was followed is a balance between the research by design approach and design by research. The first part the literature study was based in the research of the complex and multifunctional cellular structures in nature and also in other porous and foam structures.

In addition the potentials of AM processes to generate complex components were researched. The conclusions from the research gave the input in order to design and compare several shapes and sizes of cellular structures in Rhinoceros 3D. The main categories were spheres and polyhedra. In addition the designs were validated with thermal simulations by using digital tools (COMSOL Multiphysics) and were 3d printed in order to make physical experiments (thermal tests, structural tests) and obtain additional results. The 3d printing process is an important aspect of the thesis and many decisions were taken for the direction of the final design of the material and finally the facade component according to the possibilities that 3d printer provided during the production phase of the thesis. In order to create the final facade component other aspects such as loadbearing structural behavior was investigated and also alternative materials for the final product. The research and design of the graduation project was not a linear process that means that the additional functions that are needed the final product which is a facade component influenced the decisions for the shapes and the size of the cellular structure.
Moreover the results from the different processes (Generation of the design-3d printing-digital simulations-physical experiments) were compared and the conclusion gave each time a direction for the design of the facade panel. The final product is a facade sandwich cellular panel that according to certain requirements(support from the main structure, thermal insulation, resistance to wind load, maintenance, watertightness, program and geometry of the building) has complex shape.

The decision of combining both research by design and design by research in general gave me the opportunity to study from different perspectives the topic and validate the results that I received in each stage according to different aspects in order to conclude in an integrated result. The tools that were used in order to receive several results are valuable, however there were some aspects that decreased the amount of tests (thermal and structural) and caused a delay in the process during the thesis and limitation in the range of results. The time of producing the samples was longer than expected. The design of the drawings in order to 3d print was time consuming. The tolerances and the geometry of the cellular structures caused a delay into start 3d printing and making the first physical tests. Moreover the 3d printing process in good quality of complex geometries turned to be time consuming for the specific model. Time also was spent in order to get familiar with Comsol digital tool and start having the first results from the digital simulations. Additionally the lack of decision making in order to move from one step to the other and the lack on flexibility into giving alternative solutions in issues that might appear during the thesis had as a result to delay in the process of the thesis. Moreover the first part of the thesis (developing the material) could be more in balance with the facade product development which could be investigated more into depth in order to receive more results in that part. Additional functions (such as watertightness, design of details and assembling methods for the facade component, research on materials maintenance could be researched more into depth and also more tests in loadbearing behavior).

Societal relevance
A sustainable product design incorporates economic imperatives, ethics and socio-economic dimensions of sustainability, and uses ecological principles as method of designing (Olaf Diegel 2010). During the last decades additive manufacturing methods became more feasible in the field of architecture and building construction. One of the potentials of additive manufacturing is the production of complex objects that can integrate multiple functions.
This advantage can be applied also in the building industry. In this thesis the advantage of generating complex shapes influenced the facade design in order to create a component that first has good thermal insulation but also integrate additional functions such as capability to receive the self-loads and the wind loads and transfer them in the main loadbearing structure.

In that direction the result for a building would be an envelope that consists of individual elements that are customized according to the conditions and the performance required in the certain position of the building. Using traditional methods this result would produce more material waste an time consuming in comparison with additive manufacturing. The validation of the societal relevance is one of the aspects that could be developed more into depth during this thesis by introducing more examples of building typologies where this facade could be applied (shelters, office buildings, mix use buildings). However the reduction of waste material in addition with providing thermal comfort to the occupants is a valuable direction for future development and research in producing tailored components in the facade industry.