°GRADUATION PLAN

ANDREJA ANDREJEVIC

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In the graduation plan the practical information about the graduation project is getting discussed. There will be elaborated upon the problem, goal, methodology and the relevance of the graduation topic. There is also shown in what timeframe the project is planned.

Personal information

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MSc Building Technology

Departments: Climate design & Structures
Theme: Climate integrated structural design
Teachers: Prof. Dr. Ir. P.M. Bluyssen & Dr. Ir. P.C. Louter
Theme choice:
Designing, engineering and constructing structures have to happen from a certain point of view. In this theme the full driving force behind creating structures is the importance of climate design. The interaction between structural and climate design ensures enguinity.

Title graduation

''The design of a maximum transparent roof to create the most optimal micro climate for the Khalifa International Stadium in Qatar''

Problem statement

With the FIFA World Championship 2022 coming to Qatar, a lot of development is happening in the capital city of Doha. The biggest occurring development is the construction of 12 stadiums, which 9 are to be build new and 3 to be renovated and transformed. Since Qatar 2022 is going to be organised in summer, where the average temperature is 40 °C, the FIFA stated very strict climate regulations for the stadiums. The target temperature in stadiums may not occur higher than 26 °C, while the used cooling energy has to come from a self-sustaining source.
The new stadiums that are getting build can deal way easier with this challenge, since this climate principle can be integrated in the whole design. However, the to be renovated stadiums contend with the challenge that this climate requirement has to be added to the existing situation. This makes transforming an existing stadium that has to be energy efficient a huge defiance.

Research question

How can a maximum transparent roof for the Khalifa International Stadium (KIS) in Qatar, with efficient use of energy, create an optimal semi outdoor climate in extreme summer weather conditions?

Research Goal

The main goal of this graduation project is creating a climate integrated structural transparent and/or translucent roof design for the Khalifa International Stadium (KIS) situated in Doha, Qatar. With designing an additional transparent roof to the KIS the challenge of creating an ideal semi-outdoor climate should be tackled, in such way that the roof has to be climate adaptive. This means complying with the requirements of the Semi-Indoor Environmental Quality (S-IEQ); Acoustical quality, Air quality, Lighting quality and Thermal quality and the climate criteria of Qatar 2022. These qualities combined will give the challenge to design a very complex structure for a transparent roof that in the end deals with all the climate challenges. Structural design support climate design.

Method description

With the design of a stadium roof in such extreme weather conditions, the research and design approach has to come out of 2 disciplines; Climate Design and Structural Design. The research on Climate Design has to be the foundation for a proper Structural Design. The scheme below explains how climate research and analysis evolves into a design of a roof structure (see fig. 0).

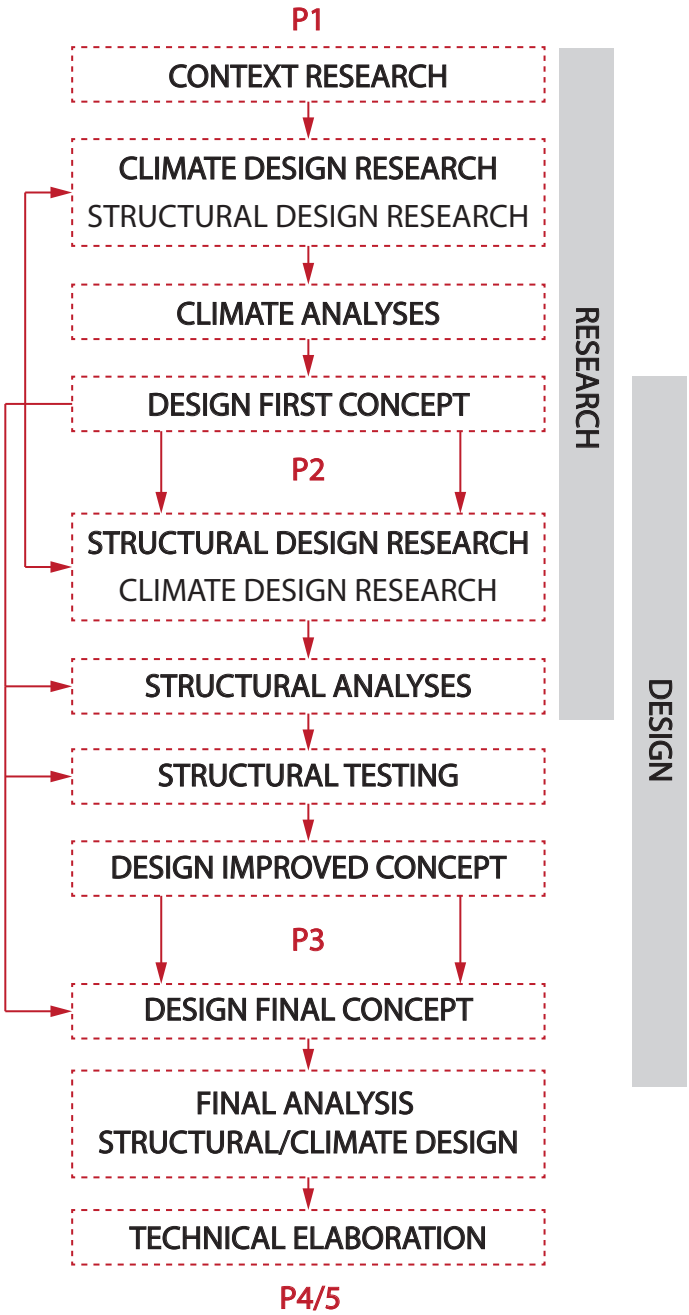

Fig. 0: Methodology (Andrejevic, 2016)

From P1 till P2, the first period of the graduation project, the main focus is on analysing and researching the stadium context, stadium case studies, stadium environmental qualities and setting up the climate analysis. With the research on the stadium context, I look into the main plans of Qatar 2022, the situation of the local climate and researched the technical requirements regarding constructions of stadiums. After the context research, I focus on the literature of three case studies where three types of stadiums are being discussed. Varying from stadia in extreme climates (Climate Design) to stadia with retractable large span roofs (Structural Design). The third part of the research is the literature study on Semi-Indoor Environmental Quality in stadia. Where I focus on three key aspects of S-IEQ, namely Aerothermal Quality, Lighting Quality and Acoustical Quality. In this research I find out what the most important aspects are that have be taken into account with the design of a stadium climate. Concluding these findings into climate boundary conditions. After all the literature research, the last step in the period between P1 and P2 was to set up the climate analysis that can be conducted in the period between P2 and P3. This climate analysis is going to be conducted with multiple software, such as Rhinoceros, Grasshopper, Ecotect, Ladybug and Flowdesign.
From P2 till P3, which is the second period, the main focus is researching different types of stadium roof structures, conducting the S-IEQ analysis and structural analysis and formulating the improved concept. With research on stadium roof structures, I dig into types of roof structures that are feasible to apply, such as conventional glass structures, lightweight large span glass structures and tensile/tensegrity glass structures. Next to the structural behaviour of glass, I also investigate the climate behaviour with glass, given its mechanical properties. After the roof structure research, I start conducting the climate analysis on different variants where 1 best variant is going to be structurally analysed. After the analysis, the roof design gets improved and climatically analysed again. This way the roof design will be most optimally balanced on the two disciplines. From these analyses the improved concept gets formulated. The improved concept gets structurally tested in the lab.
From P3 till P4, the third period, the dedication is to designing the final concept, conducting one final analysis and elaborate on all (technical) drawings. The final concept will meet the programme of demands and gets one final climate, structural and SWOT analysis, to prove the design is feasible. After the final check, everything can be drawn out.
From P4 till P5, fourth and final period, it is al about finalising the report and final presentation.

Relevance

Academic and practical relevance

The research on creating a comfortable microclimate in stadia started in the early eighties, where at the time knowledge in this field was very little. During the nineties, more information came available on creating microclimates in large semi-indoor spaces. Thus academic experimenting began on the quality of air, lighting and acoustics in stadia. This resulted in new stadiums built with new techniques from these academic analyses. In the zeroes one discovered a lot of inconveniences in the findings of the nineties and started to improve the academic research on stadia. With the rise of computers, it was a lot easier to conduct more complex and feasible analyses. Which brings us till today, where climate adaptation with complex forms can be tested and actually be made with the use of new kinds of materials. Because of the help of computers, designs are becoming much easier to predict, which makes us challenge ourselves to design in the most extreme situations where efficient and sustainable engineering can be achieved. Designing a roof for a stadium or a whole stadium is in this way relevant because it brings the academic world and the building practice to a new level, where new insights in different use of materials and the quality of sustainable building are obtained.

Personal relevance

Designing a roof for the Khalifa International Stadium gives me a clear insight in the complexity of the structural demands of a stadium and the relevance of climate adaptive building. From a climate till a structural perspective the design has to balance between both disciplines, without exceeding each other's preconditions. For such roof a wide knowledge range of design and engineering skills are required. In this way, the topic is perfectly relevant for a building technologist, since we are educated to speak the designer's language as well as the engineer's language.

Planning

Academic week	Graduation week	Date	Plan
4.0	0	11/04 - 15/04	˚Draft graduation plan ˚Preparation P1
		19/04 *13.45*	**P1**
4.1	1	18/04 - 22/04	˚Problem statement, research question, goal, title, methodology ˚Analysis context: Khalifa International Stadium, Doha, Qatar
4.2	2	25/04 - 29/04	˚Analysis problem stating Qatar 2022 ˚Literature case studies on existing roofs stadiums
4.3	3	02/05 - 06/05	˚Literature study on IEQ of semi outdoor climates involving Acoustic, Air, Lighting and Thermal Quality ˚Drafting design brief with programme of demands and boundary conditions
4.4	4	09/05 - 13/05	˚Prepare CAD model for analysis ˚Scripting algorithm Grasshopper to conduct analysis with Autodesk Ecotect, Galapagos, Flowdesign
4.5	5	16/05 - 20/05	˚Acoustical pre-analysis with Grasshopper & Galapagos ˚Air flow pre-analysis with Grasshopper, Autodesk Ecotect & Flowdesign ˚Lighting pre-analysis with Grasshopper & Autodesk Ecotect ˚Thermal pre-analysis with Grasshopper & Autodesk Ecotect
4.6	6	23/05 - 27/05	˚Improve and finalise case studies findings ˚Improve and finalise climate design literature study ˚Set boundary conditions and programme of demands
4.7	7	30/05 - 03/06	˚Conclusion climate pre-analyses ˚Make set-up for climate analysis part of report ˚Formulate roof concepts for stadium to elaborate on
4.8	8	06/06 - 10/06	˚Complete graduation plan ˚Draft graduation report ˚Prepare P2 presentation
		13/06 13.45	**P2**
4.9	9	13/06 - 17/06	˚Literature study on large span tensile/tensegrity structures for stadiums ˚Literature study on large spans with structural glass
4.10	10	20/06 - 24/06	˚Research on different types of materials according to climate boundary conditions
4.11	11	27/06 - 01/07	˚Scripting algorithm parametric design roof structure with Kangaroo & Millipede
		04/07 - 02/09	**Summer holidays**

Academic week	Graduation week	Date	Plan
1.1	12	05/09 - 09/09	˚Acoustic, Heat, Light and Wind analysis on 4 variants for formfinding ˚Structural form pre-analysis in combination with climate analysis
1.2	13	12/09 - 16/09	˚Grasshopper climate optimisation analysis ˚Grasshopper Kangaroo & Millipede optimisation analysis ˚Conclude best variant and design structure
1.3	14	19/09 - 23/09	˚Design structure ˚Diana structural analysis on proposed tensile/tensegrity roof structure
1.4	15	26/09 - 30/09	˚Design structure ˚Obtain accessory materials mock ups ˚Building mock ups roof structure
1.5	16	03/10 - 07/10	˚Structural testing of mock ups ˚Structural analysis on testing results
1.6	17	10/10 - 14/10	˚New adjustments and further elaboration on structural design ˚Completing of drawings as concept drawings, situation plan, roof plans and section
1.7	18	17/10 - 21/10	˚Further progress graduation report ˚Prepare P3 presentation
		21/10 *time*	**P3**
1.8	19	24/10 - 28/10	˚Principle hand calculations on structural elements to determine final dimension ˚Elaboration technical drawings
1.9	20	31/10 - 04/11	˚Finishing technical drawings ˚Elaboration detailing 1:20 and 1:5
1.10	21	07/11 - 11/11	˚Finishing detailing 1:20 and 1:5 ˚Structural analysis final design in FEM ˚Climate analysis final design in Grasshopper, Autodesk Ecotect, Flowdesign and galapagos
2.1	22	14/11 - 18/11	˚Technical drawings final mock up ˚Building final mock up
2.2	23	21/11 - 25/11	˚Building final mock up ˚Elaboration graduation report
2.3	24	28/11 - 02/12	˚Finishing graduation report
2.4	25	05/12 - 09/12	˚Finishing graduation report ˚Prepare P4 presentation

Academic week	Graduation week	Date	Plan
		09/12 *time*	**P4**
2.5	26	12/12 - 16/12	˚Final improvements & changes
2.6	27	19/12 - 23/12	˚Final improvements & changes
		26/12 - 06/01	**Christmas holidays**
2.7	28	09/01 - 13/01	˚Completely finishing graduation report
2.8	29	16/01 - 20/01	˚Making final model and finishing touch mock up
2.9	30	*Date time*	**P5**

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