Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Rinze Wassenaar
Student number	4276418
Telephone number	00316 1457 3655
Private e-mail address	Rinze.wassenaar@hotmail.com

Studio	
Name / Theme	Architectural Engineering (Robotic Building)
Teachers / tutors	Henriëtte Bier, Sina Mostafavi
Argumentation of choice of the studio	I chose the studio of Robotic Building (within Architectural Engineering) because I think that computational design and robotic production are novel tools which can produce new design outcomes, but their potential has not been completely capitalized on in construction industry. I chose the studio to do research into what kind of societal problems these tools can solve in order to further explore their added value for society. Besides this, I believe in the possible added value of these new design and production methods with respect to sustainability and circularity in the built environment and would like to develop my skills regarding both. I think that this studio is a good place to develop these skills which I can apply later in a wide range of fields.

Graduation project	
Title of the graduation project	Responsible Urban Densification
Goal	
Location:	Grotemarkt, Rotterdam, Netherlands
The posed problem,	Living in cities is in high demand. In the Dutch city of Rotterdam, for example, population is set to increase with 10% between 2016 and 2030 (CBS, 2016). As a result, the demand for apartments in Dutch cities greatly outruns the supply. Developers are quick to build new apartments in inner cities to capitalize on the increase in housing prices. These apartments all follow roughly the same design approach: the repetition of parallel floors stacked up to a certain height, as permitted by the municipality. These buildings are relatively easy to design and

	manufacture due to their repetition and put financial output as their main objective. We can question whether this is desirable in a context where a building has such an intrusive impact on its inhabitants and its surroundings. I argue that this design approach is unfit for high-density environments for several reasons, and that we need to think about new forms of living that are specific for individual lifestyles in high-density environments. These new forms of living will be made possible by employing computational design and robotic manufacturing, which enables us to use the limited space we have in inner cities more responsibly. My thesis researches the problems with current densification approaches and how non-standard architecture can solve these problems. This concept is presented in the form of an alternative for a current densification design of Rotta Nova in Rotterdam. The urban development project on Rotta Nova is currently on hold because of its negative impact on the urban environment which makes it an interesting site for my new densification project which deals with space more responsibly.
research questions and	Main question: 1) How to generatively design and robotically manufacture an inner-city apartment building which uses space more responsibly, specifically for the site of Rotta Nova? Sub questions: 1.1. Which irresponsible uses of space can be formulated when looking at current housing densification designs in general and specifically the design of Rotta Nova? (newspapers, public debate) 1.2. Which bounding volume minimizes shading impact on surrounding public spaces and buildings on the chosen site? (computational analysis) 1.3. Which relevant spatial, structural, and environmental requirements can be formulated to be implemented in a generative design model? (research by design) 1.4. How to incorporate these requirements in a generative design model? (precedent studies, computational studies, research by design) 1.5. How can computational functional allocation procedures increase density, while quality of indoor and outdoor space is ensured? 1.6. What is the most optimal robotic manufacturing technique for my design goal, based on several criteria? [3D-printing vs. casting] (literature study, strength/weakness analysis) 1.7. How to connect structural concrete shell elements? (literature study, prototyping, computational studies)

	1.8. How to incorporate other functionalities within this concrete shell structure? (literature studies, prototyping, research by design).
design assignment in which this result.	The design assignment of my thesis is an alternative housing densification design proposal for the site of Rotta Nova. This design proposal contains several characteristics: • Based on site-specific conditions, a bounding volume will be designed which reduces the negative impact of the building on its surroundings. A goal here is to reduce shading impact on neighboring public spaces and buildings. • Within this bounding volume we can insert apartments. To do this, a physics simulation engine will be used where each functional space of the apartments (living room, bedroom, etc.) is represented by a volume. Within this simulation engine we can apply certain goals to these volumes. For example, certain volumes could be pulled towards daylight, while others will be pulled towards the circulation space. The translation of practical requirements into a computational model is a main challenge of my design. • Besides this, an alternative concrete structural system will be designed which is able to structurally support the spatial variation coming from the generative design strategy as well as othe requirements (insulation, finishing, connection to other elements and supporting fixed furniture). The design output will be a façade element which is able to answer these requirements. This system will rely on mass-customization instead of mass production. This is necessary since the organization of the apartments within the bounding volume will highly likely not be mass-producible. For insulation I will look at two options: 1) adding insulation materials 2) integrated option of adapting the concrete morphology in order to attain a higher insulation value without the use of extra materials. These efforts result in an alternative design on the site of Rotta Nova. On one hand, this is site specific; the bounding volume of the generative model is based on local site conditions. However, the generative algorithm as well as the structural system are applicable in other dense urban areas as well, be it with slight modifications.

[This should be formulated in such a way that the graduation project can answer these questions.
The definition of the problem has to be significant to a clearly defined area of research and design.]

Process

Method description

Site

- To study the site several approaches are applied. Primarily, a **literature review of current public debate** and relevant precedents is conducted concerning densification strategies in Rotterdam and public opinion about the impact of the building of Rotta Nova in general. This public opinion informs my design.
- Secondly, based on these criteria **site analysis** will be conducted. The current design for Rotta Nova, for example, is said to greatly reduce the amount of sun on adjacent public spaces. Digital shading analysis tools are used to investigate which building morphologies can reduce these negative effects, while maintaining a certain building volume.

Generative design

- For the translation of design requirements into a generative design model several approaches have been used. **Literature precedent studies** are applied in order to investigate earlier applications of generative design in architecture, specifically in the distribution and organization of space.
- Besides this, **physical models** in the form of clay models and sketches are made to think about how physical requirements can be translated into a digital environment. This can be seen as a **research by design approach**, where there is a highly iterative process between sketching and thinking about the integration of physical requirements in the digital model and actually testing whether this works in a digital model. Within the digital model physical simulations are used to generate the organization of the apartment space according to several requirements.

Robotically fabricated structural concrete

- In order to develop a sound robotically fabricated concrete structural system, **literature studies** have been conducted to investigate the challenges concerning this type of structural system and the possibilities of robotic fabrication. Research is also conducted towards the state-of-the-art in the use of robotic fabrication in current precast concrete industry, specifically in the Netherlands and Europe.
- Besides this, 1:1 **prototypes** of the structural system are produced in a **research by design approach.** One prototype concerned itself with the use different robotic fabrication methods (hot-wire cutting + milling) for casting concrete shell elements. Besides this, the possibility of an informed thickness variation (based on local force requirements) was applied in the prototype, as well as the incorporation of EPS as a form of insulation. The second prototype investigated the connection between concrete elements in a shell structure. The location of these connections was informed by structural analysis. These prototypes inform the robotic manufacturing process of the structural system in my design and clarify its formal and functional limitations and possibilities.
- **Strength/weakness analysis** are used to gain insight in different design decisions that need to be taken regarding the structural system. For the production method, for example, there are two main possibilities: casting and 3D printing. When making a choice between the two a strength/weakness analysis can give insight in which method is most suitable for my design.

[A description of the methods and techniques of research and design, which are going to be utilized.]

Literature and general practical preference

Site

- CBS (Centraal Bureau voor Statistiek) (2016). *PBL/CBS prognose: Groei steden zet door*. CBS.
- König, E. (2018). College Rotterdam wil meer hoogbouw. *NRC*. [online] Available at: https://www.nrc.nl/nieuws/2018/11/15/college-wil-hoogbouw-uitbreiden-a2755181 [Accessed 30 Dec. 2018].
- Liukku, A. (2017). Nieuwbouw naast Markthal gaat ten koste van tijdelijk parkje. *AD*. [online] Available at: https://www.ad.nl/rotterdam/nieuwbouw-naast-markthal-gaat-ten-koste-van-tijdelijk-parkje~af5a19ed/ [Accessed 30 Dec. 2018].
- de Zeeuw, F. (2018). Vooral nadelen bij hoogbouw. *NRC*. [online] Available at: https://www.nrc.nl/nieuws/2018/11/09/vooral-nadelen-bij-hoogbouw-a2754661 [Accessed 30 Dec. 2018].
- Gemeentewerken Rotterdam (2011). *Hittestress in Rotterdam Eindrapport*. [online] Rotterdam: Wageningen University. Available at: http://edepot.wur.nl/174673 [Accessed 30 Dec. 2018].
- gemeente Rotterdam dS+V, afdeling Stedenbouw (2011). *Hoogbouwvisie 2011*. Rotterdam: gemeente Rotterdam dS+V, afdeling Stedenbouw.

Generative design

- Braach, M. (2014). Solutions You Cannot Draw. *Architectural Design*, 84(5), pp.46-53.
- Kojima, K. (2014). Crafting Space: Generative Processes of Architectural Configurations. *Architectural Design*, 84(5), pp.38-45.
- Bader, C., Patrick, W., Kolb, D., Hays, S., Keating, S., Sharma, S., Dikovsky, D., Belocon, B., Weaver, J., Silver, P. and Oxman, N. (2016). Grown, Printed, and Biologically Augmented: An Additively Manufactured Microfluidic Wearable, Functionally Templated for Synthetic Microbes. *3D Printing and Additive Manufacturing*, 3(2), pp.79-89.

Robotically fabricated structural concrete

- Wangler, T., Lloret, E., Reiter, L., Hack, N., Gramazio, F., Kohler, M., Bernhard, M., Dillenburger, B., Buchli, J., Roussel, N. and Flatt, R. (2016). Digital Concrete: Opportunities and Challenges. *RILEM Technical Letters*, 1, p.67.
- Hack, N. and Lauer, W. (2014). Mesh-Mould: Robotically Fabricated Spatial Meshes as Reinforced Concrete Formwork. *Architectural Design*, 84(3), pp.44-53.
- K. Oosterhuis, H. Bier “Robotics in architecture”, Heijningen: 2013H.

- Bier, T. Knight “Data-driven design to production and operation”, Delft: 2014
- Lim, S., Buswell, R., Le, T., Austin, S., Gibb, A. and Thorpe, T. (2012). Developments in construction-scale additive manufacturing processes. *Automation in Construction*, 21, pp.262-268.
- Janssen, B. (2011). *Double curved precast load bearing concrete elements*. [Master Thesis] TU Delft repository, Delft.
- Bruggi, M. and Taliercio, A. (2013). Design of masonry blocks with enhanced thermomechanical performances by topology optimization. *Construction and Building Materials*, 48, pp.424-433.
- Asprone, D., Menna, C., Bos, F., Salet, T., Mata-Falcón, J. and Kaufmann, W. (2018). Rethinking reinforcement for digital fabrication with concrete. *Cement and Concrete Research*, 112, pp.111-121.
- Gosselin, C., Duballet, R., Roux, P., Gaudillière, N., Dirrenberger, J. and Morel, P. (2016). Large-scale 3D printing of ultra-high performance concrete – a new processing route for architects and builders. *Materials & Design*, 100, pp.102-109.

[The literature (theories or research data) and general practical experience/precedent you intend to consult.]

Reflection

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

My studio topic is Robotic Fabrication, which is of course closely connected to my graduation topic which deals with the application of robotic fabrication to achieve new forms of housing and living. The project relates to my master track of Architecture because its main focus and design goal the design of an object in the scale of a building. This sets it apart from the more managerial focus of MBE and the larger-scale focus of Urbanism. While the development of the structural system in my design also touches on fields like Building Technology and Civil Engineering, the main goal of this structural system is to support new forms of living. The project relates to the master programme because the project concerns itself with the (high-density) built environment.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

My project tries to provide better design solutions for social problems (urban densification). Densification as a result of urbanization is part of a larger, global problem which needs new solutions to be dealt with correctly. My graduation project also tries to provide alternative solutions for densification strategies in general, outside of NL.
Besides this, the solution direction I’m focusing on (robotic production) also builds knowledge which helps towards solving other social issues, like the current labour shortage in construction industry in the Netherlands which makes the very process of making more houses rather difficult.

I think my project is relevant from a professional point of view because it shows how architectural designers are not just concerned with the design of beautiful spaces but also with a lot of things that make this design process possible; which manufacturing techniques are used? How are digital methods used in the design process, and how do I master them? How to solve societal issues with design? By having a wider professional scope, the designing expertise of architects can be used outside of the design of buildings in times of economical crisis.

Planning: see next page

planning

week	first day of week	Mon	Tue	Wed	Thu	Fri
37	17-Sep	site analysis: where to apply concept?				
38	24-Sep	computational sphere packing model development				
39	01-Oct	literature study on precast concrete structures & robotic production				
40	08-Oct	3D site model of Blaak area			site research (public debate,	
41	15-Oct			**workshop 1**		
42	22-Oct	robotic production of double curved concrete cast elements with EPS insulation				
43	29-Oct	concept development and presentation production				**P1**
44	05-Nov	**workshop 2**	preperation			
45	12-Nov	**workshop 2**	interactive installation production			
46	19-Nov	site analysis (setting up solar analysis)				
47	26-Nov	research by design & computational tests				
48	03-Dec					
49	10-Dec	**workshop 3**	connections between shell elements based on struct. analysis			
50	17-Dec	computational model for bounding volume based on solar analysis				
51	24-Dec	christmas break				
52	31-Dec	christmas break				
1	07-Jan			space packing model		presentation
2	14-Jan	preperation	**P2**	setting up growth model		
3	21-Jan	designing additional apartment types				
4	28-Jan	integration of apartment types in computational model				
5	04-Feb	refining bounding volume generation and developing alt. growth methods				
6	11-Feb					
7	18-Feb	strenght/weakness analysis: 3D printing vs. casting				
8	25-Feb	**design of structural shell system: first iteration (based on workshops)**				
9	04-Mar					
10	11-Mar	scaled prototypes (casting, 3D printing)				
11	18-Mar	interior design of apartments				
12	25-Mar				presentation preperation	
13	01-Apr		**P3**	refinement of generative design algorithm		
14	08-Apr	and apartment types				
15	15-Apr	**design of structural shell system: second iteration with detailing**				
16	22-Apr					
17	29-Apr	physical site model				
18	06-May	phyiscal design model				
19	13-May	presentation preperation (plans/sections of design)				
20	20-May		**P4**			
21	27-May	refining visuals and physical model of P4				
22	03-Jun	refining visuals and physical model of P4				
23	10-Jun	refining visuals and physical model of P4				
24	17-Jun	refining visuals and physical model of P4				
25	24-Jun		**P5**			

legend

- micro
- meso
- macro
- presentation preperations
- presentation