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:

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Studio	
Name / Theme	Building Technology Sustainable Design Graduation Studio / Robotic Building
Teachers / tutors	Dr.ir. H.H. Bier Ir. Sina Mostafavi Dr.ir. F.A. Veer
Argumentation of choice of the studio	n/a

Graduation project	
Title of the graduation project	Re [mod]: reuse plastic & robotic modification

Goal	
Location:	Delft - Netherlands
The posed problem,	How can computational design and robotic production help to reuse non-recyclable plastic in architecture? Plastic waste is a great environmental problem that we have to face nowadays. In fact, it is not always possible to recycle plastic objects and sometimes it does not even seem the best option. Consequently, an enormous amount of plastic ends up in the landfill, polluting land and sea.

	For this reason, it is becoming every day more important to apply circular economy principles in the built environment, reusing objects otherwise designated to finish in a landfill. To achieve this goal, great support could be given by employing computational design together with Design-to-Robotic-Production (D2RP) methods in order to create a system that could be applied to many different geometries, allowing a considerable amount of freedom in the design but at the same time avoiding randomness. In fact, thanks to computational design it is possible to build a system that can be applied to many different shapes, while thanks to D2RP it is not lost the complexity and the high level of freedom in the design, because every component can be custom cut in a precise way. This collaboration between circular economy principles together with computational design and D2RP will allow the designer to aid to the plastic environmental problem, saving many plastic objects from the landfill and at the same time originating constructions with a unique geometry.
research questions and	MAIN The study considers the hypothesis that plastic objects that are designated to end up in a landfill, could still have the potentiality to be reused, and some of them even be applied as construction material. Therefore, the introduction of this practice into the built environment would have great effects on the problem of plastic waste and on its share of the global oil consumption. In the context of sustainable design research, the following research question was formulated:

	• How can we reuse plastic objects in the building industry in order to contribute to reducing the problem of plastic waste and its share of global oil consumption? SUB In the context of supporting a different way of thinking about plastics, according to the fundamentals of the circular economy, the following sub-research questions were defined, in order to establish: • How can we elongate the life of a product avoiding the use of new materials and energy? • How could we use plastic objects in an upcycle scenario? The research will be conducted on different scales; hence, it will also be possible to conclude: • Which requirements do the plastic components need to have to be used on a pavilion or even on a building scale? • What strategies can be adapted to connect the plastic components with each other without the use of extra material? In the framework of a wide range of opportunities offered by the current technology advancement and the Industry 4.0, the following sub-questions were formulated: • How can computational design and 3D scanning assist the designer in ideating a construction system based on reused components? • How can robotic fabrication and assembly aid to the reuse of plastic components? • What are the limits in shape and geometry when reusing objects and how can robotic fabrication help us to overcome them?

design assignment in which these result.	The final product of the design will be a temporary structure, in particular, a pavilion, for outdoor use during the summer season; could be employed for instance in festivals, events or even on our campus. The design of the pavilion is highly flexible because it depends first of all on the desired shape, then on the tessellation of the faces of the pavilion, that could include the use of different polygons, such as triangles, quadrilaterals, pentagons and hexagons, and finally on the dimensions of the pavilion. The different components will be placed within the pavilion scale according to different requirements, as structural ones, regarding the performance of the overall structure, the strength of each component and the optimal geometry. Moreover, the architectural aspects should be considered, in fact, it should be able to provide shade, therefore the transparency ratio and the number of openings should be placed in strategic locations. Additionally, being a temporary structure, it should be easy to disassemble; therefore, all the connections should be made of solutions like snap fit or nut and bolt. Otherwise, in case the welding connection results more efficient, the size of two components welded together should be still manageable by hand. To conclude, this typology of structures, based on components that are designated to end in a landfill, could have an interesting application in developing countries, where the construction materials are in short supply.

Process

Method description

1.0 BACKGROUND

The global impact of solid waste is becoming more worrying day-by-day, uncollected solid waste could encourage flooding, impact public health and air pollution; In fact, solid waste is an important source of supply of methane, a greenhouse gas that has a great impact on global warming.

In this context of changing climate, accelerated waste generation and large reduction of the resources, the building industry can play an important role in the system. Indeed, the designer together with the constructor should consider since the design stage to think differently, in a more sustainable way, using in their project reclaimed or recycled materials or components, with the aim of reducing the amount of waste destined to the landfill and at the same time changing the way the building industry works.

2.0 GENERAL OBJECTIVE

The general aim of this study is to contribute to the efforts in sustainable design research through the help of computational design, D2RP, and structural design.

In particular providing an alternative option to the traditional techniques applied in the building construction, promoting the practice of reuse in architectural design, delimiting as well the limits of it.

Firstly, the aim of this study is to build a system based on reused plastic components that could be applicable to many typologies of structure and geometry, allowing freedom in the design and encouraging as well geometry complexity, through the study of it in different scales, the material, the component, and the pavilion scale.

The second objective of this research is to find a few components, suitable for the design, from different points of view (strength, complexity, recyclability, shape, geometry…). In order to push forward the current research about reusing, avoiding the repetition of a single component but instead promoting the combination of different ones.

3.0 RESEARCH DESIGN

Micro - Material scale

The word plastic is used indiscriminately to refer to any artificial material, but there are thousands of different plastics. Chemist and professionals prefer to define it in terms of its chemistry, calling it a polymer. In fact, plastic materials consist of many repeating groups of monomers in long chains and hence are also known as polymers.

Meso - Component scale

The meso scale refers to the component scale and in case of a structure based on the reused object; it is the starting point of the design. The research of possible components was performed according to some main parameters, such as the non-recyclability, the difficulty in reusing the objects in daily life, the strength and a wall thickness of at least 1 mm, in order to be able to perform snap-fit connections with D2RP techniques. Afterward, the research has been carried out from a physical point of view, through the exploration of different locations, however only two of them resulted relevant for the project. The first location is called Scrap XL, a store in Rotterdam that gives to waste material a second chance.

The second location is a recycling shop present in different cities in the Netherlands, called Rataplan. For the purpose of the research were visited the Rataplan in Delft and the one in Spijkenisse.
After the research in the stores, some components were selected because suitable and interesting for the design. The first one is a disposable keg, which is used to store and transport beer, wine, cider, and soft drinks and it can be found in different design variations according to the brand. A pressure release tool is used to let out the air from the kegs. The second is a hollow and openable item used to transport and store drill components and it is available in two different design variations from the same brand. The third one is used to wrap around cables of machinery to keep them in order and is available in two different heights and eight color variations.

Macro - Building scale
The macro scale is the largest scale of the design and it refers to the geometrical organization of the components within the pavilion structure.
The design idea started from the analysis of the potentials of the components, to create a system and avoid randomness in the design. In particular, the concept is to take advantage of the flat base of the drill container object to create junction elements out of patterns of triangles, quadrilateral, pentagons, and hexagons to create stable structures; as it was already done by Buckminster Fuller in the '90s with the geodesic dome. In fact, a geodesic dome is a structure based on a geodesic polyhedron that is a geometry made of the repetition of triangles.

4.0 COMPUTATIONAL DESIGN
The role of computational design in the research is mainly related to aspects like simulation, optimization, and fabrication. Accordingly, it was ideated a script based on the idea of building a system that could tessellate every possible shape, placing the joints based on the nail container components, at the vertex of the tessellation.
The script is made of three main steps.
The first one includes the tessellation of the shape, or else the subdivision of shape in faces based on polygons, such as triangles, quadrilateral, pentagons, and hexagons.
The second one regards the transformation from a volumetric structure to a ribbon structure, or rather extracting the ribbon structure of the tessellated shape, excluding the surfaces present on it.
The third step concerns the positioning of the components at the vertex of the structure originating the connections; the components are placed with an orientation that is perpendicular to the rib on two planes and parallel on another.

5.0 D2RP (Design-to-Robotic-Production)
Starting from the best design option, with ideal geometry and performances, originated from the script; two D2RP tests will be performed for the connection of the components with each other. The first D2RP test regards the robotic removal of a part of the component, in order to create a space to interlock (or fit) the components into one another. The connections are optimized according to the angle between the components, and thanks to the robot, the component can be cut at a specific optimum angle in an extremely precise and accurate way, while increasing speed.

The second D2RP test concerns the robotically drilling of one hole on top and one on the bottom of the parts that are overlapping between the components, to ensure a stronger connection. The third D2RP refers to a technology that is particularly relevant when the designer is working with already existing objects, called 3D scanning, in particular, 3D scanning with the robot.

Literature and general practical preference

Bell, M. and C. Buckley (2014). Permanent Change: Plastics in Architecture and Engineering, Princeton Architectural Press.

Engelsmann, S., et al. (2012). Plastics: in Architecture and Construction, Birkhäuser.

Bier, H. (2018). Robotic Building, Springer International Publishing.

Kula, D., et al. (2013). Materiology: The Creative Industry's Guide to Materials and Technologies, Birkhäuser.

Daas, M. and A. J. Wit (2018). Towards a Robotic Architecture, ORO Editions.

Brownell, B. (2013). Material Strategies: Innovative Applications in Architecture, Princeton Architectural Press.

Maas, W., et al. (2015). Barba: Life in the Fully Adaptable Environment, nai010 publishers.

Oosterhuis, K. (2003). Hyperbodies, Birkhäuser.

Addington, D. M. and D. L. Schodek (2005). Smart Materials and New Technologies: For the Architecture and Design Professions, Architectural Press.

Bontempi, E. (2017). Raw Materials Substitution Sustainability, Springer International Publishing.

Colabella, S., D'Amico, B., Hoxha, E., & Fivet, C. (2017). Structural Design with Reclaimed Materials: an Elastic Gridshell out of Skis. Proceedings of the IASS Annual Symposium 2017. Retrieved from http://infoscience.epfl.ch/record/231033

Brütting, J., Desruelle, J., Senatore, G., & Fivet, C. (2018). Optimum Truss Design with Reused Stock Elements. Proceedings of the IASS Symposium 2018, Creativity in Structural Design, 8. Retrieved from http://infoscience.epfl.ch/record/255199
Freinkel, S. (2011). Plastic: A Toxic Love Story, Houghton Mifflin Harcourt.

Ellen MacArthur Foundation, (2017). The new plastics economy: Rethinking the future of plastics & Catalysing action. Retrieved from http://www.ellenmacarthurfoundation.org/publications

World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company,(2016).The New Plastics Economy – Rethinking the future of plastics
Retrieved from http://www.ellenmacarthurfoundation.org/publications

Superuse Studios. "Harvest Map." Retrieved 20/12, 2018, from https://www.harvestmap.org/.

Stiho, R., Elektroned, Knauf, Tetris, JLL, TGN, Wavin, steenfabriek Douveren, de Ruttegroep, het NIBE, ABN AMRO en Thinkle. "URBAN MINING COLLECTIVE." Retrieved 10/11, 2018, from http://urbanminingcollective.nl/.

Bhada-Tata, Perinaz; Hoornweg, Daniel A. (2012). *What a waste? : a global review of solid waste management (English)*. Urban development series knowledge papers; no. 15. Washington, DC : World Bank Group. http://documents.worldbank.org/curated/en/302341468126264791/What-a-waste-a-global-review-of-solid-waste-management

Lave, L. B., et al. (1999). "Municipal Solid Waste Recycling Issues." Journal of Environmental Engineering 125(10): 944-949.

Addis, B. (2006). Building with Reclaimed Components and Materials. London: Routledge.

Testa, P. (2017). Robot House: Instrumentation, Representation, Fabrication, Thames & Hudson.

Boehler, W., Heinz, G., Marbs, A., 2001: The potential of noncontact close range laser scanners for cultural heritage recording, XVIII. CIPA Symposium, Potsdam, Germany, Proceedings. Retrieved 31/12, 2018, from http://www.i3mainz.fh-mainz.de.

Lasi, H., Fettke, P., Kemper, HG. et al. Bus Inf Syst Eng (2014) 6: 239. https://doi.org/10.1007/s12599-014-0334-4

Facilities used to retrieve the components:

- Scrap XL
  Schoterbosstraat 6C, 3032 CN Rotterdam.
  http://www.scrapxl.nl/
- RataPlan
  Groene Kruisstraat 4, 3201 CA Spijkenisse.
  https://rataplan.nl/

CASE STUDIES:
Blobwall (Greg Lynn, 2005)
EcoARK (Far Eastern Group & Arthur Huang, 2010)
One Bucket at a Time (Factor Eficiencia & 5468796 Architecture, 2017)
Head in the clouds pavilion (studiokca, 2013)
Gallery of Furniture (Chybik + Kristof, 2016)
Skyscraper | the bruges whale (studiokca, 2018)
GIRA (maarqa, 2016)
Bima Microlibrary (SHAU Bandung, 2016)
Living Pavilion (Ann Ha and Behrang Behin, 2010)
Tetra Brik Pavilion (CUACS Arquitectura, 2011)
Bonheur provisoire (SHSH, 2008)

Reflection

Relevance

SOCIETAL RELEVANCE

Plastic has become the most common material used in the modern economy, because of its practical properties and the low budget needed. Its use increased in the last half-century by twenty-fold and it is expected to increase even more in the coming twenty years. Indeed nowadays, every person around the world is exposed to plastic multiple times during the day on a regular basis.

In this context, the research aims to contribute to a sustainable future based on circular economy principles through the employment of reused plastic object in the built environment.

In fact, in a world where sustainability aspects are being integrated into several scientific fields, the construction industry plays a highly contributing role. Furthermore, even if the plastic problem has been discussed extensively, it is still not widely embraced by designers through its employment as construction material. Therefore, the value of this graduation project is to underline the role of the built environment in the plastic problem, and most of all to individuate a system in order to make use of waste plastic objects in the architecture field.

SCIENTIFIC RELEVANCE

From a scientific point of view, the research will provide a reliable methodology to produce complex architectural geometries through the reuse of plastic components in the built environment, in particular on a pavilion scale. Additionally, the study promotes the use of computational design together with D2RP (Design-to-Robotic-Production) technologies to provide a system in order to reuse plastic objects according to their properties, originating a wide range of complex architectural shapes. Thus, the main innovation of the research is firstly the use of waste components as construction material, even if the knowledge in this field is still lacking, and it still considered easier to build with new materials. Secondly the introduction of D2RP techniques in remodeling and connecting the components, in order to create intricate architectural shapes, or pavilions, avoiding the use of extra material.

Time planning