

Reflection

Glass is a versatile material applied in a large number of industries. It can for example be found in everyday household items, inside high tech machines or it can be used as part of mechanical structures in buildings. This research focuses on using structural cast glass components for a dome design forming a sustainable living habitat for Lori parrots in a moderate climate while being minimum invasive for the local environment.

This reflection addresses and explains the following **topics**: **01**. The relationship between research and design, **02**. The relationship between the theme of the graduation lab and the subject/case study, **03**. The relationship between the methodology of the graduation lab & chosen method, **04**. The relationship between the project and the broader social context and finally **05**. Personal interpretation of the research and design process.

01. The relationship between research and design

This research proposes a design technology for a dry assembled cast glass dome which provides thermal comfort to Lori parrots without compromising its primary aviary function. The zoological garden 'Parc des Oiseaux' in Southern France is proposed as a building location since the moderate climate is beneficial for utilization and design. The moderate climate makes it possible to realize a large glass dome structure that requires a minimal consumption of energy while maintaining an acceptable thermal comfort in the interior of the glass dome. This research aims for a solely glass dome where the glass dome forms a noticeable structure to the Lori parrots while transmitting, reflecting, distorting the colours of the environment to mimic a natural environment onto the glass dome surface. This results in a dome design which offers the best for the birds. In order to establish a final design two key aspects need to be taken into account. First, avoidance of buckling failure while minimizing the steel visible connections. Secondly minimizing the energy demand during the manufacturing process of the glass components and during the lifetime of the glass dome.

The main subjects of the literature studies are glass technology, dome structures, thermal comfort, passive strategies, dry assembled systems and interlayers. The first design limits and criteria of the glass dome are obtained from the glass technology, dome structures and thermal comfort literature. These first design limits and criteria resulted in a conceptual design of the glass dome. This concept design includes general dimensions (sagitta and span) and thermal comfort criteria of the interior for the glass dome.

From additional literature focused on passive strategies, dry assembled systems and interlayers, improved design limits and criteria were formulated. The dry assembled systems and interlayer literature resulted in design studies of the component, interlayer and mold. These last mentioned design studies contributed to a fundamental understanding of the structural and durable performance of the glass dome, such as critical buckling stress and amount of different components, interlayers and steel molds. Research in passive strategies has resulted in passive systems that require minimal energy while maintaining the desired thermal comfort in the interior of the glass dome. From the performed literature study a multi-disciplinary approach was developed where glass, dome construction and thermal comfort were combined into one integral design.

02. The relationship between the theme of the graduation lab and the subject/case study

The sustainable graduation lab aims for sustainable and innovative design technologies within three fields of expertise: facade, structural and climate. For this research these fields represent glass, dome construction and thermal comfort and are explained in terms of durability below.

Using glass as a structural component in domes is a new challenge because an increased thickness is needed to prevent the glass planes from buckling failure. This increased thickness can be reached by using float glass, although float glass panels do not ensure a monolithic thickness due to its limited production process. In addition, the float glass production technique does not allow high form flexibility that is preferred since the glass dome design is a double curved structure and consists of changing curvatures in every horizontal section. To ensure this increased thickness, high form flexibility and strength, monolithic cast glass with a dry assembled system is proposed for the design of the glass dome.

A steel precision mold is needed to produce the cast glass components which construct the dry assembled system of the glass dome. Constructing a dry assembled system from cast glass components adds the advantage of re-assembly in different locations within moderate climates. Re-using in terms of reassembly makes the cast glass component a durable product because glass consists of: components abundant in earth, is corrosion-resistant and can be easily cleaned [1]. However the production and recycling process of cast glass components is not durable. Glass has a high embodied energy and this is even higher for the included steel molds. Minimization of the amount of different cast glass components is needed to reduce the required production energy and cost for steel molds.

Horizontal dome sections present the changing curvature of each ring and add complexity to the minimization of the total amount of different cast glass components. Two possible solutions are considered for the curvature that varies from ring to ring. The first option is to shape omnidirectional glass components, which are possible in every direction. Secondly, to construct an adjustable mold that adapts the changing curvature of each ring. In this research an omnidirectional shaped component is proposed since an adjustable mold is complex and therefore more expensive to produce. In this research omnidirectional is defined as a shape that is based on spheres.

The aim for minimizing energy while maintaining thermal comfort for Lorri parrots, visitors and caregivers is achieved by using passive systems. It should be noticed that some passive systems require active systems, e.g. heat recovery systems and ground air heat exchange. Because of this aforementioned reason a current mixed mode is proposed to provide thermal comfort in the interior of the glass dome. Mechanical systems are used if additional cooling and heating is needed and cannot be covered by passive systems.

03. The relationship between the methodology of the graduation lab & chosen method

The methodology of the graduation lab can be summarized in three steps: 1) provide literature study, 2) design by research and 3) build scale models in order to establish the relation with the larger social and scientific framework.

Literature studies were used to define the design criteria and to obtain the design limits. These were further developed, in the final design phase, into specific criteria such as interlayer and passive system requirements.

3D prints were made in order to increase understanding about the dry assembled system and peak stresses. The optimal shape for the glass dome components and structural system was derived from this.

Structural validation was derived from analytical, numerical and experimental analyses. Experimental qualitative analyses were performed at arch- and component level. These analyses gave fundamental insights about the structural behavior of the dry assembled system of the glass dome. Apart from these structural validations analytical and numerical simulations were performed to validate the thermal performance in the interior of the glass dome. In order to validate the thermal and structural performance both analytical and numerical simplifications of the real dome design were made. This is due to the omnidirectional components that require complex simulations. It is predicted that even these complex simulations will not lead to accurate results and it is assumed that only 'real' physical experiments validate the glass dome design.

04. The relationship between the project and the broader social context

Since structural cast glass applications become more popular, for example in real applications such as the Crystal house in the building industry or the Giant Telescopic mirror for NASA, research on cast glass has improved significantly. However, structural double curved cast glass configurations in buildings require new investigation concerning their structural performance. This because double curved structures from structural cast glass have not been built before. Instead these double curved structures are constructed with a steel main structure and glass substructure. This research can be set as a basis on how cast glass can be used in other structural double curved configurations.

The structural performance in this research is obtained from a fully compressive dome principle by means of a dry assembled system out of omnidirectional cast glass components. The relationship of this research and the broader context is two folded. First, it will provide a new way of thinking for architects and structural engineers where a sphere based design covers the structural and durable performance. Secondly, it presents new possibilities for the building industry of cast glass configurations and possible related functions.

The aviary function for Lori parrots inside the glass dome includes the ethical aspect of this research. In this research thermal comfort is obtained for Lori parrots, visitors and caregivers. In general an (opaque) aviary structure is not preferred because parrots do not need to be locked but should be treated as humans [2]. This research presents the contradiction with the above sentence because current aviaries are most often constructed from a steel or wooden structure that is covered a bird-net. This type of aviary design prevents interaction with the surrounding park and leaves both visitor and parrots with a locked up experience. In order to form a more natural habitat for Lori parrots this research proposes to construct a glass dome out of cast glass spherical (omnidirectional) components that have a slight matt surface. Hence, the cast glass blocks will form a noticeable structure to the Lori parrots while colours of the environment are transmitted, reflected and distorted in a nice colour pattern onto the glass dome surface. and will not create a locked up experience. The colour pattern on the glass dome surface shows a mix of colours of the environment such as the colours of different trees, flowers and the sky. Note that in reality the behavior of the Lori parrots should be observed by a biologist in order to conclude the positive or negative influence on behavior of the Lori parrots within the glass dome.

05. Personal interpretation of research and design process

For this research an integral design approach is used which include facade, structural and climate challenges. Three different spheres are shaped into one omnidirectional component for the glass dome. The component design makes scaling of the components possible when the structural performance is not achieved. Another advantage of the omnidirectional component is that new spheres may be added or removed to improve the dry assembled structure. The reasons mentioned above present the complexity but also the exciting part of my thesis where a geometrical and mathematical shape represents the structural performance and esthetics of the glass dome design.

Finally it may be said that the glass dome design meets the main aim of this research: develop a solely glass dome from structural assembled cast glass components while providing thermal comfort to Lori parrots and being minimum invasive for the local environment, this reason is two folded. First, omnidirectional components that are equal in geometry create a solely glass dome from structural assembled cast glass components. This results in a new meaning of transparency that relates to what is best for the birds. Secondly, the majority of systems, to establish thermal comfort in the interior of the glass dome, cover passive systems. The reasons mentioned above present that this research meets the aimed results. It should be noted that 'real' physical experiments, i.e. building a scale model of the glass dome constructed from cast glass and steel precision molds, lead to accurate results and validation of the glass dome design. Unfortunately the above described real physical experiments are beyond the scope and time frame of this research. However:

'What has not been built now, can be built in the future'

(Janssens, 2017).

[1] R. Nijse, Glass in structures, New York : Princeton Architectural Press, 2003.

[2] "vrolijke papegaai," [Online]. Available: <http://www.vrolijkepapegaai.nl>.