Viewing Tower, Aarhus, Denmark

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Summary

This paper describes the approach and tools used to develop the architectural and structural design concepts for a viewing tower in Aarhus, Denmark. The paper focuses on the early stages of the design process where knowledge of the structural principles in terms of load transfer, stability, in-plane stresses and deflection, were used to influence the architecture and aesthetics of the tower.

Keywords: conceptual design, creativity, digital tools, parametric modelling; structural interpreter; communication; sensitivity analysis; rapid prototyping.

1. Introduction

In 2013, an architectural competition to design a viewing tower structure located on the harbourside in the Danish city of Aarhus was won by Dorte Mandrup Architects. The design consisted of an 11m high angular box-like form constructed from a series of flat steel plates. Each plate is perforated by holes of varying size to introduce light and transparency.

2. Architectural and structural concepts

The main purpose of the viewing tower is to provide a raised platform which can be accessed freely by the public to view the local harbourside area and adjacent waterfront. The design of the tower symbolises and emphasises the nautical and industrial history of the harbour area through its construction using exposed steel plates and its angular form which is reminiscent of the profile of a ship.

Fig. 1: Architects renders of the competition winning design (images by Dorte Mandrup Arkitekter)

The steel plates are inter-connected to form a stiff box-like structure which acts as a vertical cantilever to resists vertical and lateral loads and transfer them to the ground via in-plane stresses. The form of the tower is irregular and consists of a number of angular cantilevers that change direction as the tower extends up from the ground to the viewing platform at the top. The nature of the design is such that the architectural and structural engineering concepts are inextricably linked whereby changes to one directly affects the other.

3. Structural design challenges

The main structural design challenges were as follows:

1. Stability
2. Foundation loads
3. Steel plate thickness
4. Deflection
5. Hole distribution

4. Our approach

At the start of the project it was recognised that the tower geometry was the key to solving challenge numbers 1-4, while the in-plane stresses in the steel plates was the key to solving challenge number 5. The challenges could be reduced to the following two questions:

1. What effects do changes to the architectural geometry have on the structural performance of the tower and extent of the new foundations?
2. How do the in-plane stresses in the steel plates influence the size and distribution of holes in the tower walls?

Our approach was to use a combination of dynamic modelling using a parametric modelling tool (Grasshopper 3D) [1] and rapid prototyping using 3D printing. The parametric model was used to make quick changes to the tower geometry and was combined with Finite Element Analysis (FEA) as part of a structural sensitivity analysis whilst 3D printed physical models were used to test these changes and demonstrate the effects to the architect.

5. Discussion and conclusions

The Viewing Tower project acts as a case study to demonstrate a contemporary approach to design collaboration through the use of digital design tools such as parametric modelling, structural interpreters and FEA modelling. These tools should be regarded as creative tools and as a natural extension, but not a replacement of, more traditional tools like the pencil and paper. Furthermore, they should be used as a device for technical feedback to influence the architectural concept in a way that is sensitive to the original design aspirations. This should result in a solution which is valid architecturally, structurally, practically and economically.

The use of rapid prototyping to create quick scale models of different geometrical variations also added to the dialogue between architect and engineer and helped with understanding physical properties such as stability as well as exploring the visual aspects of the tower design.

Overall, this approach allowed the main structural design challenges to be addressed in a creative way so that issues such as stability, foundation loads, material stress and deflection were resolved through simple manipulation of the geometry instead of adding more steel and concrete. This resulted in a number of changes to the original concept which minimised the cost of the project whilst at the same time preserving as far as possible the original architectural vision.

6. References

[1] Grasshopper, Graphical Algorithm Editor. Developed by David Rutten. For more information see: http://www.grasshopper3d.com/