ZHS Boathouse Starnberg

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ZHS Boathouse Starnberg

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Table of Contents

Subject and task
Collaboration through Building Information Modelling
Architectural concept
Structural analysis and optimization
Final design
Issues and solutions
Business process model and notation (BPMN)
Bill of quantities
Conclusion

4
6
10
14
26
32
34
36
38
Subject and task

Task

The site in Starnberg is home to the sports club’s sailing club that offers a wide range of sailing course activities. In order to extend its capacity to offer more, a new boathouse and new workshop spaces are needed.

How to arrange the different spaces and offer a variety of usage possibilities is just one of the primary tasks. In addition to parking spaces for the sailing boats, an area for workshop spaces should also be considered to complete the new boathouse.

ZHS Starnberg

In Summer 2018 the TUM Craft Race at the Starnberger lake takes place for the first time. The Lake with panoramic views of the Alps is a very popular destination and recreation area for the metropolitan region of Munich.

The center for watersports of the ZHS (Zentraler Hochschulsport München) lies perfectly situated close to Starnberg at the north-west end of the lake. Besides activities like Sailing, Windsurfing, Stand-Up-Paddling and Slacklining there is a private lawn for sunbathing with access to the lake for swimming.

For the TUM Craft Race, interdisciplinary teams from Product design and Sports should design and build their own boats and compete in a race. For this reason, the ZHS wants to construct a new boathouse with workshop area to provide space for the students to design and test their prototypes.
The site: ZHS Starnberger See
Collaboration through Building Information Modelling

To optimize the collaboration and integration of different professions in the evolution process, Building Information Modelling is a holistic approach of providing support throughout the whole building’s life cycle based on a digital Building Information Model was applied.

Interdisciplinary teamwork

Besides the convincing implementation of the architectural idea, it is equally crucial for us, to integrate structural and engineering inputs. For an effective teamwork, we divided the planned project workflow into phases.

Focus tasks, applied software and data exchange requirements for each phase need to be clearly defined. Along with an early exchange of expectations of the project, a transparent overview of the tasks must be discussed and further reveal topics that require a much closer cooperation. In the following, the three phases defined by the team are described briefly.

1. Concept design

Based on the site analysis and selected references, in this early phase, the space concept needs to be defined. To evaluate the structural feasibility, a discussion about an initial structural concept is also held by the architect and the structural engineer. Moreover, modeling guidelines, data exchange requirements and milestones also need to be clarified for a smooth workflow during the project.

2. Interim: Design Focused Modelling

In this phase, the team focuses on the implementation of the architectural design into a digital model. In this phase, it is always important to keep the integration of the initial structural design in mind as well as the predefined modeling guidelines.

3. Final: Structural Analysis and Optimization

After finishing the digital architectural model of the new building, the team concentrate on the structural optimization, the fusion of resulting structural improvements and changes with the design concept.
Collaboration through Building Information Modelling

Data-Exchange and Software Utilizations

Depending on the stages, different software is used by among team members. In the conceptional design phase, Rhino and Archicad were used to develop the optimal volumetric proportions. The geometric model is constructed with Revit. The structural analysis was achieved in SOFiSTiK, an engineering plug-in interface for Revit. Necessary changes to the model resulting from the analyses were done in Revit. The digital model has been constantly tested with Solibri Model Checker. A data exchange platform sync+share was used to upload the latest results.

Modeling Guidelines

To smoothen the collaboration based on a digital model and the exchange of the models between the team members, modeling guidelines, and data exchange requirements should be defined at the beginning of a BIM project. In this project, with only two professions involved and only the very beginning of the life cycle of a building covered, the team focused on the following guidelines and exchange requirements.

1. Contained Information in the Model for First Structural Analysis

While modeling the geometric model, the architect first distinguishes between load bearing or non-load bearing elements. The materials in general (e.g. concrete without more detailed information on composition and grain size) are also defined.

2. Changes and Additions of Elements while Structural Optimization

To optimize the structure design, structural analyses need to be conducted. Depending on the results, materials and profiles must be adjusted. If these changes do not provide the desired results, additional elements might need to be considered.

All the supporting elements could be designed by the structural engineer along with the analytic information. However, trying to maintain the design ideas, major changes (e.g. adding a column for a better roof load transmission) are discussed with the architect before changes are conducted in the model.
The BIM Tools applied to the project
Architectural concept
At the beautiful lake border, our core idea is to locate our boathouse in proximity to the water and to enhance a strong visual and functional connection between the lake and its interior. Located in the northern corner of the site, one existing building has to be removed in order to provide the necessary infrastructure.

The volume is based upon a reversed boat hull, similar to the position how boats are built in the docks. Its interior volume offers a space to park boats in combination with the workshop and very high flexibility in room organization. For the TUM Craft Race, interdisciplinary teams from Product design and Sports can design and build their own boats and compete in a race right at the doorstep. Even larger sailing boats can find shelter in the structure.

Wide window openings allow generous light penetration through wide transparent polycarbonate panels. In its symmetrical floor structure, the main space combines parking and workshop spaces. The central corridor connects the building to the open beachside in the south. In the 4 corners, WCs, changing/locker rooms, office and a communal kitchen can be found, where the club members can work, eat and celebrate while enjoying panoramic views of the Alps.
Architectural concept

Early design sketch
References and materiality

To contextualize our vision, we decided to use sustainable materials such as wooden beams, coming from the local forests. To approach the wooden texture of the boat body, we decided to use shingles as coverage for the outer shell.

Reference: Natural science museum, Schengen, Luxembourg, Herrmann Valentiny architectes

Material: Wood shingels from local Bavarian forests

Boatmaterial: Dark colored wood
Structural analysis and optimization

Right dimensions

During the development and design process, the structural analyses need to be conducted. After applying a new design, the results of the structural analysis were evaluated. Due to this process, the dimensions of the primary structure could be reduced by a severe amount. To start on the safe side, the dimension of the Glued-Laminated-Timber were quite large at the beginning of the structural process.

To hold up to the loads, a secondary structure needed to be applied, according to the structural engineer. However, all changes concerning the structure, whether applying a beam or adding a column were discussed with the team before any severe changes had been made.

Due to the structural analysis, the support structure has been changed a lot, as one can see from the following pictures.
Changes within the structure, from parallel to entangled, throughout the design process.
Structural analysis and optimization

Final structure, in top view with main structure (glulam) GL28c 160 mm x 600 mm (dark brown) and secondary structure (spruce) C24 150 mm x 300 mm
**Structure optimization**

At this step of the project, the structural engineer needed to work hand in hand with the design team. It was a repetitive scheme: changes in design

- customize the support structure
- structural analysis
- apply changes to the design.

After the main geometric model was set up in Revit, the structural analysis was conducted in SOFISTIK. The support structure can be divided into three parts: Foundation, primary beams, secondary beams, and braces. The Foundation is foundation Piles under a steel reinforced concrete slab. The primary structure from glued laminated timber is 15 cm broad and 60 cm high. The secondary structure is from softwood and has following dimension: 15 cm x 30 cm. Its main function is to give support for the roofing and to distribute the loads to the primary structure.
Structural analysis and optimization

Analytical Model in Revit for Export to SOFISTIK
Analytic Model

Besides the dead load of the structure, the dead load of the roofing is calculated to 0,45kN/m². To apply the snow and wind loads correctly at an elevation of the building of about 600 meters, the snow Zone was determined to be “Zone 2” and the wind zone to be “Zone 2, category 1”, as well. Snow and wind loads refer to DIN 1055. The Building is about 14 meters high and the shell is divided into 3 sections with different angles to the horizon. Therefore the snow and wind loads are applied in three different quantities, as seen below. As there is no traffic load to expect on the structure, it is neglected.

Snow: (Zone 2, elevation: 600 m üNN)
2,72 kN/m² (upper section)
0,27 kN/m² (middle section)
0,00 kN/m² (lower section)

Wind: (Zone 2, Kat. I)
0,72 kN/m² & -0,58 kN/m² (upper section)
0,72 kN/m² & -0,58 kN/m² (middle section)
0,82 kN/m² & -0,44 kN/m² (lower section)
After the first export to SOFISTIK, the structural engineer must deal with a whole lot of errors. A complex structure consisting of only beams and braces in ununiform directions and angles is not meant to be calculated with SOFISTIK. It took a lot of effort to reconnect all batons and to get the connections right concerning the degrees of freedom. However, any chance during the design process forced the connections apart, and the errors, that had been solved previously, occurred again.

Another severe problem required a complex workaround. As the roofing could not be exported to SOFISTIK, because it is not a load bearing object, no area loads could be applied. The structural engineer also tried the “load distribution” SOFISTIK tool in Revit, but it offered no solution for the problem, as well, as loads can only be distributed to beams or braces if their surfaces are flat to each other (see picture below).

The final solution for the problem is, to apply line loads to each beam. This causes uncertainties concerning the load distribution by hand. On the safe side, the largest area was taken as decisive, and the whole structure is stressed with this decisive line loads.

**Analysis**

The decisive load combination occurs to be the following:

\[ 1,35 \times G + 1,5 \times \text{wind} + 0,75 \times \text{snow} \]

Considering this case, the stress ratio is at about 1,07, what is acceptable considering the load distribution far on the safe side.
Pressure load model
Structural analysis and optimization

Roofing

As the whole structure is not clearly divided into walls and Roof, the whole structure is covered with Roofing. The roofing consists of shingles, Battens, and wooden boards. The detailed composition is shown in the following pictures.

Roof structure
Building layers
1. Wooden shingles
2. Wooden lattens (3x 6cm)
3. Secondary structure (15x 30cm)/ insulation
4. Wooden boards (d= 2,4 cm)
5. Primary structure (16x 60cm)
Difficult connections

Whereas there are some very difficult wood connections the structural engineer also planed the most difficult connection at the highest point, where nine beams come together. To realize such a knot a custom-made steel fitting must be manufactured. It consists of a steel cylinder and welled on steel plates, where the beams can be fixed. As the connection must be a hinged connection, the beam is secured with a single steel bolt to the steel fitting. The connection was modeled with SKETCHUP because it was a lot easier than with REVIT or AutoCAD.
Construction layers
Final design

Floorplan

1 Parking
2 Workshop
3 WC
4 Changing/locker room
5 Office room
6 Kitchen

Gross volume 5000 m³
Usable area 620 m³
Workshop 175 m²
Parking 175 m²
Circulation 135 m²
Alternative 135 m²
Final design

South elevation

Longsection
Strong view connection between lake and workshop
Issues and solutions

Connecting beams in Revit did not turn out to work as expected. Connecting itself was not the problem. Displaying the correct architectural Detail was. Two objects can only be cut correct if they share at least one plane.

Therefore displaying the correct connection for multiple objects cannot be done easily. A possible solution could be to design each detail for itself or to spare connecting beams out.

Constraints with connections
In the course of displaying the connections right, the structural model often stayed not ready for use. Therefore, the structural engineer has to overwork his structural model, which leads again to unwanted problems with the display of connections.

Therefore, we choose at the final state of the planning process to divide the model into a structural and an architectural model. Consequently, we could create an architectural model, which was able to display everything right, and was usable for rendering.
Business process model and notation (BPMN)
Bill of quantities

To get a vision of the quantities we used the Revit plugin for RIB iTWO. As there were several problems with filtering the elements for certain attributes we choose to create an own text parameter for each building component. As a result, the groups can be easily chosen and its masses calculated. Afterwards, we checked the quantities with the information from Revit.

<table>
<thead>
<tr>
<th>OZ</th>
<th>Leistungsbeschreibung</th>
<th>Menge</th>
<th>ME</th>
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<td>Gates</td>
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<tr>
<td>1.6.20.</td>
<td>Doors</td>
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<td>1.6.30.</td>
<td>Inner windows</td>
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<tr>
<td>1.6.40.</td>
<td>Round facade windows</td>
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## Solibri Model checker report

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<tr>
<th>Überschneidungen</th>
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<tr>
<td>Objekte und andere Komponenten</td>
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Solibri Model checker report

Modelling
Conclusion

Although our schedule was quite accurate in its prediction, we spent far less time on model evaluation than initially planned. Results from Solibri were documented but mostly not fed back into the model. This is mostly due to the massive count of errors we did get from Solibri which were simply wrong and false alarm.

We have experienced a lot of difficulties in the modeling process. Problem-solving happened mostly on a trial and error basis and was, therefore, were time-consuming and ineffective. Data exchange between Revit and Sofistik did work great. However laying area loads on our model would have been as time-consuming as our massive count of linear loads, which was not satisfying.

On the other hand, we did not have any problems with the RIB Itwo Plugin and its use. However, there is no proper way to control your masses, except checking them in Revit or by hand.

Finally, most of our problems resulted in choosing a wood construction, which has a lot more elements to be taken care of. Also, Revit is not construed for wood constructions and handles them not perfect.
<table>
<thead>
<tr>
<th>Used Programms</th>
<th>Potential</th>
<th>Limitations</th>
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<tr>
<td>RIB Itwo</td>
<td>Quick Mass calculation</td>
<td>Mass detection</td>
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<td>Detect mistakes</td>
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<td>Revit</td>
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BIM tools: Potential and limitations
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Students:
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Lukas Schmidt
Julian Hartwig
WS 17/18 | Technische Universität München