ZHS Boathouse BIM Course WS 2017/18

Chair of Computational Modelling and Simulation | Prof. Dr.-Ing. André Borrmann
Chair of Architectural Informatics | Prof. Dr.-Ing. Frank Petzold

Assistants: Katrin Jahr, Benedict Rechenberg

GROUP M
David Hacker
Stefan Schirmer
Michael Sedlmair
Table of Contents

1. Introduction 3
2. Collaboration in BIM 4
3. Architectural Concept 8
4. Downstream Results 12
5. Project Progress 23
1. Introduction

Topic
This brochure describes the process of modelling a new boathouse at the ZHS Campus at the Starnberger See. At the end of this course work a building information model will have been created. The general conditions and details are defined in the project task of the BIM course in the WS17/18.

Structure
All organisational and coordination efforts are depicted in chapter 2. The process map will give a detailed view of all treated topics. General guidelines for working together are shown. Problems and limitations of software and the errors in the workflow will also be discussed and evaluated.

Chapter 3 explains the architectural concept of the building. Main concepts, locations for certain activities and trajectory curves of the boats within are presented.

In chapter 4 the results of all downstream applications are shown. The structural concept part describes general assumptions, the applied load cases and support definitions. Furthermore, two different approaches to generating a quantity take-off will be displayed for iTWO. Some examples of clash detection results with the Solibri model checker show the workflow of fixing the model more clearly.

The changes in the design throughout the planning work can be seen in chapter 5.
2. Collaboration in BIM

Process Management
The first thing to be established in this project was a process management map along with some simple guidelines for working together to coordinate all members efforts in an efficient and timely manner. Figure 1 and 2 show the basic approach and workflow.

Areas of Responsibility
As it is usual for planning a building project to have different professionals for certain tasks this workflow concept was also applied here. The project was split into three main areas, for which only one member was responsible. The BPMN-map is basically divided into those three parts: architecture, BIM management and structural planning.

Phases
The project was structured into four phases. At the end of each, specific milestones had to be accomplished.

In the first phase an architectural concept had to be found. In this early phase it was also important to consider the concept from a structural point of view. Sketches and comments were exchanged to define the basic ideas and guidelines for modelling the building. BIM A360 was also set up as a common exchange and collaboration platform.

In the next step a first impression BIM model was created in Revit and declared as a central file. This first try was reviewed by the structural engineer.

For the optimizing process architectural model and structural model have to be checked for collisions and other rule violations. Changes and reviews will be commenced until the model checking is successful. During this process extensive and contemporary communication is important. At the end of this phase the building information model should be completed.

The last phase is for documenting the working process in this project and evaluation. Questions would be how tasks could have been managed in a better way or where the limitations of software and BIM lie.

Workflow Guidelines
For working together on a central model certain rules have to be established to facilitate interaction. Since this project only covered the beginning of the BIM lifecycle, the team focused only on the following few guiding principles.
While creating the geometric model the architect also has to distinguish between load bearing and non-load bearing building elements. It is important that all elements are provided with a distinct material definition.

For the optimization process of the digital model it is essential for all parties to communicate changes immediately. The basic building concept should only be changed after consulting with all members.

Problems and Limitations

The working process with the central file was often difficult. That may have been in part because of the ownership of release of several building elements or work areas. The working hours of the participants was mostly not parallel so requests for release of certain parts were not answered right away. This is of course not a problem that would occur in the industry.

The requirements needed for model consistency and observance checking were not defined clearly enough. This problem is actually related to the first one, since the inaccurate separation of work areas was the main reason therefore.

There were also a few software related problems that will be addressed in the respective chapters. An important issue here is the exchange via IFC, in some cases not all elements were transferred correctly. Software developers have to put more effort into the export via IFC in the future.

The concept for the boathouse was in the beginning very suitable and therefore had to be reworked. This setback was not expected and hence not considered in the process map. It took the team about two weeks to finalize the concept to a satisfactory state.
Figure 1: Process map with first two phases
Figure 2: Process map with last two phases
3. Architectural Concept

Location
The property is situated at the north-west end of the lake. There are three buildings on site which have to be considered when choosing a location for the new boathouse. Figure 3 shows the chosen location at the northern border of the estate. The old garage at this place will be removed for this project.

The place was chosen because of the proximity to the lake, so that boats don’t have to be pulled over long distances. Moreover, there’s a steep slope, which has been a natural border in the landscape but can be put to good use in the building concept, as can be seen later. Additionally, by moving the new building into the northern corner, the green, which is a main field for leisure time and recreation at the lake’s shoreline, stays untouched.

Form and equipment
Since the determining requirement for the workshop area is a clearance height of ten meters the building is basically designed as a very high cuboid. In order to not create an oversized looking building three of the boat garages are not directly integrated in the building, but instead lie in front of the workshop area. This offers the possibility to design a terrace on top of these garages overlooking the lakeside, giving a nice view and a place for recreation.

Figure 4 shows the ground plan of the boathouse. The main area is the workshop on the ground floor with 186 m² of space. Up to three boats can easily be processed here at the same time. There will be workbenches with tools and space for storing equipment. The three garages on the front are reached via large openings. The boats can also be pulled out directly to the lakeside via the garage doors there. Another three parking spaces are integrated on the northern side with a clearance height of 3.40 meters. The boats here can also be pulled out
directly on the side via garage doors. The driveway at the northern side of the building is almost seven meters broad to ensure that the boats can be pulled around the corner.

Situated above these garages is part of the first floor. It is reached via a staircase situated in the workshop at the wall on the west side, which adjoins to the soil of the slope. There are sanitary facilities, an office room for working together on designs etc. and a large area for relaxation on rainy days. The main entrance is also on the first floor facing westwards. The terrace
can be accessed via the crosswalk on the first floor or another staircase on the northern side of the front garage.

Boats can also be pulled outside through the large door on the east façade without dismantling the mast.

The roof’s slightly curved form lightly imitates the waves. It is inclined towards the westside of the building in order to not offer a too great surface for the predominant west winds.

Glazing and natural lighting
Working on a boat requires a high and steady amount of light, ideally without any disturbance caused by glare.

In order to provide the right amount of light there are large windows on every side but the west because it mainly adjoins to the soil. The glass façade on the south side is completely shaded with metal-lamellar. The glass façade on the northern side provides nice lighting for the office space and the relaxation area on the first floor. The western façade facing the lake has compared to the southern and northern side a

Figure 5: Front view from the lake (east facade)
smaller ratio of windows but still very high and large windows. Additional smaller windows on the sides of the garages illuminate the boat parking space at the front.

Façade and walls
Except from the large glass façades the building will be designed with wooden tiles giving it a fitting look for a boat-workshop.

The office space is separated from the main hall with composite walls to keep the noise at an acceptable level. All other non-load bearing walls are designed also as insulated composite walls.

Figure 6: Section view from the north
4. Downstream Results

Early structural concept

The building’s first concept was designed with load bearing reinforced concrete walls all around. This was economically not justifiable and not sustainable. Furthermore, due to the large spans, no satisfactory roof construction could be found. That is why the team decided to reconsider the whole structural concept.

It was then decided that only the walls which adjoin to the ground, should be modelled in solid construction. The roof structure is a framework construction consisting of primary and secondary beams. This is supported by wooden pillars, which extend from the floor slab to the roof.

The roof-supporting pillars are stiffened by means of a crossbar with each other. The load-bearing components of the storey-ceiling and the terrace are also designed in wooden construction.

General Assumptions

On its western side, the building is integrated into the existing slope. Thereby, the loads acting on the west side due to wind are relatively small. Furthermore, for the sake of simplification, an optimal north-south orientation for the building is assumed. Likewise, the decisive wind direction is determined to West.

Support Definition

The floor slab of the building, as well as the walls in solid construction are hinged.

The structural pillars are provided on the bottom plate with fixed supports. In addition to the shifts, twisting in the longitudinal direction of the rod is also prevented here.

In the roof construction, a rotation in the longitudinal direction of the beams in the supports to the load-bearing structural pillars is also prevented.

Loads

In the following, a distinction is made between five load cases.

1.Own weight: If the materials of the components are equipped with the corresponding physical properties and recorded in the calculation model, the weight of the components is independently recognized and calculated in Revit.
2. Snow load: According to the German Institute for Construction Technology, the district of Starnberg is in the snow load zone 2. Accordingly, the following formula is used to calculate the snow load:

\[ s_k = 0.25 + 1.91 \times \left( (A + 140) / 760 \right)^2 \text{ [kN/m}^2\text{]} \]

\( A \) is the geographical altitude (here: 591 m). This results in a snow load of 2.02 kN/m².

3. Traffic load: For the workshop area a traffic load of 5 kN/m² was defined according to EN 1991-1-1. For the office and working areas, a traffic load of 5 kN/m² was also defined. The terrace got a traffic load of 4 kN/m².

4. Earth pressure: In the following, only the earth pressure at rest is considered. The calculation is carried out in accordance with DIN 4085 and DIN EN 1997-1. The earth pressure is calculated using the following formula:

\[ e_{0gh} = \gamma \times K_{agh} \times z \text{ [kN/m}^2\text{]} \]

\( \gamma = \text{Density} = 21 \frac{kg}{m^3} \)

\( K_{agh} = 0.22 \) (earth pressure coefficient)

\( z = \text{Depth} \)

The earth pressure is increasing linearly from the surface with 0 kN/m² to the lowest point of the building (-5.50 m) with 25.41 kN/m².

5. Wind: According to the German Institute for Construction Technology, the Wind Zone 2 prevails in the district of Starnberg. For the further calculations, the gust velocity pressure \( q_p \) is decisive. \( q_p \) is determined to be 1.00 kN/m². Here, of course, the value for coast was used. The higher value than that of the inland therefore offers increased security in the following calculations. According to DIN 1991-1-4, the following assumptions can be defined by means of the building geometry.

The roof can be assumed simplistic as a flat roof. Furthermore, the floor plan can be assumed to be rectangular. With these assumptions, the tensile and compressive forces acting on the wind could be calculated.

Load calculation

While the earth pressure forces could be applied as simple area loads, the other loads had to be calculated manually down to the respective elements. Especially in the roof area, the loads had to be calculated due to the curved roof shape on the individual secondary beams.
Analytical model

After the architectural model was built, the team had to adjust several times the couplings of the components. In the roof area, several levels had to be created for the load request, depending on the respective component. These processes had to be repeated due to several structural changes.

Subsequently, the model should be exported to the software SOFiSTiK in order to perform the static calculations there.

Export to SOFiSTiK

The export of the model via the plugin in Revit, initially only resulted in an error message. There was obviously a problem when trying to export a central model of Autodesk A360 directly into SOFiSTiK. The problem could be avoided if the

Figure 7: Scheme for calculating roof loads

Figure 7 displays the scheme that was used as an aid for determining the load indentation areas.

Figure 8: Static system
central model was unpacked before being exported and stored locally.

After talking to an expert of SOFiSTiK, a possible cause could be identified. The program seems to have a problem when using a central model and a username that contains a point. After the point, the program believes to read the file extension, which does not yet come at this point.

Calculations in SOFiSTiK

Pre-defined wood materials in Revit are not included in the export to SOFiSTiK. Accordingly, new materials must be assigned before the calculations. During the first calculations, these caused many errors or calculations even had to be cancelled. Most of the time it was ultimately about missing couplings of components, overlaps, accidental double modelling or incorrect support conditions. After eliminating the error messages, the model was optimized based on the calculation results.

The adaptation included the modelling of additional cross members and stiffeners as well as the optimization of cross sections.

Decisive load case

The decisive load combination for the building is calculated as follows:
\[1,35 \times G + 1,5 \times S + 0,9 \times W + 1,05 \times B_L + 1,0 \times G\]

Under these circumstances, the maximum deformation is about 13 mm, as can be seen in figure 12. According to DIN 1052-1-A1 \((f = L / 300)\), the deformation should be smaller than 42 mm, hence this construction is permissible.

Figure 12: Detail load calculation in SOFiStTiK
Quantity Take-off
For the export in RIB-iTWO two different variants were examined.

The first possibility is via the IFC-format interface. Unfortunately, not all parameters were transferred or recognized correctly. Furthermore, there were some errors in geometry validation resulting from complex intersections of geometry components and void forms.

Since the program did not recognize a closed volume on some of the components, as shown in figure 13, the calculations on the corresponding components were also wrong or inconclusive.

In the second variant is using the export of the Revit model via the cpixml-Plugin. This additional tool also includes applications that are useful for checking room definitions and geometry intersections. Otherwise, overlapping elements will lead to incorrect calculations in the quantity query.

For the quantity calculation of individual items there are different possibilities to assign a certain geometry. In this project the “Matchkey-method” was used to get a well-defined and correct allocation of every geometry element. Additionally, you can check if every component is considered and included in the quantity calculation.

For this method, a shared parameter named “cpiFitMatchKey” was created for every instance of the components. The naming of the parameter should be based on a specific structure that uniquely describes each component.

*Figure 13: Issue - Closed volumes could not be recognized in iTWO*
group. For that task the following table of key parameters was prepared (Table 1).

To clearly show this attribute assignment, the following example is introduced:

According to the table overview, the parameters “02” (for wooden beam components) and “1” for the first component group are assigned to all instances of the family “BSH Stütze 30x30”.

This assignment must also be done for the quantity take-off in the specific sections. Thereby all components with the respective values are selected as the basis of the calculations. The output parameter for each component depends on the size needed for the cost calculation in the bill of quantities. As an example of different output values for the same component type, the pillars and beams are calculated by the number of pieces, the length or the material volume.
Finally, the exact calculations for each individual component can be reproduced in the geometry-based bill of quantities. Here the assigned geometry and the divided quantities can be reconstructed and controlled. This can be used to quickly detect calculation errors.

**Figure 15: bill of quantity, checking for calculation errors**
<table>
<thead>
<tr>
<th>Struktur</th>
<th>Schlüssel</th>
<th>Matchkey</th>
<th>Bezeichnung</th>
<th>Mengenabfrage</th>
<th>ME</th>
<th>Menge</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td><strong>Ausstattung</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.10</td>
<td>01.1</td>
<td>Bodenplatte 40 STB</td>
<td>QTO(Typ:=&quot;Volumen&quot;;ME=&quot;m³&quot;)</td>
<td>m³</td>
<td>255,082</td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td>01.2</td>
<td>Wand Außen 30 STB</td>
<td>QTO(Typ:=&quot;Volumen&quot;;ME=&quot;m³&quot;)</td>
<td>m³</td>
<td>57,462</td>
</tr>
<tr>
<td></td>
<td>1.30</td>
<td>01.3</td>
<td>Natursteinmauer d=50</td>
<td>QTO(Typ:=&quot;Volumen&quot;;ME=&quot;m³&quot;)</td>
<td>m</td>
<td>29,441</td>
</tr>
<tr>
<td>2</td>
<td>2.10</td>
<td>02.1</td>
<td>BSH Stütze 30x30</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>28,000</td>
</tr>
<tr>
<td></td>
<td>2.20</td>
<td>02.2</td>
<td>Unterzug 25x50</td>
<td>QTO(Typ:=&quot;Attribut(Länge)&quot;)</td>
<td>m</td>
<td>76,348</td>
</tr>
<tr>
<td></td>
<td>2.30</td>
<td>02.3</td>
<td>Unterzug 30x60</td>
<td>QTO(Typ:=&quot;Volumen&quot;;ME=&quot;m³&quot;)</td>
<td>m³</td>
<td>50,314</td>
</tr>
<tr>
<td></td>
<td>2.40</td>
<td>02.4</td>
<td>Unterzug 25x25</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>11,000</td>
</tr>
<tr>
<td></td>
<td>2.50</td>
<td>02.5</td>
<td>BSH Stütze 25x25</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>6,000</td>
</tr>
<tr>
<td>3</td>
<td>3.10</td>
<td>03.1</td>
<td>Tür Drehflügel 3.40x3.50</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>6,000</td>
</tr>
<tr>
<td></td>
<td>3.20</td>
<td>03.2</td>
<td>Garagentor 8.50x3.70</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>3.30</td>
<td>03.3</td>
<td>Eingangstür 2.20x1.01</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td>3.40</td>
<td>03.4</td>
<td>Eingangstür Fassade 2.20x1.33</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>3.50</td>
<td>03.5</td>
<td>Fenster Typ 2.00x3.01</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td>3.60</td>
<td>03.6</td>
<td>Fenster Typ 3.00x3.00</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>3,000</td>
</tr>
<tr>
<td>4</td>
<td>4.10</td>
<td>04.1</td>
<td>Geschosdecke 10G</td>
<td>QTO(Typ:=&quot;Deckenfläche&quot;;ME=&quot;m²&quot;)</td>
<td>m²</td>
<td>154,093</td>
</tr>
<tr>
<td></td>
<td>4.20</td>
<td>04.2</td>
<td>Terrasse Ost Bodenaufbau</td>
<td>QTO(Typ:=&quot;Deckenfläche&quot;;ME=&quot;m²&quot;)</td>
<td>m²</td>
<td>115,869</td>
</tr>
<tr>
<td></td>
<td>4.30</td>
<td>04.3</td>
<td>Dachaufbau</td>
<td>QTO(Typ:=&quot;Deckenfläche&quot;;ME=&quot;m²&quot;)</td>
<td>m²</td>
<td>522,528</td>
</tr>
<tr>
<td></td>
<td>4.40</td>
<td>04.4</td>
<td>Dämmverbund d=0.3475</td>
<td>QTO(Typ:=&quot;Deckenfläche&quot;;ME=&quot;m²&quot;)</td>
<td>m²</td>
<td>37,061</td>
</tr>
<tr>
<td></td>
<td>4.50</td>
<td>04.5</td>
<td>Dämmverbund d=0.2975</td>
<td>QTO(Typ:=&quot;Deckenfläche&quot;;ME=&quot;m²&quot;)</td>
<td>m²</td>
<td>7,986</td>
</tr>
<tr>
<td></td>
<td>4.60</td>
<td>04.6</td>
<td>Innenwände</td>
<td>QTO(Typ:=&quot;Volumen&quot;;ME=&quot;m³&quot;)</td>
<td>m³</td>
<td>23,292</td>
</tr>
<tr>
<td></td>
<td>4.70</td>
<td>04.7</td>
<td>Fliesenboden</td>
<td>QTO(Typ:=&quot;Deckenfläche&quot;;ME=&quot;m²&quot;)</td>
<td>m²</td>
<td>8,742</td>
</tr>
<tr>
<td>5</td>
<td>5.10</td>
<td>05.1</td>
<td>Verglasung</td>
<td>QTO(Typ:=&quot;Attribut(Fläche)&quot;)</td>
<td>m²</td>
<td>335,248</td>
</tr>
<tr>
<td></td>
<td>5.20</td>
<td>05.2</td>
<td>Holzfassade</td>
<td>QTO(Typ:=&quot;Attribut(Länge)&quot;)</td>
<td>m</td>
<td>976,366</td>
</tr>
<tr>
<td></td>
<td>5.30</td>
<td>05.3</td>
<td>Aluminium Grill Fassade</td>
<td>QTO(Typ:=&quot;Attribut(Länge)&quot;)</td>
<td>m</td>
<td>503,603</td>
</tr>
<tr>
<td></td>
<td>5.40</td>
<td>05.4</td>
<td>Panoramafenster Ost</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>6,000</td>
</tr>
<tr>
<td></td>
<td>5.50</td>
<td>05.5</td>
<td>Holz-Glas-Abschluss 6x12</td>
<td>QTO(Typ:=&quot;Attribut(Länge)&quot;)</td>
<td>m</td>
<td>127,279</td>
</tr>
<tr>
<td></td>
<td>5.60</td>
<td>05.6</td>
<td>Grill Fassade Gesamt</td>
<td>QTO(Typ:=&quot;Attribut(Fläche)&quot;)</td>
<td>m²</td>
<td>77,669</td>
</tr>
<tr>
<td>6</td>
<td>6.10</td>
<td>06.1</td>
<td>Treppe EG OG1</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>6.20</td>
<td>06.2</td>
<td>Treppe OG1 Zugang</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>6.30</td>
<td>06.3</td>
<td>Treppe Terasse</td>
<td>QTO(Typ:=&quot;Stückzahl&quot;;ME=&quot;Pc&quot;)</td>
<td>Pc</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>6.40</td>
<td>06.4</td>
<td>Geländer</td>
<td>QTO(Typ:=&quot;Attribut(Länge)&quot;)</td>
<td>m</td>
<td>73,379</td>
</tr>
</tbody>
</table>

*Figure 16: Complete bill of quantities*
Clash Detection

Model checking is an essential part for optimizing a BIM. All elements attributes must be tested for compliance. Therefore, in this project the Solibri model checker was used for this task.

The export from Revit via IFC was easy and everything was displayed correctly and entirely. Although some errors occurred with the curved roof beams. The model checker never recognized them to be connected with their supports.

The difficulty in the optimization process of the building model was that the team was unsure of how and when best to use the software tool. It seemed to be unreasonable to check the model for clashes after every small change since the working progress was, as mentioned before, not always simultaneous.

The collaboration and passing of information worked very good in Solibri and problems were communicated clearly, so that everything could be solved in the end.

In the following there will be some examples of clashes that arose throughout the modelling process.

Figure 17: Clash ruleset for distances to windows, doors or openings
Figure 19: Free room in front of doors, the other door had to be deleted

Figure 18: supports were not fixed to upper roof beams
5. Project Progress

Changes
Throughout the design process the concept of the boathouse has changed in parts significantly from looking like a typical lakeside villa to a, for its purpose more suitable, working hall. The following chapter depicts the steps that lead to the final building concept. It also shows a few renderings of the final building model.

Figure 20: first model design - "the lake villa boathouse"

Figure 21: ground plan of the first model idea, three parking spaces were outsourced into a separate garage
Figure 22: Connecting the northern garage to the main building

Figure 23: Almost getting there...
Figure 24: Renderings of the final design
Figure 25: Renderings from the inside of the boathouse working area
Imprint

David Hacker
Civil Engineer

Stefan Schirmer
Civil Engineer

Michael Sedlmair
Civil Engineer