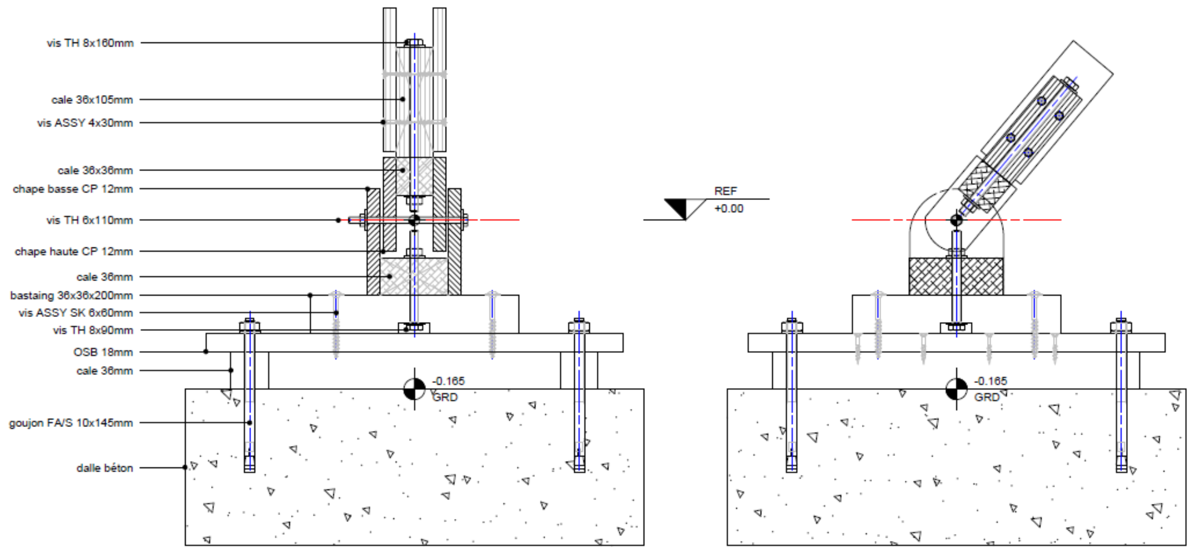
SUMMARY OF THE « FOUNDATION » GROUP ACTIVITIES

1. Theoretical Design

We decided to aim for a straightforward yet efficient design for our foundation system. The idea was to pin each structural member end to the concrete ground slab.

To achieve this result, we based our design on two concepts: first and foremost the connection needed to be a hinge; second it needed to be very adaptable so that it could be reshaped according to new design needs.

The eventual design is a very classical one, with 3 axes of rotation and an embedded bottom platform for each hinge, the design would be adaptable, the hinge could be repositioned during the construction phase and the production would be efficient. The bottom platform of hinges would be fastened to a wooden slab used to transfer the loads to the ground concrete slab. One wooden slab would carry from one to 5 {platform + joint} system(s) depending on the distance between two consecutives hinges.



One challenge that came up with the design of the hinges was the choice of the "head" (the piece of wood at the end of the hinge that would act as the connection between the pin and the timber structural elements). We learned that in some cases, two timber elements would be close to each other at ground level, which means we would not be able to use two different hinges for these two elements. We then decided to design special pin "heads" to adapt to each situation.

2. Testing the resistance of the anchoring bolts

In order to verify the foundations, it was necessary to test the performance of each bolt embedded in the concrete. The bolts should be designed to connect the bottom platform to the concrete slab, so as to resist normal and shear efforts.

With the purpose of testing the resistance of the bolts to normal efforts, we placed some samples in the concrete slab, using the same procedure which would be implemented in the final construction: perforation of the concrete slab, cleaning of the hole, hammering and screwing down of the bolt. Then we used a dynamometer to measure the necessary force to pull out the bolt. During the five tests performed, the dynamometer reached the force of 32 kN, which we considered the “limit of the device”. The bolt had not been pulled out yet.

Once we had the results of the tests, we could calculate the theoretical normal efforts that the bolt could resist in ELU and ELS. This is done simply by means of a security coefficient. The shear effort that the bolt would resist is considered to be equal or bigger than the normal one (due to the comparison of the two rupture mechanisms).

Therefore, we came to the conclusion that each bolt could resist a normal and a shear effort of 12 kN in ELU. Comparing this force to the efforts transmitted to the foundations by the structure, we concluded that only two bolts should be sufficient to both transmit the forces to the concrete slab and block the wooden base platform in all liberty degrees.

3. Production and positioning

The time being scarce, we divided the tasks to be done in order to follow an assembly line scheme. Each group member, as well as other students that joined during the sessions, was assigned a specific task and would perform it for every support to be built. Priorities were set so that there would be as few people unoccupied as possible along the whole process.

To prevent from possible construction constraints during the fabrication days, a mock-up hinge had been previously manufactured. This exercise brought to light optimal dimensions, manufacture and assembly tricks for a faster result and discarded numerous errors issued from our lack of expertise.

The production went smoothly once the hinges were designed. What happened in practice is that we were actually drawing the production plans while the first parts were already being produced because of the short time allocated to each step of the project. This did force us to check several times each design decision in order to prevent any loss of material and of production time. This also had us think of a design revolving around adaptability because we expected the structure to not correspond to the ideal shape we based our drawings on.

For instance, the special hinge “heads” were oversized so that they could adapt to unexpected structure angles or offsets. This adaptability revealed to be crucial during the construction phase. After construction, the unused parts of the “heads” were sawed off.

Another example is the importance of the embedded platform at the bottom of hinges that would be pinned to one of the wooden slabs, itself pinned to the ground concrete slab. This platform was easily repositionable so that the construction process could easily adapt to unpredictable issues during the elevation process or emanating from timber elements production errors.

4. Implementation and adaptation

As suggested above, our main task during the construction process was to reposition the hinges and fasten them to the structural members. While some pins did fit well the final manually elevated shape of the structure, most of them had to be repositioned during the construction phase (although all the offsets remained acceptably low). The highest values for final construction offsets were found to correspond with the member ends in the region of the grid that had to be put under high shear to reach its final shape. As presented in the “Form, Design & Structure” section, some timber elements failed in this area and the resulting offsets on the ideal position had us reposition all of our hinges a bit further.

In conclusion, adaptability is the key word when it comes to foundations. Note that this was essential in our case because of the restricted time frame allocated to production and design which eventually led to small errors during the construction. However, we would recommend keeping the hinges readily adaptable whatever the production and design conditions of such gridshell projects may be.

5. Suggested improvements:

With the assistance and the help of one expert from the company Wurth France during all the week, we established the most important modifications and improvements in order to achieve a more efficient design in terms of performance and economy (time of the fabrication and construction, cost of the material). However, the time and material constraints of the project made impossible to introduce these modifications that would have improved the element's design.

In the first place, the chipboard that constituted the transition between the hinge element and the concrete slab was not suitable for a structural use. For this reason its substitution for an element of a more adequate material, structural wood for instance, was envisaged, but it was not available at the time of the construction.

Another possible improvement affected the number of bolts used to fix the structure to the ground. The first prototype included four bolts per hinge element, but this was found to be largely conservative. In-situ experiments on the resistance of the bolts and further calculations conducted with the support of Wurth's software showed that, in terms of resistance, solutions with only one bolt per hinge could be considered. This would have required a radical change in the foundations design, reducing considerably the installation tolerances. Being the adaptability of the foundations a critical factor for this project as mentioned above, the one bolt solution was not implemented. Nevertheless, the total number of bolts was optimized regarding the initial designs, as only two bolts were used for the standard support units.