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Design and construction of an all glass cube for the Raaks project in Haarlem (NL)

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On a square in the old city center of Haarlem (NL) on top of an underground car park garage a glass entrance building was designed by architect Kraayvanger Urbis. ABT/ Rob Nijsse developed the all glass structure for this spectacular building. The fact that the stability was provided by the roof in combination with the four walls of the project makes it something special. Also the application of full glass rods in the structure of the roof is an innovation in the world of making glass structures.

Keywords: Glass, Cube, Stability, Glass rods.

1. General

A part of the old city center of Haarlem (NL) came free due to the demolishing of an old factory. This area was rebuilt with houses and shops around a central square. Under this square an underground parking garage was planned. This underground garage requires an entrance building; for this purpose an all glass cube was designed by the architect Kraayvanger Urbis. ABT/ Rob Nijsse was invited to work out the structure for this all glass cube mainly because for another all glass structure; the holiday house in Burgundy, France, another Kraayvanger Urbis project, an all glass structure was realized, too.

Figure 1: The Burgundy all glass walls pavilion, see [2].

The challenge with all glass structure is to reduced the number of steel connections to an absolute minimum. The best way to do this, is by making glued connections, as ABT/ Rob Nijsse experimented in an all glass conservatory in Leiden (NL).

Figure 2: The all glass, glued corner detail, meeting of fin and beam for the Leiden Conservatory, see [2].

Here the meeting of a glass façade fin and a glass roof beam was made by a glued connection. And it still holds after, now, 5 years. But municipality officials (to approve of the building) and the insurance companies have great difficulty in accepting glued connections. The question asked is always; Will it still hold after 100 years? And can you guarantee this? Since no decent answer can be given to this, mechanical connections are essential for the approving (and the safety….) of glass structures.

So the following elements were selected to compose the all, well as all as possible, Haarlem Glass Cube. For the roof six glass panels supported by beams that rest on the glass fins in the façade. For each of the for walls or facades of the cube, again, six glass panels, standing on top of each other for gravity and supported by glass fins for the wind. In figure 3 the overall structure of the Haarlem Glass Cube is sketched. The glass cube will be constructed in from March to May 2010.

Figure 3: Sketch of the structure of the Haarlem All Glass Cube.

2. Roof structure of the Haarlem all glass cube

When loaded vertically by dead load, snow or wind the vertical glass panels of the roof are loaded in an unfavourable way. This means that they will have to be thick to resist bending. That is why they have to be two times laminated 12 mm thick glass, heat strengthened. Also each panel of 2.35 x 2.35 meter had to be supported on the four edges of each panel. This could be done with a glass beam but we decided to do it with a slender as possible steel hollow section. This is some way in contradiction with the wish to make an all glass structure but the detail where the glass beam meets the glass fins of the facade is a notorious difficult meeting detail. It can be solved like the glued connection as shown in figure 2 but for the dimensions of the cube this is one step too far. So steel hollow sections 70 x 140 mm, t= 6 mm where selected. To improve the stiffness a steel suspension cable D= 8 mm was put under the steel beam. To emphasize on the glass character of the Haarlem cube an all glass rod D=30 mm, l= 400 mm was used to the steel cable separated from the steel beam. The connecting detail steel hollow section to the top of the glass fins/ beams in the facade was worked out in such a way that assembling the all glass cube should be easy and quick.The plane of the roof also has to provide lateral stability by forming a stiff plain. For this purpose the connections between glass panels are detailed in such a way that horizontal stability forces can be transported by them, see figure 5.

3. Facade structure of the Haarlem all glass cube.

The Haarlem cube has four facades of glass; three made all out of glass and one with a door; a glass door in a steel frame inside one of the standard 2.35 x 2.35 meter panel of the facades. Two large glass fins in each facade spanning from floor to roof take care of the wind loads on the facade. The glass fins are 7050 mm long each and are made out of one piece; this means that they have been made in China.

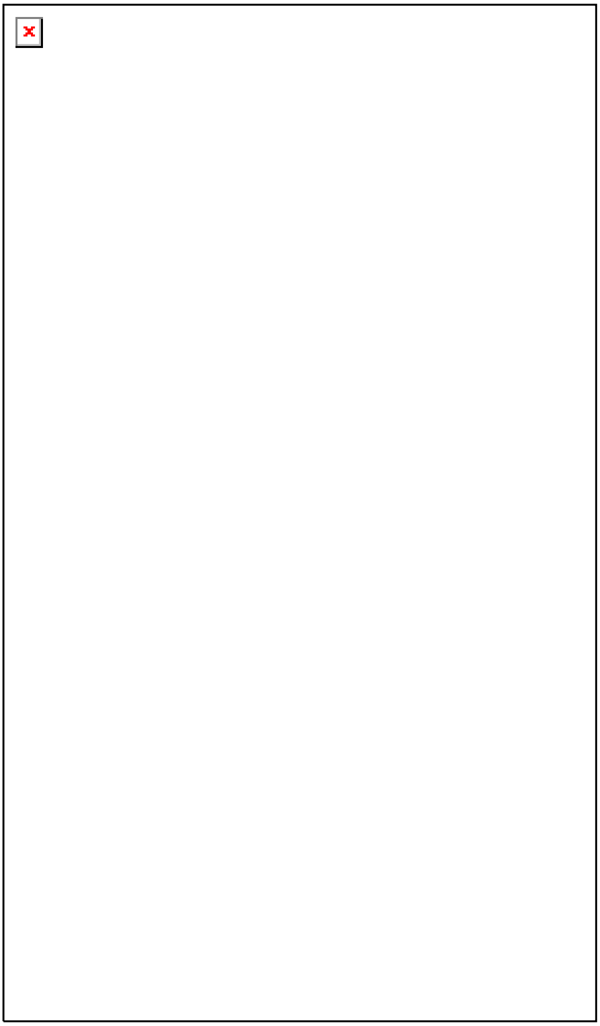

Figure 4: Glass fin in the façade, indicated are the stresses caused by the max. wind load, perpendicular to the façade.

A big length indeed; but with a width of 450 mm the deformation by wind load is reduced to only 3.3. mm. The glass composition of the fins is 3 times 12 mm, heat strengthened glass. Since the wind load can both pull and push against the facade the free edge of the glass fin can be loaded in compression, hence the danger of instability or partial buckling is present. The 7.05 meter is indeed a great length! Therefore we decided to attach one cable system at the rear of the glass fin to reduce the buckling length from 7.05 meter to the half; 3.525 meter. Calculation showed that the danger partial buckling is reduced by this measurement to almost zero, see figure 4.

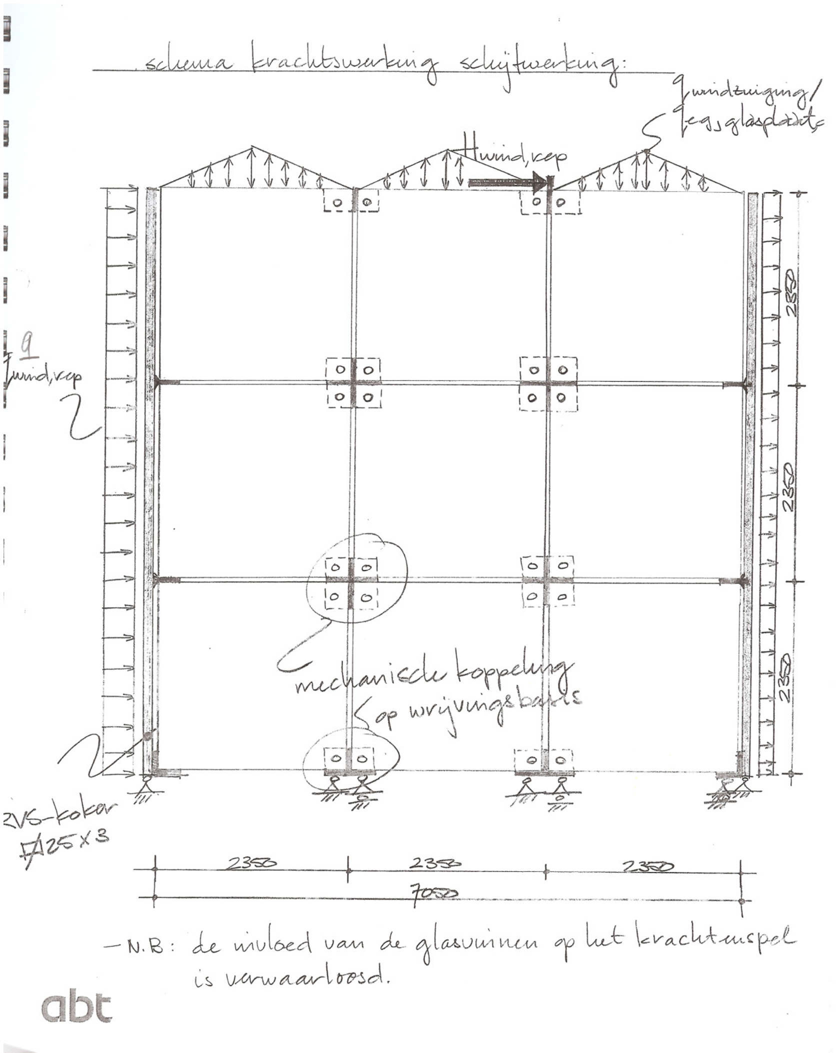

Figure 5: The built of a glass wall prepared for acting as a stability wall.

Due to the support of the glass fins the glass panels of 2.35 x 2.35 meter have two supported edges and can be made out of heat strengthened glass of one layer of 10 mm and other layer of 8 mm in laminated configuration.

Besides taking up the wind load perpendicular to the facade the four faces of the cube also have to take up the stability forces summoned by the wind load on the cube in general. This meant that we had to build in the possibility to create the occurrence of compression-diagonals in the plain of the glass facades. This aspect required connecting details that could transport these compression forces without flaws. Since the compression forces are in the plain of the glass panels we incorporated in the point where four glass panels meet a steel cross thick 6 mm in the 12 mm (=theoretical size) joint to make sure that the joint fill at this point would not be too fluffy and is able to transport relatively large stresses over this location. A steel plate was mounted over each cross point of the various panels that the facades are made from to fix/ clamp the glass panels to the glass fins. Horizontal push and pull forces caused by the wind can be taken up in this way. See figure 5.

This system of connections and glass panel that provide stability was calculated with a finite element program showing the so called stress trajectories. These trajectories indicate the flow of stresses through the plane of the façade (Figures 6, 7).

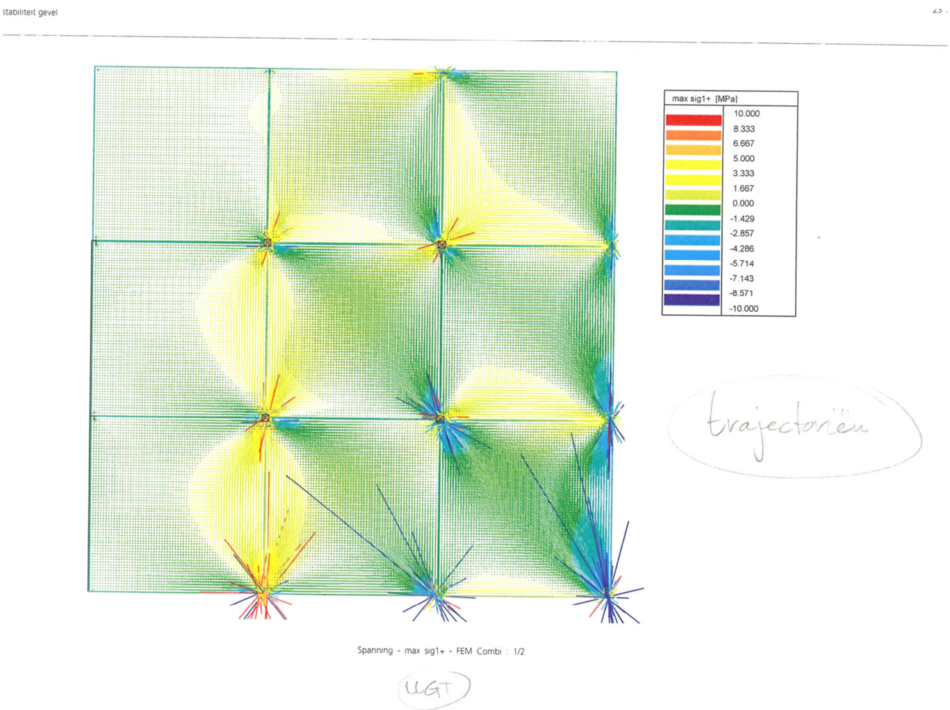

Figure 6: The flow of stability stresses through an all glass façade (with steel crosses in the joint where four glass panels meet).

4. Special features: Vandal protection, the Replacement of broken parts and the Incorporation of a big door.

Since this glass cube stands on a square in the city heart of the old city of Haarlem a lot of (possible) vandals are likely to pass this glass structure on their way home from a nice evening/ night in the entertainment businesses of Haarlem. So detailing should be thus that a malicious treatment of the poor glass cube does not lead too easily to cracking of the glass. For this reason we selected heat strengthened glass for all parts of the glass cube. Heat strengthened glass is about two times stronger than float glass but does not break in the spectacular way tempered glass breaks; or should I say explodes. Heat strengthened glass, however can break but will remain intact and stay in place with a few big cracks. This enables the caretaker of the glass cube to mount another glass panel or glass fin without any haste because no big hole gaps in the structure of the glass cube. That would have been the case if we had chosen for tempered glass.

To reduce even more the effect of vandalistic behaviour we made sure to detail in such a way that the critical edges of the glass elements of the cube were covered/ protected. For as we all know the edges of a glass element are the critical point where a concentrated blow will inevitably lead to cracking of the glass. In most of the details this “preventing form reaching the edges” meant incorporating steel strips protecting the glass edges. On the corners of the glass cube the most innovative detail was created. Here a stainless steel hollow section of 30 x 30 mm protects the edges of the glass panels. But this detail also plays a role in the transportation of the horizontal forces of stability. And it is architecturally a pleasing feature in the appearance of the all glass cube. Acting in this way we tried to protect the glass as much as possible.

However; against a real malicious person one is helpless. Therefore care has to be taken to detail in such a way that replacing broken glass elements is easily possible without too much, or complicated temporarily structures. The detail in which this is worked out the most clear is the foot detail of the glass fin, where the glass fin can be shifted out and in into the stainless steel foot without any trouble. The roof detail where the steel hollow sections of the roof meet the glass fins in the facades was worked out in an identical way.

The fact that one glass panel, either in the roof or in the facades may not lead to an instable all glass cube since the plains of glass panels provide overall stability. Fail save options where worked out for the plain of the roof and each façade.

One special feature still has to be mentioned. Of course an entrance building to a parking garage requires a door. In the case of the all glass cube one central placed glass panel on ground level was replaced by a steel frame made out of hollow sections 140 x 140 mm, t= 6 mm. In this frame two glass of course sliding doors were installed. The steel frame was calculated as being an integral part of the glass panelled facade providing stability, see figure 7.

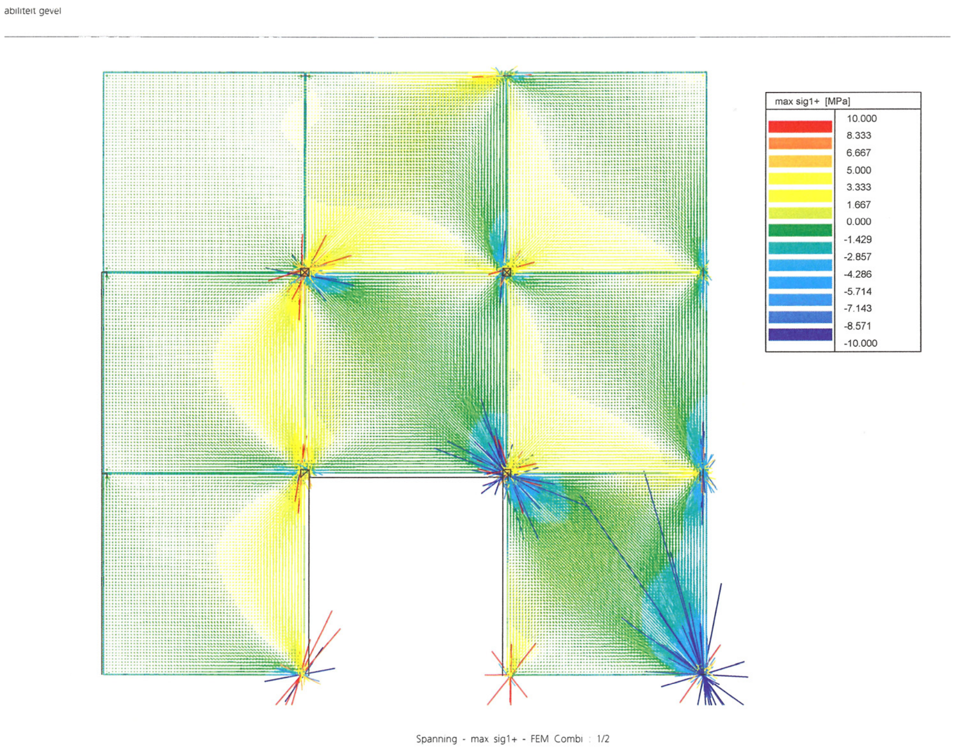

Figure 7: The flow of stability stresses through the façade with the big door.

5. References

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