FRAMELESS STRUCTURAL CONCEPT OF GLASS BARRIER

M. Slivanský[1]

ABSTRACT

The frameless structural concept of the transparent protective barrier is a highly modern type of structure, the barrier "behaves" susceptibly and not contradictory to the adjacent historically valuable zone. The installation of the glass protective barrier was realized in December 2013.

1 STRUCTURAL CONCEPT

Schematic view of the glass barrier in context to the adjacent objects is illustrated in the Figure 1. Full length of the barrier covered with glass panels is approximately 43,75m.

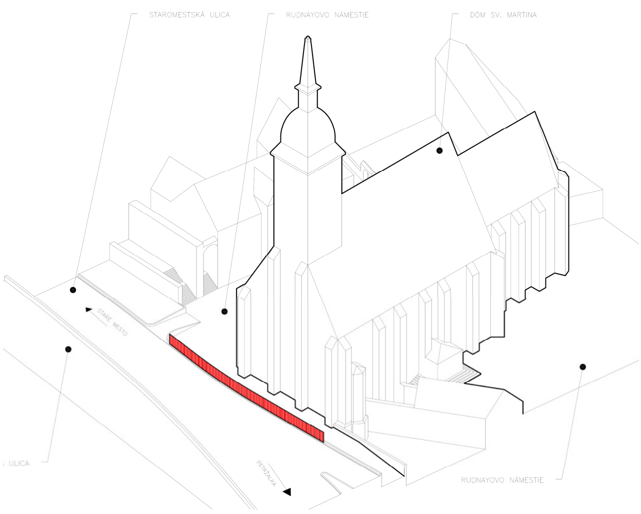

Figure 1: Protective barrier's situation

[1] Ing. M. Slivanský, PhD. - SUT in Bratislava, Faculty of Civil Engineering, Radlinského 11, 813 68 Bratislava, milos.slivansky@stubas.k

Total height of the barrier measured from the level of the pedestrian zone is approximately 3,2m (figure 2 - on the left). The glass panels are connected to the existing retaining wall made of reinforced concrete. The refurbishment of the existing concrete wall was necessary to be executed before the glass panels were mounted.
In the construction of the glass barrier 2 different types of the glass panels are used, depending on the location. The panel of the regular rectangle shape with dimensions of 1250mm x 2500mm can be considered a standard type of the glass panel (according its boundary condition and also geometric dimensions). The laminated glass made of 3 sheets of fully tempered glass with thickness 10mm is used. The glass panels are bonded by the PVB foil of theoretical thickness 1,52mm. Consequently, the total thickness of the standard glass panels is 33,04mm. In order to avoid scratches and cracks on the surface of the glass, the edges and holes in glass panels have to be treated very carefully (polished edges). The panels are fitted into a solid steel profile, which is mounted on the head of the concrete retaining wall. The glass panels work statically as a cantilevered beam with the only rigid support being the load-bearing steel profile. Interaction between neighboring glass panels against the horizontal load is not considered.

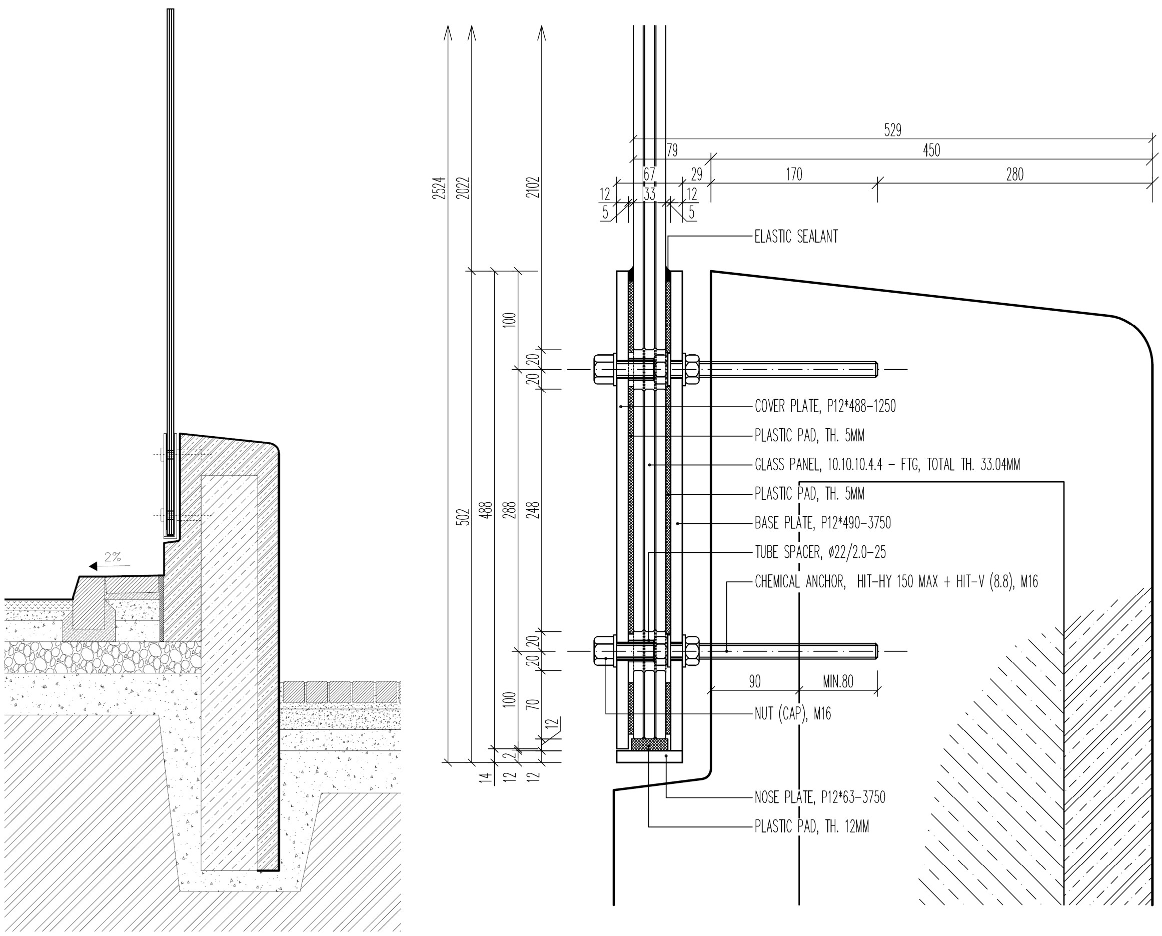

Figure 2: Glass panel's installation, scheme and detail

The steel profile consists of 2 basic parts - fixed steel plate with the set up nose plate and the cover flat steel plate designed to clamp the glass panels. Both of them are made of steel sheets with thickness 12mm of material quality S235. The corrosion protection is realized by means of galvanization. The steel plates in the fixed part are joined together by welding; specifically by 1/2 V welds. The steel profiles are installed on the head of concrete retaining wall using the chemical anchors HILTI HIT-HY 150 MAX + HIT-V (8.8), 2pc+2pc of M16 on each standard segment. The actual resistance and the appropriate way of the chemical anchors application were tested by contractor right on the site.

The glass panel is embedded into steel profile by the plastic pads to avoid a direct contact between steel plates and the glass surface. The panel's position, as well as transfer of the load forces to both parts of the steel profile, is ensured by the chemical anchors. The anchors are mounted to the concrete wall, pass through the fixed part of steel profile and circular hole in the glass panel and end with bolt nut on the outer (cover) steel plate. Detailed solution of the glass panel's mounting, including dimensions of the load bearing members, is illustrated on the Figure 2, picture on the right side.

Considering the glass barrier's geometry and also stronger wind actions at the edges compared to the wind actions in the intermediate central area of the barrier, an atypical type of glass panel is used around the edging. Laminated glass consisting of 3 sheets of fully tempered glass with thickness 12mm is used. The glass panes are bonded by the PVB foil of the theoretical thickness 1,52mm. Total thickness of the "atypical" glass panels is thereby 39,04mm. The steel profile is made of steel sheets with thickness 15mm. The steel profiles are mounted to the head of concrete retaining wall using the chemical anchors HILTI HIT-HY 150 MAX + HIT-V (8.8), 2pc+2pc+2pc of M16. The other details are the same as in case of standard (typical) segment.

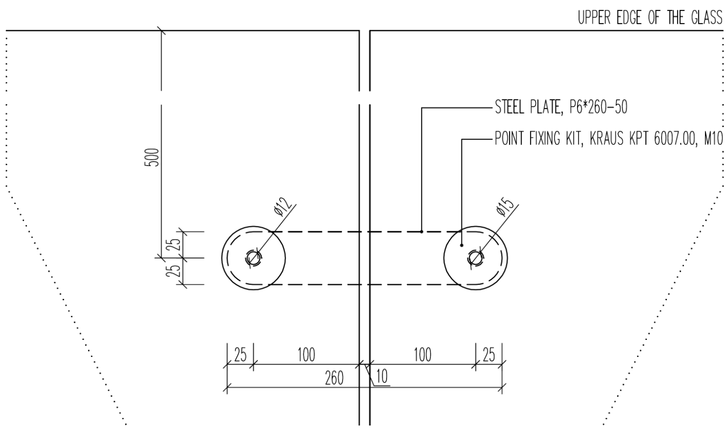

Figure 3: Coupling of the neighboring glass segments

Post-breakage load-bearing capacity after the total collapse of the glass panel, caused by the accidental loading actions (e.g. impact of the automobile), is achieved by coupling the neighboring glass segments by the steel plate with thickness 6mm with glass point fixing kit (circular steel pad of diameter 60mm and a bolt of dimension M10). In case total collapse of one of the glass panels occurs, a support by the adjacent undamaged intact segments is considered and the risk of injuring persons close to the barrier is decreased to minimum (Figure 3).

2 STATIC CALCULATION

The use of the glass barrier was not considered by the general investor as a road traffic reducing device (a mechanical performance and stability requirements given in the European Standard STN EN 1794-1 and STN EN 1794-2), so the construction was designed according the European Standard STN EN 1990 Basis of structural design, STN EN 1991-1-4 Action on structures, General actions, Wind actions, STN EN 1993-1-1 Design of steel structures, General rules and rules for buildings, prEN 13474-1:1999 Glass in building, Design of glass panes, Part 1: General basis of design and prEN 13474-2:2000 Glass in building, Design of glass panes, Part 2: Design for uniformly distributed loads.
The wind actions were calculated for fundamental wind velocity $v_{b,0}$ = 26 m/s, terrain category IV and altitude above the terrain of +10,0m (the coefficient of wind exposure $c_e(z)$ = 1,2). The aerodynamic coefficients for the separated walls were defined according to the table 7.9 with the values A = ±3,4, B = ±2,1, C = ±1,7 a D = ±1,2. All the glass panels of the standard type are designed for wind actions given by the values of area B, the glass panels used around the edging are designed for the stronger wind actions given by area A.
Considering the vertical distance between the glass barrier and pedestrian zone, the horizontal load according chapter 6.4 (Horizontal loads on parapets and partition walls acting as barriers) was irrelevant. In case of the accidental loading actions (e.g. impact of the automobile), the collapse of the glass panel is acceptable, because the structural system has a built-in post-breakage capacity achieved by coupling the adjacent segments, so the impact forces were not considered in the static calculation.

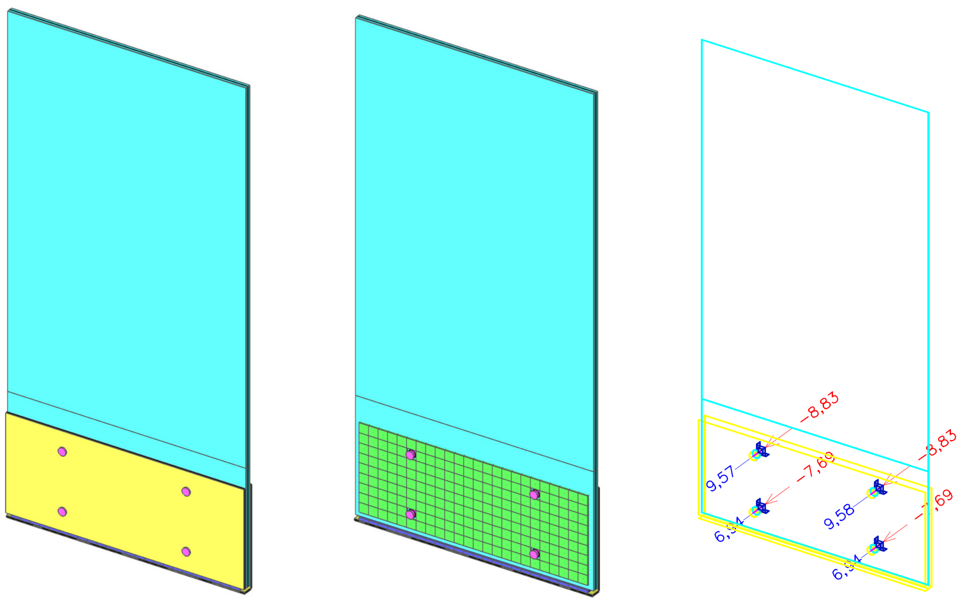

Figure 4: View of the FEM model, non-linear contact elements (green color) and the reaction in the anchorage

Static behavior of the glass barrier was analyzed using FEM modeling. Nemetschek SCIA Engineer computational software was used. The software is supposed to be used for static analysis in cases where the 1D or 2D FEM elements are sufficient. Layered nature of the laminated glass (10mm glass + 1,52mm PVB foil + 10mm glass + 1,52mm PVB foil + 10mm glass) was not implemented into the FEM models; laminated glass was replaced by single-layered (shell) element of thickness 30mm, or 36mm alternatively for the panels on the edging of the barrier.

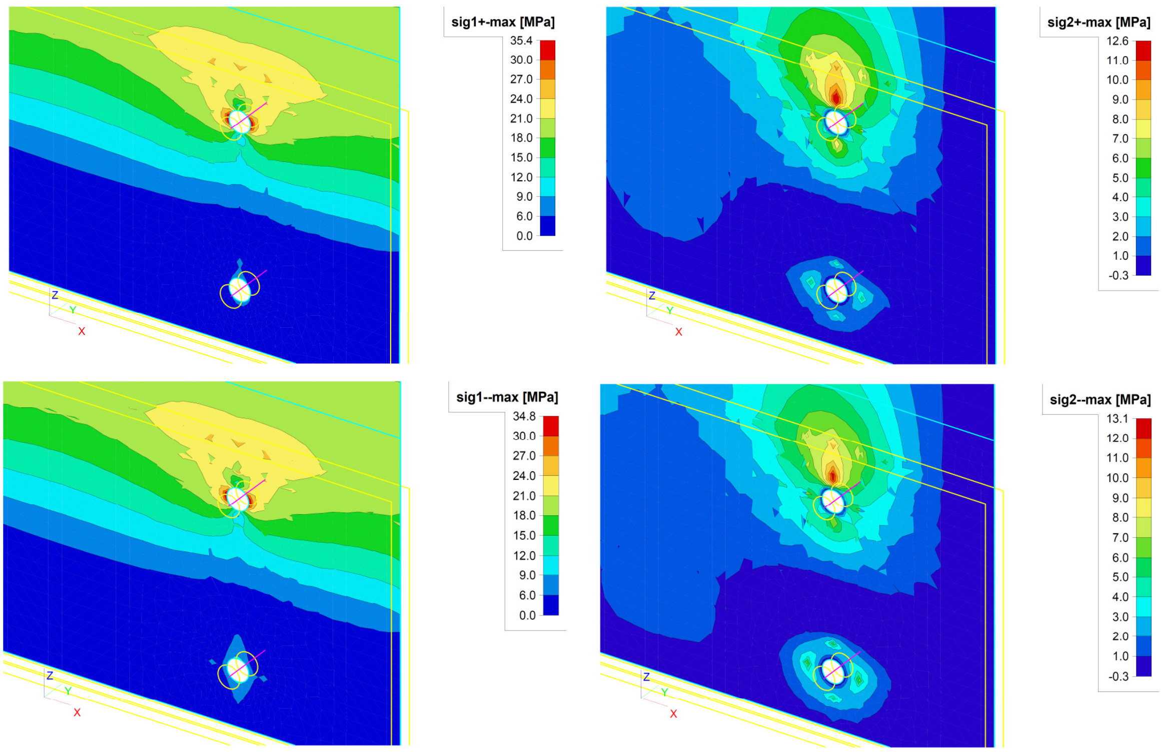

Figure 5: Principal normal stresses at the glass panel's surface, detail

According to recommendations stated in the prEN 13474, the visco-elastic nature of the PVB foil can be neglected and PVB foil as an interlayer can be taken as a full shear coupling of the glass sheets in case of short-term loading (e.g. wind actions) and normal temperature. Interaction between the glass panel and steel profile via the plastic pads was modeled through non-linear contact elements (1D elements set in the nodes of the FEM mesh, which were not capable to carrying any tension forces).

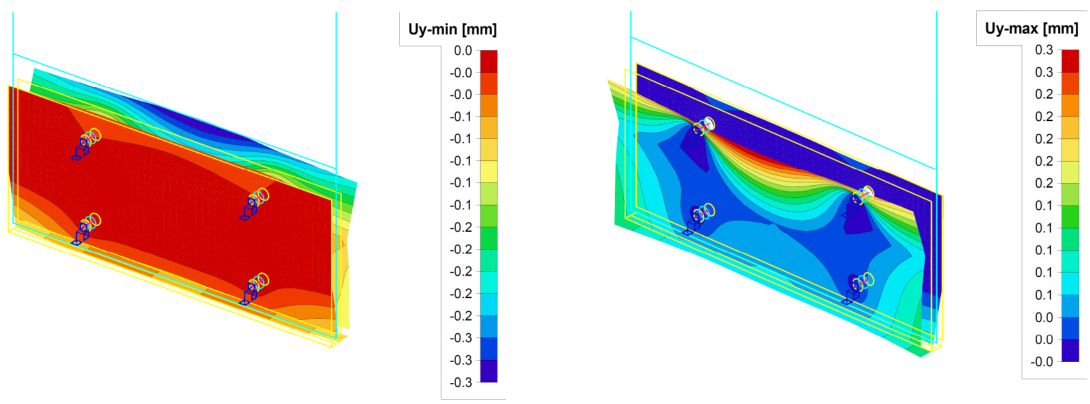

Figure 6: Steel profile deflection, detail

The FEM model with some results of the analysis is illustrated in Figure 4, 5 and 6.
One of the aims of the static calculation was an optimization of the thickness of the glass panel and steel profile. Several computational models were appraised by the FEM analysis. They differed from one another by thickness of the elements and number or geometrical position of the anchors. Even in case where the relatively huge thickness of the steel profiles was modeled, normal stresses in the glass panels were not distributed uniformly. The concentration of normal stresses around the holes in the glass panels was therefore crucial for the glass thickness evaluation (Figure 5). Deformation of the sheets of the steel profile is shown in the Figure 6.
The glass panels used in the structure of the protective barrier were checked to comply with Ultimate limit state and also Serviceability limit state. The allowable effective stress for the fully tempered glass (FTG) was calculated according the prEN 13 474 (Glass in building – Design of glass panes) for the short-term loading. The limit deformation of the glass panel was rated as a 1/100 of its total height (the panel's length above the steel profile).

3 RESULTS EVALUATION, CONCLUSION

The principal normal stresses in the typical glass panel reached the maximal value of 35,4 MPa, the allowable effective stress for the fully tempered glass in the normal conditions and the short-term loading is 49,8 MPa. The maximum horizontal deflection of the typical glass panel caused by the wind action was 18,6mm, a limit deformation evaluated as a L/100 is 20,0mm.
Project of the glass barrier was created in cooperation with an architectural studio TOTALSTUDIO s.r.o., the author of the architectural study and also chief engineer of this project is Mgr. art. Tomáš Tokarčík. The frameless structural concept of the transparent protective barrier is a highly modern type of structure, the barrier "behaves" susceptibly and not contradictory to the adjacent historically valuable zone. The installation of the glass protective barrier was realized in December 2013.

LITERATÚRA

[1] Slivanský, M.: *Static calculation of the glass structure "Protective barrier - Staromestka street"*, 06/2013

[2] *STN EN 1990 Basis of structural design*

[3] *STN EN 1991-1-4 Action on structures, General actions, Wind actions*

[4] *STN EN 1993-1-1 Design of steel structures, General rules and rules for buildings*

[5] *prEN 13474-1:1999 Glass in building, Design of glass panes, Part 1: General basis of design*

[6] *prEN 13474-2:2000 Glass in building, Design of glass panes, Part 2: Design for uniformly distributed loads*