Static assessment of selected transparent and translucent designs of roof over railway exposition

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Abstract

The area of the First steam railway station in Bratislava built in 1848, is situated on the territory of the monument restoration zone of the Slovak capitol Bratislava. This railway station functioned as the end terminal of the Hungarian Railway in 19th century. In 1871 the station was substituted by a new station building, which was built along the new passing railway track close to the original area. Nowadays the whole area of the First steam railway station became a monument registered in the Central List of the Monument Fund. Original objects built in 19th century along the rail tracks, which later served as warehouses, became in 1999 together with rail tracks a part of Museum of Transport. The rail tracks are used as an external exposition presenting locomotives, wagons and steam cranes.

Faculty of Architecture STU in Bratislava was addressed by contemporary management of the Museum of Transport to work up designs of the roof over the rail tracks protecting the exhibited showpieces. Because of the registration in the Central List of the Monument Fund, we approached to the task by working up several alternative designs (Figure 1). The roofs were designed with the use of various materials of support structures (timber, steel) and also different cover structures (glass, textile membrane and polycarbonate).

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### 1. Introduction

Museum of Transport in Bratislava is situated on the raised territory, bordered by Pražska Street and Square which creates traffic hub in front of the Main railway station. Three monument protected buildings, which served as warehouses, are used as museum exposition. In front of these buildings there are monument protected rail tracks serving for presentation of exhibited showpieces. The protection of the exhibited showpieces against unfavourable weather conditions was the reason for searching an appropriate shelter above the rail tracks. The architectural style of the former storages is typical for the operating factory objects from the period around the year 1900. Non-mortared brick architecture is combined with stone tectonic elements, which have aside from support also decorative function. Rougher pilasters bear the large roof. Infill walls as fulfilments between pilasters are perforated by wide doors to the particular arrays of the storages. The storage objects are covered by gable truss roof.

![Figure 1: Alternatives of the architectural designs of the roof in textile membrane.](image)

Beside an evaluation of the new added architectural layer to the protected monument area we considered a static analysis of the structure and its loads as important. The comparison of two architectural designs with the use of textile membrane roofs differentiated in shape and one
architectural design of the glazed roof was evoked of two possible ways of inserting new architectural object to the monument protected territory. The traditional approach is presented by design with application of traditional materials (timber) and traditional structures and shapes (gable roof) in maximal ratio. The method of contextual new added design is presented by application of new materials (PTFE membrane) and new structural elements and shapes (steel columns, arches), which have to be in harmony with monument protected surroundings.

Selected designs were modelled in computer RFEM static program and loaded by the most unfavourable combinations of the loads: dead load of bearing structures, permanent loads (cover structure), variable loads (wind, snow) according to the actual standards (Melcerova, O. 2014). The cross-sections of the separate structural elements were suggested and reviewed in both structural materials (timber, steel). The results obtained in static assessment would serve for the optimal design from the static point of view.

2. Alternatives of the architectural designs

The span of the projecting roof, the number of the rail trucks (changing from 5 to 2) and the rhythm of the industrial architecture in longitudinal direction were the main limits for the design of the new reversible roof. The shape of the projecting roof and its altitudinal position considering the height of the cornice gutter of the storage objects in cross section was important. The cornice gutter of the gable roof is by some designs in contact with the projecting roof above the rail tracks. The gable roof's shape of the origin objects didn't determine the design of the new roofs above the rail tracks. There is possible to consider the new style design of the roof as an element of new historical level. The composition of the new textile membrane roof with curvature shapes regarding the simple shape of existing gable roofs of the storage objects had to be taken in account. From the structural point of view the following types of the roofs were designed and calculated:

2.1. Timber truss frames in shape of the gable roof

Timber truss system in gable roof's shape made of timber laminated glued prisms laid on a pair of the columns (Figure 2, 3). Axial distance of the frame system's columns implied from their emplacement with regard to the position of the monument protected rail tracks and it is variable according the account of the tracks and their line. In modelled situation for the static design of the cross sections we thought over the axial distance about 4,5m. The axial distance of the trussed frames in longitudinal direction regarding the used material was designed 4,55m and corresponds with axial distance of the façade pilasters on the origin warehouses in longitudinal direction. The shape of the design comes out of origin non-existent timber shelter above the platform station from the year 1848-50. The design by shape, material and structure relates on the traditional architecture of warehouses and encourages the industrial expression.
of the whole museum area. Based on static calculation the truss was designed of glued timber GL 20 with following dimensions: top and bottom chord 2*100/350mm, vertical and diagonal web members 100/200mm, load transfer from the roof will be secured via nods to the structure. The columns are designed as 400/400mm in variant with use of glued timber profiles. To get the slender profile of the columns, we decided to use composite timber-steel profile with dimensions 250/250mm. In upper part of the frame the steel rod element Ø57/10 mm will be inserted for better static effect. The maximal deflection value is higher than 1/350 of the span regarding to the glazed roof. In the longitudinal direction the truss frames are stiffened by secondary aluminium steel grid created by cable trusses. The roof is created by glass laminated plates (4/PVB/6) fixed by spiders or in transom-mullion grid.

Figure 2: Glazed roof on timber truss frames - cross-section and elevation.

Figure 3: Glazed roof on timber truss frames - visualization.
2.2. Column structures with double-sided cantilevers in cross direction

Primary support structure is created by steel columns with circular cross-section in the shape of Y in the middle of the rail tracks (Figure 4, 5). Axial distance between columns in longitudinal direction corresponds with axial spans of the pilasters on historic façade. Design of this roof presents new element as a new contemporary layer to the industrial area and reacts with the shape of steel primary structure on the origin gable roof in reversed form. Wave-arched shape of the membrane presents possibilities of new contemporary material in lightweight roof structure (Sumec, J. 2010).

Figure 4: Membrane roof on column structures with double-sided cantilevers - cross-section and elevation.

Figure 5: Membrane roof on column structures with double-sided cantilevers – visualization.
Bended steel profiles with circular cross-section create secondary support structure in longitudinal direction. The span of the structure is 16.8m and the height of the roof is 8.8m. Textile membrane PTFE with Teflon layer is used as material of the roof. Membrane is tensed by method of the edge tension and in cross direction fixed by edge clamping, and stiffened in longitudinal direction by arched steel profile (Kalesný F. 2011). Membrane precasts are connected by combined sewing-welding (Seidel M. 2008). Rain water is drained through inner columns. Based on static analysis the columns were designed with hollow circular cross-section Ø660/14.2mm, cantilever cross elements with hollow circular cross-section Ø355,6/10 mm and rods with hollow circular cross-section Ø355,6/10 mm.

2.3. Combination of the steel frames in shape of the gable roof and arched frames

Steel frames in the shape of the gable roof and steel arched frames are alternately laid in longitudinal direction in axial distances corresponding in this case with axial double-spans (9100mm) of the pilasters on origin object. The frames with gable roof shape are used as reference on the origin roof's shape in new transformed material version. Alternately settled arched frames in doubled module distance provide dynamics to whole mass in longitudinal section. This design also presents new added design inserted contextually to the industrial area (Figure 6, 7).

Membrane is tensed by method of the edge tension and stiffened in longitudinal direction by steel cables. Membrane precasts are connected by combined sewing-welding. Primary structure is due to using doubled module distance light. The cross-section for the elements of the frames implied from the static analysis. Cross-sections of the columns and rafters of the steel frames in shape of the gable roof were designed with hollow circular dimension Ø406,4/10 mm. The steel profiles for the arched frame are designed with hollow circular dimension Ø273/4 mm.

Figure 6: Membrane roof on combined gable roof frames and arched frames.
3. Results of the research

All three roof designs were modelled in static program SCIA Professional and loaded with the most unfavourable combinations loads: own weight of the support structures, permanent load from the roof, changeable load (wind, snow) according to the actual codes (EN 1990, EN 1991-1-3, EN 1991-1-4). For each model the profiles of particular support elements were calculated. In analysis due to the snow load the II. Snow territory for Slovakia was taken in account with characteristic value of the snow load $s_k = 1,05 \text{kN m}^{-2}$ (annual maximum for 50-year period). The calculation of the wind excitation we came out from the II. Wind territory for Slovakia, where the fundamental basic wind velocity is $v = 26,0 \text{m s}^{-1}$. Twelve loading states were calculated for generation of 72 the most unfavourable combinations of the load.

The support structure of all three models were assessed for the First limit state (the resistance of the designed profiles) and for the Second limit state (the applicability of the structural elements) comparing with limit values settled by code (EN 1993, EN 1995).

It is possible to compare models 2 and 3 from the point of expenditure and steel consumption. The weight of the steel support structure in model 2 is 103,2t and in model 3 is 33,8 t.
4. Conclusion

The designs of the new shelters above the railway trucks in monument protected area of the Museum of Transport in Bratislava were analysed from the point of the architectural approach and statics point of view. Compared models present differentiated design and use various materials for the support structure and for the roof. The choice of the material and the geometry of the roof have essential importance on the statics and the material expenditure. When finished, the research will served as decision making base for the Slovak Monument Board and Museum of Transport in Bratislava.

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