THE PORSCHE PAVILION IN THE AUTOSTADT WOLFSBURG, GERMANY

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***Abstract**: The Porsche Pavilion is an innovative stainless steel construction using the principle, often used in ship and car design, as an advantage for building a light but stiff structure. The Pavilion is a one of a kind and outstanding construction that you can find. It fits right in the existing parts of the Autostadt within the lagoon landscape and was built in only eight months. With its curving lines and exiting bends the structure is an extraordinary work which was designed by Henn architects, Munich. The monocoque has a good balance between material and support structure. The stiffness is achieved by the upper and lower side sheathing plates and the intermediate formers. Also the roof shell has no joints and a smooth surface. The assembling of the structure requires a large time and effort cost due to many welds which are necessary to connect all section to one large shell.*

***Key words**: Autostadt Wolfsburg, Porsche Pavilion, exhibition building, monocoque, stainless steel, polygon shell, ramp, innovative building design, light steel construction, construction welding*

1. Introduction

The Autostadt near the Volkswagen factory in Wolfsburg, Germany, was established in June 2000 by the Volkswagen Group. The Autostadt is the interface between customer and company [1]. On 28 hectares of hills and lakes, visitors are invited to a journey into the world of mobility. The pavilions of Volkswagen, Audi, SEAT, Škoda, Lamborghini are situated in the park. Each of the pavilions expresses its own brand philosophy via its architecture.In June 2012 the new Porsche pavilion with the dimensions of approximately 50 x 35 x 10 [m] [length x width x height] opened. The construction time was 8 months for approximately 1400 m² floor area. In a unique combination of functionality and design, visitors can experience the philosophy and values of the traditional sports car brand [1].

2. Architectural concept

The unique shape of the roof (Fig. 1) creates a new focal point in the park and lagoon landscape which is a protected space. In line with the Porsche tradition of lightweight construction, the spatial envelope based on a monocoque design forms the self-supporting

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structural system. A stainless steel surface, combined with dynamically elegant lines, clearly alludes to Porsche automobile styling [1].

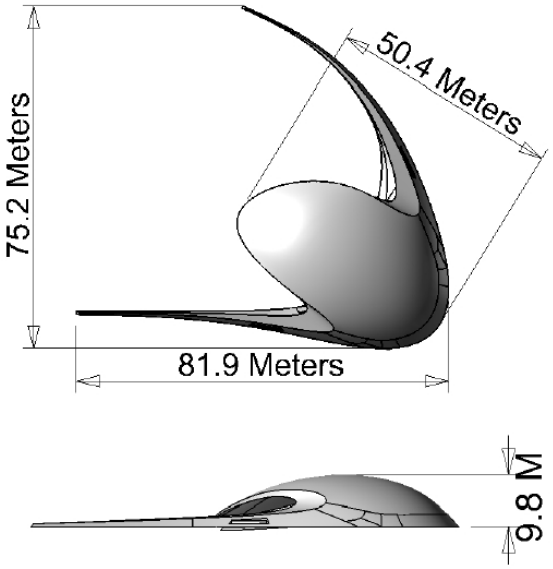

Fig. 1 Upper view and elevation, dimensions [3]

3. Building design

3.1 Foundation and concrete construction

This building part is built out of reinforced concrete C 35/45 except for the inner wall axis 1 (C45/55). Due to the soil conditions in the Autostadt, the foundation is constructed on a 50 cm thick surface. The roof parts consist of the polygon shell and the roof shell (monocoque) supported on a concrete construction. Both roofs will be supported by the wall (axle 1) and the lisenes (axle 2 – 9). While the monocoque is fitted on top with prestressed steel connected to the concrete, the supports for the polygon shell are on the side with shear lugs out of rolled profiles.

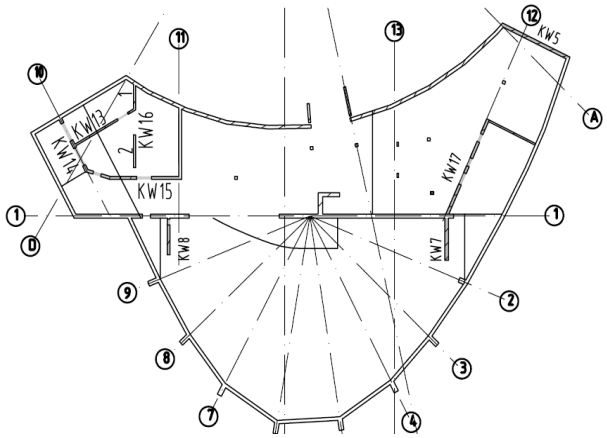

Fig. 2 Ground plan concrete construction [2]

3.2 Polygon shell

The supporting structure is formed by 10 radially arranged steel arches out of steel S355 (HEA 700) with a rise of about 1.70 m - 1.80 m. The floor plan related spans (end support wall - bearing wreath) are from 12,09 m to 17,50 m. On top of the longitudinal axes of the steel beams there are trapezoidal steel sheets. Normal to the loading direction,

the sheet metal is relatively soft and can take as little curvatures perpendicular to the beads. The trapezoidal sheets are hung on the top flange, and thus act generally as a single span. To reduce the bending of the arches there are square to axis of the free cross section in arc centre cross members (IPE 500) placed. For the presentation of the vehicles inside there are several loads such as large beamers and loudspeakers provided. Considering that on top of the polygon shell is the monocoque, there is according to the verifier [4] wind forces are expected of ± 0.15 kN/m² because of the ventilated shells.

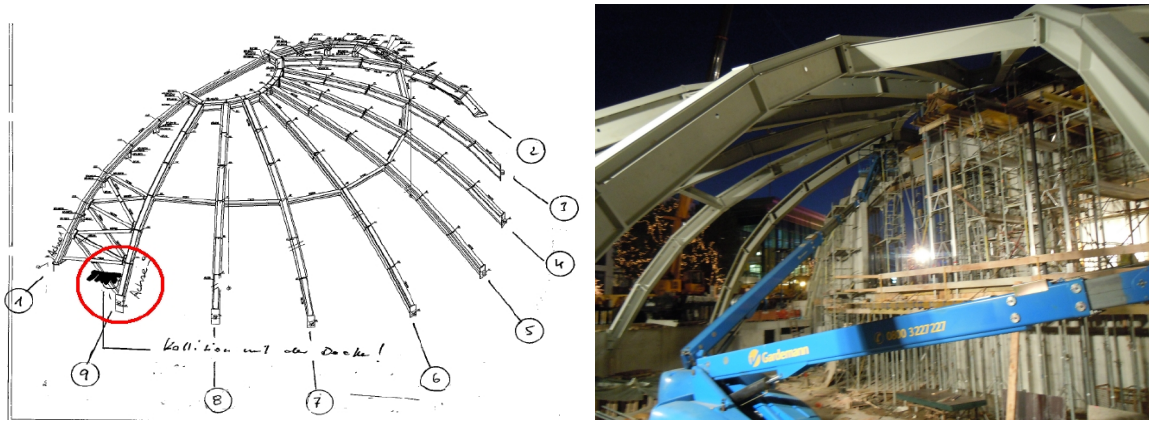

Fig. 3 left - Polygon shell 3-D drawing [2], right - Polygon shell during construction

3.3 Roof shell – Monocoque

The monocoque is a construction principle you find nowadays in the machine building industry. Usually the factoring is used with cars, airplanes or ships. This type of structure has a space forming shell which will carry the loads instead of the traditional beam construction. Apparently with this type of design the whole roof is very light compared to its stiffness. The stiffness is achieved by the upper and lower side sheathing plates and the intermediate formers as you can find in a ship. The higher design expenses and manufacturing cost are the reason why this type of structure is not used more often. The whole monocoque is built out of stainless steel. While the inner parts such as the formers is stainless steel WNR 1.4301 with a yield strength of fyk = 220 N/mm2 the cover panels are WNR 1.4571 fyk = 340 N/mm2. Fig. 4 and Fig. 5 show the different usage of the material and plate thickness. Basically, the monocoque is built out of 10 mm thick plates. Only in more highly stressed parts, such as the middle of the upper shell due to the cantilever arm, plates of 12 mm thickness are used. The base plate is made out of 16 mm plates. The plate thickness at the supports is 50 mm.

Due to the seamless and thereby highly statically indeterminate monocoque, it was required to reduce stress out of forced stress, such as temperature load, if possible to support the structure without constraints. In Fig. 6 the yellow dots show the supports with elastomeric bearings. All bearings are free to move except for the bearings at the red dashed line. The middle point was used as a fixed point with no horizontal movement. The other bearings along the red dashed line are movable along the line. Each bearing has a specific solution as a mounting part consisting of a base plate, tension rod and elastomeric bearing.

For verification of the calculation of the structure the FEM program ABAQUS® was used. Moreover plate buckling was analyzed according to [5]. A special significance during design was the load case wind. To form the wind realistically on the model the wind was implemented based on the wind report [4]. Hereby there were 12 different wind directions (0°, 30°, …, 330°) examined.

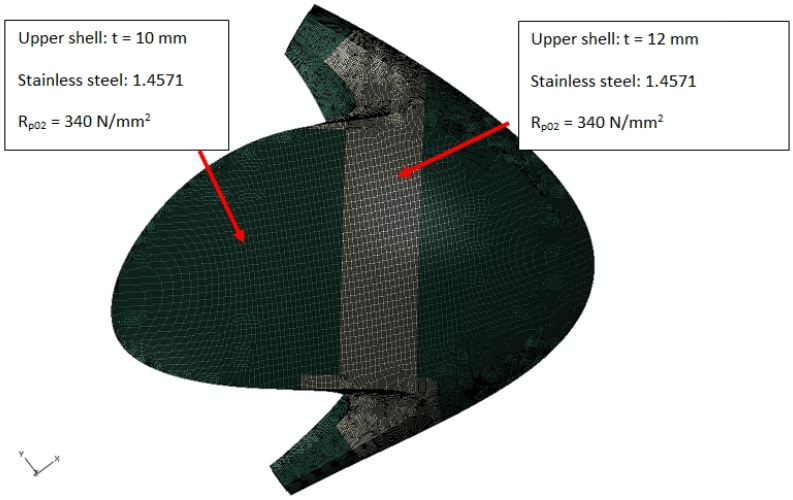

Fig. 4 Upper shell, plate thickness and material

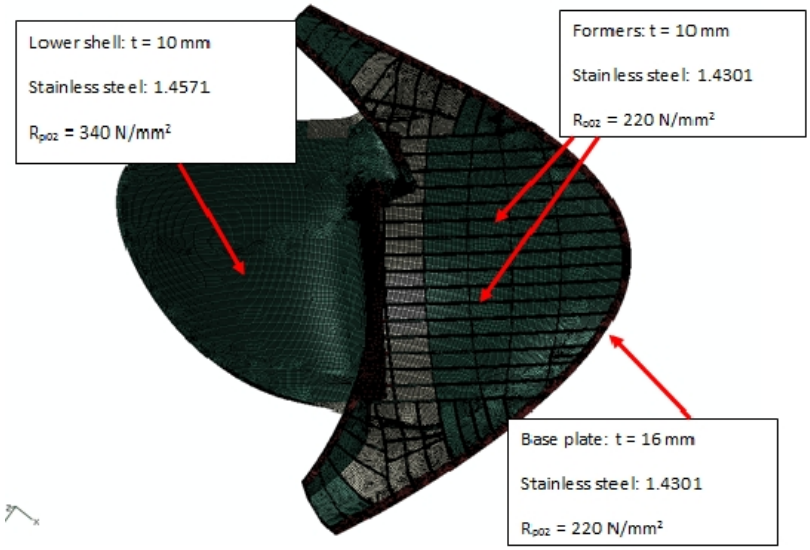

Fig. 5 Lower shell, plate thickness and material

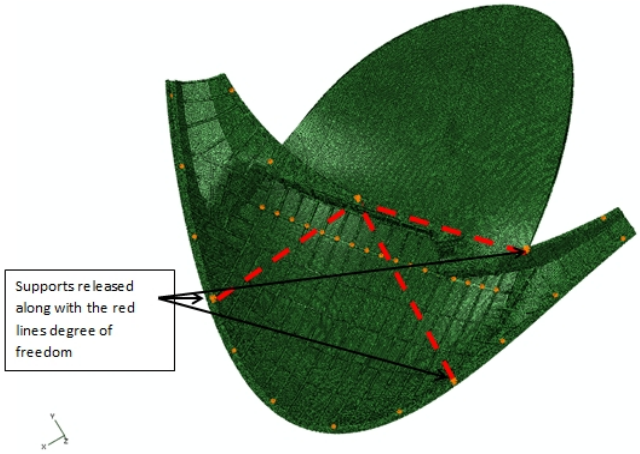

Fig. 6 Boundary conditions for the resolution of the concentration of stress

3.4 Ramp

In the staging area, a ramp made of steel S355 was built as a link between the basement and ground floor (Fig.7). The unwound ramp length is about 25 m and is

designed as a double-curved pipe with 2 rolled sections as the main support members. The construction is divided into eight elements, which are connected via torsion partition plates. In the region of the third and fourth element, the ramp is supported. As supports, rolling steel beams are constructed out of S235. The ramp is designed for an audience.

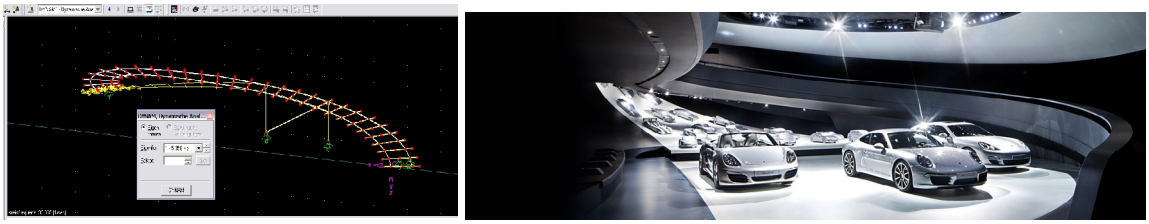

Fig. 7 left: Model of the ramp, right: Showroom with ramp in the background [1]

4. Construction and assembly

The monocouque structure is built out of 56 prefabricated sections. All stainless steel sheets were cold formed and welded together (Fig. 8) in the factory at the plant of "Ostseestaal GmbH" in Stralsund and were transported to the site in Wolfsburg. To ensure a trouble-free mounting of the parts, measurements were taken.

Fig. 8 Assembly of stainless steel sheets in the factory

On site, there were three stages of construction. Firstly, the vertical sections were placed. After the vertical parts the sections were placed above the polygon shell. The third stage was the cantilever arm. Every section was elevated by a crane of 400 tons on hoisting eyes and brought into position. All sections were welded together on site. Before the structure could support its own weight, it was temporarily supported. As the last step, the deflection of the key points in the structure, such as the end of the cantilever arm, were checked in comparison with the calculation. The differences were within a construction practice range and were considered safe.

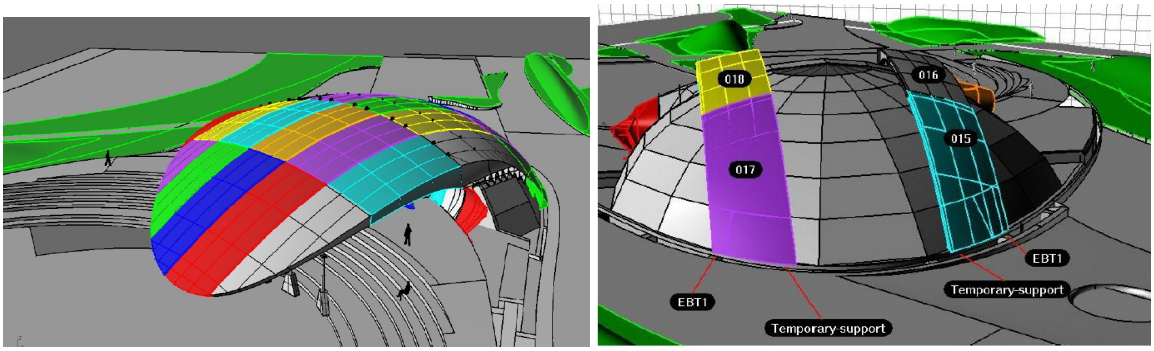

Fig. 9 left - Sections and building stages, right - Stage two [3]

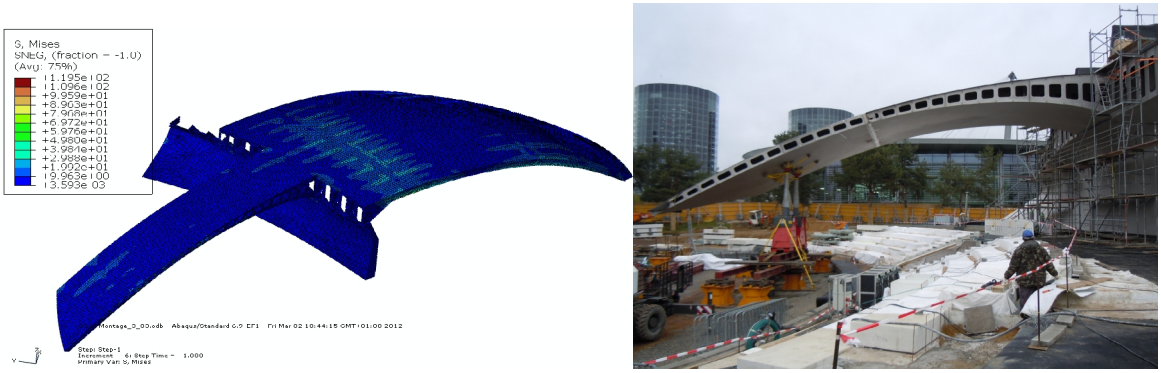

Fig. 10 Stage three - cantilever arm with temporary support

5. Conclusion

The Porsche pavilion (Fig.11) is a unique building consisting of a monocoque roof and a substructure.This type of roof is light compared to its stiffness. On the other hand you have higher design expenses and manufacturing costs. The innovative design was a challenge for all participants of the projects.

Fig. 11 Final view [1]

Acknowledgement Main project partners

Client:	Dr.-Ing. h.c. F. Porsche AG, Stuttgart
Architect:	Prof. G. Henn, Architekten, Munich
Design:	Prof M. Schlaich, sbp, Berlin (general); CSI, Groningen, Netherlands (monocoque); DBT Ingenieursozietät, Frankfurt/M. (ramp)
Construction:	Kümper & Schwarze, Wolfenbüttel (concrete); Temme Stahlbau, Bad Lauchstädt (polygon shell); Ostseestaal, Stralsund (monocoque); Ahlgrimm GmbH, Steinsberg (ramp)
Verification:	Prof. H. Pasternak, ipp, Braunschweig/Cottbus

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[3] Execution planning, CSI, Groningen (Netherlands), 2012
[4] Wind tunnel tests for the roof, Wacker Ingenieure, Birkenfeld, 2011
[5] DIN EN 1993-1-5:2010-12 Plated structures

Fig. 3 right, Fig. 4-6, Fig. 7 left, Fig. 8, Fig. 10 were done by Prof. Pasternak and co-workers.