Office Building Junghof – Visible Steel for a Fire Safe Structure

Jörg Lange, Prof., Institut für Stahlbau und Werkstoffmechanik TU Darmstadt, Darmstadt, Germany; **Karsten Ewald,** Eng., LE. Ingenieure, Rödermark, Germany

Introduction

In the centre of Frankfurt the office building "Junghof" had to be refurbished to make it attractive for modern use. When it was built in the 1950s five storeys were located around a central court. The new concept (*Fig. 1*) developed by the Architects and Engineers added two storeys, raising the building above the critical height into the class of high-rise buildings. This led to additional requirements with regard to the fire-safety, mainly escape routes and fire resistance of structural elements.

The building is located close to a district with many sky scrapers that rise up to 200 m. Because it is visible from most of these the architects invested much effort into the 5th façade. The roof was given a free form, cladded with aluminium panels.

Geometry

All four wings of the existing building have different depths. This led to varying geometric patterns in each corner. Spline-functions were used by the architects to define the form of the roof. These functions could not be used for further processing of the structural analyses and shop drawings, so an equivalent mathematical model was developed. To prepare buildable structural details it became necessary to develop plane glass surfaces and a roof structure with constant depth. This was done by defining a mathematical net for the outer surface. Relating to the net nodes, all additional design depths of the structure and dry ceiling were defined. The system lines of the structural model for the calculation of the design forces were also taken from this net. This structural model then served as the basis for the final design drawings.

Structure

The concrete cores for the staircases in the four corners of the building had to be strengthened for the additional loads of the added storeys. Between these cores no additional loads were allowed to be transferred to the existing structure. Due to the difficulties related to improving the strength of the structure the added two storeys had to be light. Therefore, and because of the long span over the old structure, a steel construction was chosen.

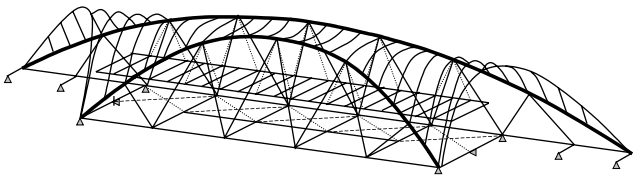
A structure was designed that resembles an arch bridge (*Fig. 3a*). In fact only the sides located towards the court act like an arch (spanning 36 m) in structural terms. The outside structures are trusses with cantilevers showing top chords having the form of an arch. They have a total length of 57 and 60 m respectively. The cantilevers have a length of up to 13 m. These arches are made of circular steel sections (diameter: 355,6 mm, wall thickness: 12 to 20 mm). The tension element tying the arches horizontal bearing forces is an I-beam. All arches, tension elements, and bottom chords are fire protected with fire board.

The need for a light structure combined with the architects goal to produce a transparent, open office space led to the use of composite slabs (depth = 160 mm, spanning nearly 2 m without temporary support) on composite beams spanning from outside wall to outside wall (maximum span = 7,5 m) without any interior columns (*Fig. 2*). This led to a common design of the 7th floor slab but to very odd shapes of the roof-beams on account of the shell-like roof (*Fig. 4*). Due to the use of a suspended ceiling it was possible to protect these beams with a cementitious coating that gave them 90 minutes fire resistance.

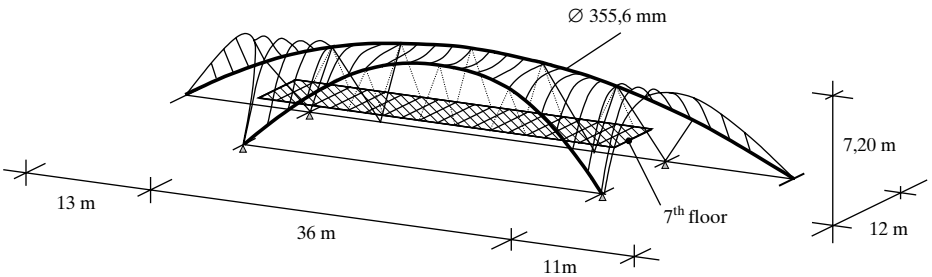
The design for heating and cooling required the use of material with high heat capacity in the roof since no air-conditioning was installed. Therefore slopes of up to 70° had to be formed in concrete. Up to 30° composite slabs with in-situ concrete were cast.

Fig. 1: View of the Junghof in Frankfurt

Fig. 2: Primary structure of 7th floor office space



(a) Serviceability state



(b) System for fire design

Fig. 3: Structural System

Fig. 4: Roof beams

A re-entrant composite profile (with a depth of 51 mm), needing no fire protection was used for the slab. It was flexible enough to follow the curve of the roof (*Fig. 4*). In bigger slopes precast concrete elements were used. They were bolted in three points to the steel structure. The joints were filled with fireproofing-material. Due to a careful planning process 90% of the roof-area was made of identical elements.

The 7th floor frames into a stringer that is suspended from the arch using circular sections (diameters of 40 and 56 mm) with fire-protection made of calcium-silicate shells.

Fire Design

A special feature of this building is the design of the ties that are part of the arch. They are designed without any fire protection. As shown in *Fig. 3,* a structural system was developed that in case of fire neglected most of the ties and the wind-loaded truss connecting the bottom chords (*Fig. 3b*). This system was analyzed under all dead and live loads. The wind loads were reduced, because it was reasonable to neglect the area of the windows. If the fire is strong enough to reduce the strength of the ties the windows will be broken.

Due to redistribution of the loads for some members the fire-design was the governing load case.

This design procedure, guided by references [1 to 9] not only saved cost but also reduced the visible width of the ties. In some load cases they have to carry compressive loads. Therefore it was not possible to reduce their diameter below 273 mm.

References

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SEI Data Block

Owner:
OfB Projektentwicklungsgesellschaft, Frankfurt, Germany

Architect:
Schneider + Schumacher, Frankfurt, Germany

Structural Design:
Lange + Ewald, Rödermark, Germany

Contractor (steel):
Stahlbau Plauen, Plauen, Germany

Steel (t):	550
Service date:	2004