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Central Hall of Liederhalle Culture and Convention Centre Stuttgart

Salle principale du centre culturel et de congrès Liederhalle à Stuttgart

Der mittlere Saal des Kultur- und Kongresszentrums Liederhalle in Stuttgart

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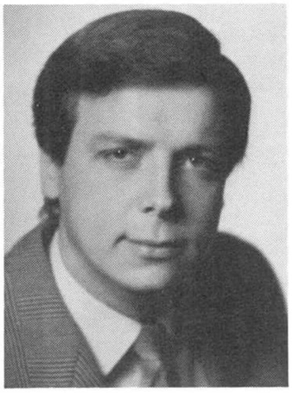

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SUMMARY

The roof structure of the Culture and Convention Centre Liederhalle had to consider concentrated high loads. Because of the sensitive glass construction, minimal deformation was allowed. While providing for a variety of interior equipment to be suspended from the roof structure, all inadmissible penetrations of the steel frame through the hanging ceiling had to be avoided. This required a comprehensive three-dimensional global analysis, which could only be achieved by means of a CAD system

RÉSUMÉ

Dans le projet du Centre culturel et de congrès Liederhalle, de fortes charges ponctuelles sont ancrées dans la zone de la toiture. Seules de faibles déformations sont tolérables en raison des sensibles superstructures en verre. L'interaction entre la structure métallique et le plafond suspendu a posé quelques problèmes intéressants, dont la solution ne fut possible que grâce à une approche globale, conséquente et tridimensionnelle recourant à l'informatique.

ZUSAMMENFASSUNG

Beim Bauvorhaben "Kultur- und Kongresszentrum Liederhalle" mussten grosse Einzellasten im Bereich der Dachkonstruktion verankert werden. Wegen der empfindlichen Glasaufbauten waren nur geringe Verformungen zugelassen. Bei der Vielzahl von Abhängungen im Zusammenhang mit dem Innenausbau durften keine unzulässigen Durchdringungen der einzelnen Bauteile auftreten. Dies war nur durch eine konsequente dreidimensionale Gesamtbetrachtung mit Hilfe der EDV möglich.

1. INTRODUCTION

To widen the many-sided cultural offer and at the same time provide the province capital Stuttgart a building for international conventions, Stuttgart decided therefore to build the Cultural and Convention Centre Liederhalle. In the beginning of the year 1988 the construction started and by August 1991 it was finished. The building consists of the Centre Hall with up to 1840 seats, the Small Hall with 425 seats and a garage with three storeys. The construction of a First Class Hotel with 300 rooms and direct access to the Convention Centre had to be considered during the planning of the Small Hall. Together with the neighbouring Liederhalle Concert Hall from 1956, which is under monumental protection, the capacity of the Cultural and Convention Centre will be about 5300 seats for various events like conventions, exhibitions and seminars.

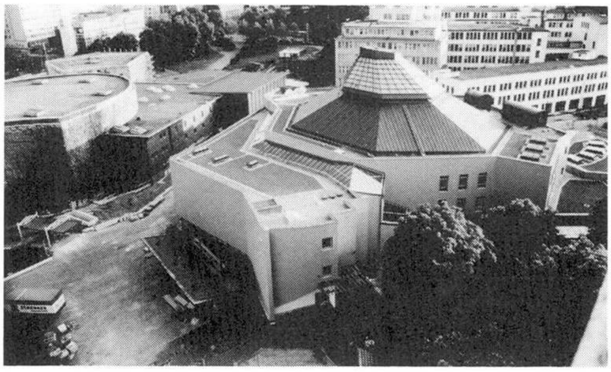

Fig. 1 Culture and Convention Centre Liederhalle

With the core of the building, the so called Centre Hall and its characteristic glass cupola the Cultural and Convention Centre gets an architectural highlight. Around the septagonal hall, the lobby areas, seminar and administration rooms are coordinated as the technical centre and the kitchen in the ground-floor. The seats in the hall and in both the galleries are stepped up and back. Moveable platforms can be slid out to accommodate tables in the galleries. The floor of the hall can be raised or lowered to meet various functions.

The roof of the hall, approximately 35 m in diameter, is a seven sided steel pyramid stump. The structural system consists of spider web placed I-profiles which are stabilized by a septagonal compression ring below the glass pyramid. To meet acoustical requirements the roof is covered with pre-cast reinforced concrete panels which were grouted afterwards. The steel construction of the roof carries a load of approximately 3000 kN. Therefore a shell structure was not possible. It was also important to minimize the deformations of the structure supporting the cupola to protect the glass and the shading elements from breakage.

The Centre Hall with its different structural systems and complex geometry and function made the engineering work highly demanding.

2. CAD-INSERTION

In order to make the planning and the structural design of the roof construction with its complicated geometry and crooked areas, an intensive CAD-Insertion was required. At that time IFB was one of the first Planning firmes in Stuttgart to work successfully with CAD-software. In that way it was made possible to tackle the complicated geometry of the floors with Post-Processors and then transfer the data into Finite Element Program.

A decisive advantage was obtained by using coordinate plans to measure out the building. In the beginning it was not planned to work with this sort of plans. To measure out the building in the traditional way turned out to be too complicated and nearly impossible. Therefore we had to work out a coordinate plan which shows all the characteristic points of the building with their x and y coordinates. Since the plans of the building were already digitalized in our

CAD-System we could develop the coordinate plans in a relatively short time. Using those plans, the survey engineer could determine exactly the layout of the building at the site with electro - optical methods. The coordination plans were therefore extremely important in order to maintain the accuracy between the steel production and the construction site.

By making the coordinate plans we gained specially two things:

- highest possible accuracy in measures for the structure
- extended use of the coordinates for the interior construction

Through this positive experience by using the coordinate plans for the reinforced concrete structure we decided to make coordinate plans also for the steel structure which will be discussed later.

3. THE STRUCTURAL SYSTEM OF THE BUILDUNG

3.1 The Reinforced Concrete Construction

Beside the roof construction all carrying elements are made out of reinforced concrete. The building itself contains no expansion joints. The floors in the basement are partly 90 m lang without expansion joints and are like the upper storeys calculated as slabs.

The loads from the roof construction are carried with corbels on to the supporting walls. Beside the high dead loads the support had to take up horizontal loads of 2000 kN from the compression ring. The reinforcement for the structural system was determined with the help of strut and tie models.

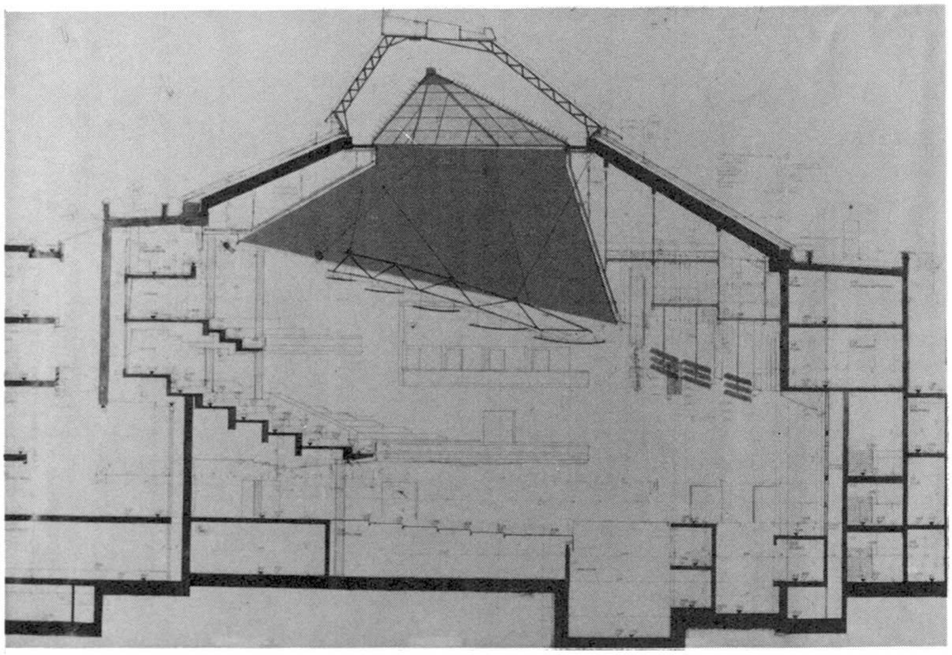

Fig. 2 Cross-Section of the Centre Hall

3.2 The Steel Construction

As portraied it was not possible to formulate the roof construction as a shell structure because of high loads. Therefore the roof was constructed as a steel frame pyramid stump with many connection points for the various demands.

Many complicated technical details placed high demands on the planning. Especially the many-sided hanging construction with its complicated technical details placed high demands on the planning. Because of that the main emphasize was on the roof construction.

4. THE HALL CEILING AND THE HANGING ELEMENTS

4.1 The Roof Construction

The geometrical form of the roof corresponds to an irregular septagonal pyramid stump with curved sides. Characteristic for this structure is the septagonal compression ring which is supported by twenty-one steel girders running from the ring down to the supporting walls. The compression ring supports then the visible glass cupola. The main girders are so arranged that the curved trapezoidal areas are devided into plane triangular areas.

That way it was possible to use pre-cas t reinforced concrete elements for the covering of the roof which had also the function as an acoustical system. To minimize deformations in order to protect the sensitive glass structure all connections were made moment-stiff. The structural analysis was done with a three dimensional truss program. For acoustic reasons the natural frequency of the roof structure had to be less than 15 Hz. Therefore a dynamic analysis was carried out. This subject led later to a Dipl. thesis which examined the resonance behaviour of the structure as well as the behaviour under earthquake loads.

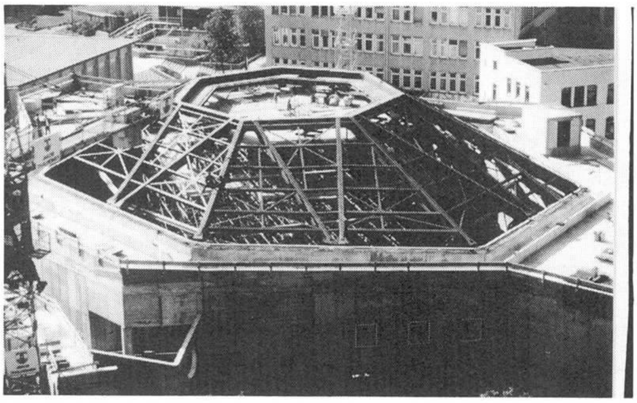

Fig. 3 General View of the Roof Construction

The core of the steel work planning was again the coordinate plan. The entire nodes, breaks and purlin connections were listed there with their x, y and z-coordinates so that all axis of the steel profiles were defined in a three-dimensional system. This was important to the planning of all the hanging components.

The compression ring consists of four parts which were assembled at the construction-site. The assembling of the whole roof construction took five weeks.

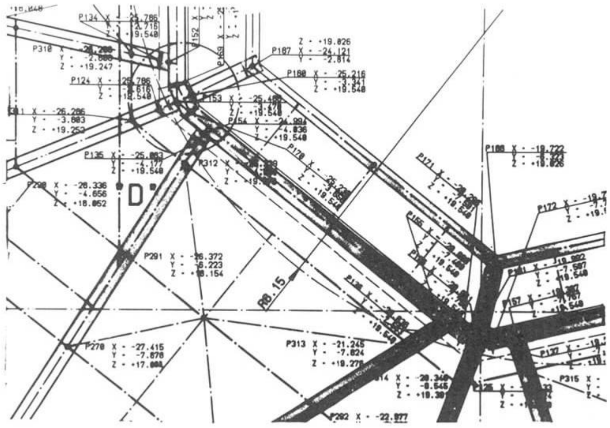

Fig. 4 Section of the Coordinate Plan

4.2 The Shading Pyramid

One of the requirements due to the utilization was the natural lighting respectively the possibility of shading the entire hall. This was reached by arranging the septagonal shading pyramid inside the glass-cupola. The structure weighs about 12 tons and is placed on seven cantilever beams which have a moment-stiff connection to the compression ring. Because of the sensitivee shading lamellas, high deformation criterias had to be met. The area between the shading pyramid and the compression ring is walkable for maintenance purposes.

4.3 The Stage Mechanics

The stage mechanics which bring extremely high loads on to the roof area are arranged on several levels. With the so called "Rolling floors" the transport of the scenery takes place. For that purpose a great number of lifting gear and pulleys are needed. The loading together with the grating structures weighs about 150 tons. Special hanging girder transfers the loading to the main girder of the roof structure.

4.4 The Construction of the Hanging Ceiling

The hanging ceiling is constructed in the middle part - similar to the steel structure - as an inclined stump pyramid, the so called 'Hat-structure', which is then tied to the roof structure. Around the 'Hat-structure', the so called 'Brim-structure' is placed, a plane area with a slight slope to the stage. The gypsum board ceiling is fixed to the base structure with common perforated ties. All areas are walkable for maintenance purposes. The spot-lights for the stage lighting are also placed there.

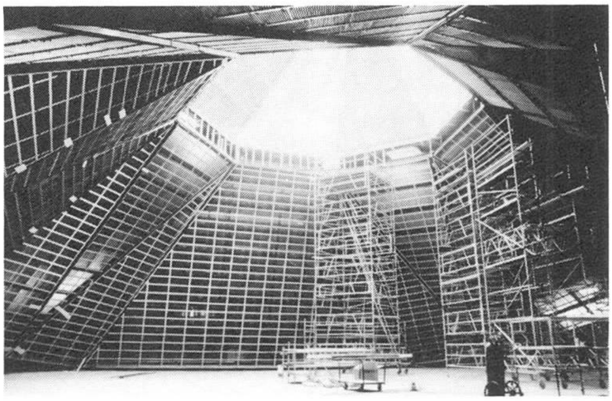

Fig. 5 Base Structure of the Hanging Ceiling

The position of the gypsum board ceiling was located exactly by the architect. It was the basis of three-dimensional modeling of the structure for the CAD-system. In addition we determined analytically with our own geometry programs the axis of the girders, the breakthrough points of the ties and the intersections of planes. Overall more than 1000 three-dimensional coordinates had to be determined. Therefrom a coordinate plan was set up which was the basis of completing the hanging ceiling. Due to the great number of unknown coordinates, three-dimensional CAD work became an important instrument in order to check-out the coordinates.

The assembly of the base structure followed directly the completion of the roof. For that purpose a scaffold was errected at the level of the second gallery.

4.5 The Acoustical Panel Supports

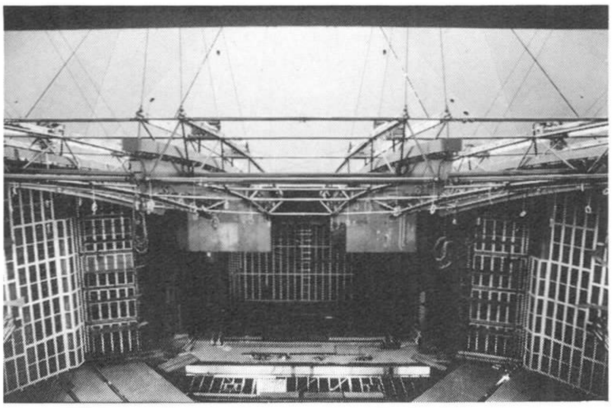

Fig. 6 Acoustic Panel Support

The acoustical panel supports with the hanging sound reflectors are basically to serve acoustical purpose but they are also used as an architectural construction for the hall. Six curved trusses are fixed to one another with cross bars and form a stiff curved shell. In between are 23 sound reflectors which are made of chemically prestressed float-composite-glass sections. They are fixed to the roof with three diagonal steel cables each. To guarantee the stability of the system, all cables have to be under tension and cannot penetrate through the base structure of the hanging ceiling. With these geometric boundary conditions given, a precise planning was necessary with the determination of all fixed and penetrated points.

Due to the high installation loades and the loads from the pulleys, some parts of the structure were made out of aluminium in order to reduce the weight. The trusses were transported into the Centre Hall in one piece by using a window-opening in the second floor. Then they were positioned individually and finally connected with the cross bars.

5. CONCLUDING REMARKS

The many-sided utilization of the "Culture and Convention Centre Liederhalle" placed extremely high demands upon both the planners and the executing companies.

Fig. 7 View of the Centre Hall

Fig. 8 View of the Lobby

High single loads had to be taken up by the roof construction. To avoid ineligible penetrations the whole structure had to be analyzed in a three dimensional system. This was only made possible by consequently using electronic resources. It turned out that perfect technical, economical and time managing planning of this building would have been impossible without using CAD.

In spite of all regards to this technical interesting building, at the end of the structural work one will find out that the given tariff is far from covering the real expenses.