GLASS HALL, NEUE MESSE LEIPZIG
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Introduction
Ian Ritchie Architects were invited by Von Gerkan Marg und Partner Architekten to collaborate with them and design the central Glass Hall as part of their international competition-winning scheme for the whole new Leipzig Trade Fair in 1992.

The Glass Hall
The Glass Hall is the principal building through which all visitors to the trade fairs enter, and provides a major space for reception, relaxation, information, informal meeting and formal events. It covers an area 243.75m long, 79m wide, and is 28m high at its crown. The glazed surface totals about 2.8 Ha (28,000 sq m or 7 acres). It provides a tempered external environment and is linked directly to the exhibition halls through glass bridges. The architectural objective is to treat the hall as part of a landscaped valley between the two ranks of exhibition halls and conference buildings, and to maintain maximum transparency within this landscape. To this end, the hall is enclosed in frameless glazing using low iron "white" glass (avoiding the characteristic green tint inherent in normal float glass). The structure is kept to a minimum, and covers no more than 15% of the surface. The glass is suspended 500mm below a tubular grid 3.125m square. This is stabilized and supported by primary trusses at 25m centres. Outriggers stabilise the grid between these trusses. End walls are structurally independent, and stand as a series of interconnected arch trusses cantilevering from the ground.

The internal environment is tempered in summer by trees internally, by white reflective fritting on the glass on the south face, and this can be supplemented by evaporative cooling of the glass with irrigation along the crown, using stored deionised rainwater, if required.

The structural envelope took 11 months to erect, and the trade fair opened to the public in April 1996.

It is the largest Glass Hall in the world, yet less than half the length of the Crystal Palace in Hyde Park.

The Principle Materials of the Glass Hall
The steel structure of primary trusses and grid shell are tubes. The lower chord of the primary arches were curved in England. Certain nodes of the primary trusses are in cast steel to form a smooth transition between members where the geometry would otherwise require complex fabrication or an abrupt change in profile. Glass support arms are cast steel. Glass fittings are machined stainless steel, and separated electrolytically from the carbon steel cast arms.

The Accuracy of the Steel Structure
The structure was conceived as an all-bolted assembly, with no site welding.

The accuracy of a steel structure depends primarily on the accuracy of its fabrication. The accuracy of the fabrication increases as the sizes of the prefabricated units decrease. On the other hand, the prefabricated units should be as big as possible - eventually, they have to be connected and each joint costs money. At the same time, each joint offers the possibility to adjust tolerances.

The sizes of the different units were finally chosen to enable an appropriate galvanising process. Hot dip galvanising appeared to us as the best procedure to ensure corrosion protection for the tubes, which could not be sealed tight.

The issue of accuracy indicates that design problems are interrelated and cannot be solved separately.

Expansion of the Structure
The Hall, with a length of 244m, will extend 6cm along the barrel vault axis at each end wall due to a temperature increment of 40°C. If this extension is fully or partially constrained, additional stresses occur in the structure, which reduce the carrying capacity of the structural components. This price has to be paid for the advantage of simplified bearings, together with restricting the relative movement between the fixed bridges connecting the Glass Hall to the exhibition halls, and the fixed escape doors from the hall itself.

We decided on a partial restraint by using rubber cushions for the barrel vault bearings (EPDM blocks with a base of 200 x 300mm and various heights).

The rubber cushions reduce the elongations at the end walls to a maximum of 3cm. A further advantage results from having no absolutely fixed points, ie bearings have to share the wind load acting in the vault's axial direction and a central wind bracing turned out to be unnecessary.

This, together with the fact that the two end wall structures are independent cantilevers and disconnected from the grid shell vault, thereby avoiding attracting wind loads onto the end of the shell, ensured that there would be no interruption in the homogeneity of the grid shell.

Deformation of the Structure
The deformation of the steel structure is one important parameter for the realisation of the glass shell. Basically, a single pane of glass with approx. dimensions of 1,5 x 3m can easily follow the deflection of the structure. Nevertheless, the out-of-plane bending, the rotation of the glass fixings and the distortion of adjacent panes has to be limited.

The replacement of the proposed top chord cables of the trussed arches by tubes was and important contribution to reduce the overall deformations (from a max. of 20cm to approx. 10cm).

As architects with a particular skill in designing glass structures, it is important that we know how much the structure will distort in all directions relative to the glass. Once we know these figures we have found it not too difficult to design the interface between them, and we do not mind if these movements are relatively large, i.e. the structure is more dynamic than static!

Corrosion Protection
The aesthetics of the structure required hidden bolt connections, and knowing the speed required to erect the building there was no question in our minds of even allowing sub-assemblies of the structure to be connected by site-welding.

Because of the difficulty of ensuring an absolute hermetic seal to all the joints and bolting access holes, the inner surface of the tubular structure had to be protected.

The most economical solution to this problem was hot dip galvanizing, which gives sufficient internal protection together with excellent external protection for the structural tubes; the structural components became significantly less sensitive to edge damage during erection, which is difficult to repair.

For the structure of the Glass Hall, with its structure outside the glass envelope, hot dip galvanizing offered the ideal protection and was applied to all steel parts above the glass shell, and complemented with a PU based two coat paint finish for all exposed surfaces.

The idea of rust dropping on the glass shell would be totally unacceptable.

The sizes of the units were chosen to suit the size of the zinc bath available (approx. 12m x 2m) at a new galvanizing plant close to Leipzig.

The corrosion protection concept was completed by air ventilation in all tubes - this could easily be insured by the holes at the head plates ready to receive the bolts, and which were already applied for the galvanising procedure.

Additional openings had to be provided for air flow only at the base and apex of the barrel vault and of the trussed arches.

Unfortunately, internal galvanising protection was not possible to the independent end wall arches because the client wouldn't pay for it. However, these are situated below or besides glass surfaces only. These have inspection points in the tubes near the base of each arch.

Connection Technique

The connection technique is one of the project's structural highlights. All the tubular joints of the barrel vault are factory welded. The tubes of the arches are welded to the tubes running parallel to the axis of the barrel vault. At the joints, a short (30cm long) tube with sufficient thickness was used to provide the necessary stability of the joint.

Consecutive tube segments are interconnected at head plates with long bolts.

In certain situations, e.g. at the outriggers which are connecting the barrel vault structure with the trussed arches to control deformations of the vault, it became necessary to use more than one bolt per joint. The connections of the trussed arches follow the above explained jointing principle, with the difference that the welded nodes became larger and all connections are plate to plate, using up to 6 high strength bolts per joint.

Erection

All design components described above were conceived having in mind a simple and accurate erection of the structure.

The welded arch units of the barrel vault structure were pre-assembled with the arch to arch parallel members by means of erection jigs on ground level, thus achieving a high degree of accuracy. The pre-assembled units were then lifted by tower cranes to a specially designed mobile erection scaffold-jig travelling on rails.

After completing each bay of the barrel vault structure, one trussed arch was erected starting from the base and progressing towards the apex by means of the tower cranes.

Prior to prestressing the bolts of the joints, one bay of the structure was adjusted to the prescribed geometry by means of jacks, which were positioned on the scaffold-jig. After prestressing the bolts, the structure was released and the scaffold-jig moved to the next bay.

The laminated glass panes with the glass fixings were pre-assembled on the ground and then hoisted to their final position by means of rail bound elevators. The rails were temporary fixed to the parallel tubes of the barrel vault by means of friction clamps.

The interconnection of the fixings to the cast 'frog-fingers' and the adjustment of the glass panes was performed from platforms, which could move along the parallel tubes of the structure on plastic rollers.

CORROSION PROTECTION

The accuracy of the steel structure is dependent on the accuracy of fabrication, which increases with decreasing sizes of fabricated units.