Olympic Stadium

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Experimental pavilion

World’s Fairs, Olympic Games and Grand Expositions are acknowledged as proving grounds for experimental architecture. The centerpiece buildings at these venues are meant to impress their international spectators with technical and aesthetical flair. In a way they act as ambassadors of the host country’s progressive industry. The applicance of both daring materials and daring techniques are therefore obligatory.

The Munich stadium complex for the 1972 Summer Olympics is a perfect example of how site and structure can blend together. Undulating roofs and dramatically sculpted earthscape unify the setting. Both inside the halls and out among the park setting visitors are provided with a sophisticated series of experiences.

Functional requirements

The original requirements, as imposed by the Olympic Committee, were very clear at the time. No less than 80,000 seats should be provided in the main stadium, and a smaller enclosed sports hall and swimming hall should also be provided. Other facilities should include a warm-up arena and an enclosed workout facility.

The adjacent Olympic Village should provide housing for 3,000 people and the necessary support functions. These facilities were to be of permanent quality and convertible to public use and parkland after the three-week Olympic games. Thematically, the competition used the motto “Olympics in the Green”.

Site

When the International Olympic Committee awarded the 1972 Olympic Games to Munich in 1966, the city had no large sports arenas. Previous planning however had already selected the best site for the new facility, an empty tract of land about three miles north of central Munich.

The site was originally the setting of a 1930’s airfield, a former training ground for the Bavarian Royal Army and the site of Munich’s first civil airport. During the cleanup after the Second World War, the ground had been used as a dump yard for ruined buildings’ rubble. Moreover a 300m tall broadcast tower, which is still present today, is a major landmark of the site.
Conceptual phase

Through its planning, development and current perception, Olympiapark manages to set several keynotes. First of all the tensile structure and translucent skin were revolutionary at the time and remain both visually and technically impressive today. The formal language as it was interpreted by architects Behnisch and partners is a strong statement about Germany and its industrial capabilities. As the whole park has been constructed on an abandoned airfield covered with remnants of the war, the city has reclaimed an important green area. Contrary to what happens to many other venue halls, the whole complex has been put to permanent use as soon as the primary purpose had been served: it has now become a sports stadium, and a frequently visited park with a main focus on sports.

Critical technical issues

A stadium of Olympic importance should respond with corresponding attention to the primary functions it hosts. Orientation to sun and wind have to ensure equitable outdoor conditions for all competitors. Moreover, accommodation and transport should be provided for many thousands of visitors.

Special circumstances heavily influenced design thinking. Two questions dominated this project. The first issue that arose was speed of construction. Deadlines were absolute and the time line for developing the huge site (including the Olympic Village) was short. Speed of construction and the risk of delays would have to be considered. Second, what would happen to the complex after the Olympics? Given the costs associated with such a grand occasion and the extensive facilities that would remain, their future use had to be designed for. A temporary structure would be insufficient, and a monumental one would be a perpetual burden.

A third requirement emerged during a later phase, and took requirements of broadcast color television into account. Television would have its say; since the 1964 Summer Olympics in Tokyo, live color television coverage had become the standard and had extensively penetrated the market. In essence the television companies had requirements towards lighting, shadow reduction, and acoustics.
Climate

Despite Munich's temperate weather, the design of a cable net roof structure had to address two critical factors: wind and snow. Freezing rain, snow or hail falls an average of 75 days per year in Munich, and wind gushes can exceed 120 km/h during stormy weather.

Heavy snow and ice accumulations on the unheated roof could impose dangerous structural loads. Basically this issue could be resolved by placing large fans under the canopy to melt snow off the top. This technique had a proven record in the Otto’s German Pavilion at the 1967 World Fair in Montreal.

Given the climate conditions in Munich and especially the prevailing wind direction, both the tensile roof and the main seating area are oriented at the western edge. Approximately 65% of the stadium’s visitors are thus given shelter from the natural elements.

The roof and the higher seating area on the western side also guarantee the eastern seats to be somewhat more protected from wind. Nevertheless, in current Olympic stadiums, an uncovered seating area would not be allowed anymore.
Roof
Without doubt the most remarkable feature of the stadium and the adjacent buildings is the tensile roof structure. It has become not only a landmark for the city of Munich, but has been a precedent for many more innovations in this field of study in later years. It is especially the size and the grandeur of the roof which has inspired many architects and designers.

The roof grid over the main stadium is formed by nine saddle-shaped nets of 25mm steel cables spaced in a 762mm square grid. The saddle spans up to 65m and reaches a maximum height of 58m. The nets are supported over the seating areas by eight tapering masts behind the stadium, ranging from 50 to 70m high. Smaller bow-shaped nets connect the larger membranes and wrap around the supporting masts.

The cable nets are doubly curved. The resulting double-curved saddle shape prevents the canopies from easily fluttering in the wind. The total length of steel cable in the complex exceeds 408km and tension loads in the cable net are as much as 5000 tons. Originally the foundation design was intended to consist of prestressed anchors. Local code officials however insisted on more conservative piers to provide stability. In some cases these piers are as much as 18m deep and 6m wide. These enormous foundations were required to resist the tremendous tensile stresses in the cable network and the live loads imposed by winds across and under the open structures.

Envelope
Originally one intended to hang a canvas fabric below the cable net, just as Otto did in Montreal. As television companies became involved however, the issue of excessive contrast for broadcast, photography suggested modification. In the end, bronze-tinted acrylic plastic panels measuring 2.9 by 2.9m were installed above the cable wires. Connections between the panels had to allow for thermal expansion and structural movement of up to 1m deflection under heavy wind loads. The acrylic panels were attached to the supporting net at the intersection points of the cables. However, because of the irregularity of the net, the panels sometimes overlapped the cable grid at varying angles.

Apart from offering enough color contrast for improved photography, the bronze tinting also helped reduce heat gains and glare without casting shadows as a canvas canopy would have.

Concrete pilings provide gravity load reactions to tension structure.
Sports Hall and Swimming Hall are enclosed under cable roof by glass walls.
Physical plant located off-site.
**Mechanical**
Buried under the stadium seating in the sports hall and the swimming pool, 49 air-handling units are served with hot and cold water from a central plant located on the other half of the site. Additionally a 19km network of hot water piping was buried 25cm below the grass surface of the stadium playing field to allow year round use.

**Experimenting**
Since this project has been executed before our current digital age, all of the calculations had been done by hand. Most of the engineering was also the result of practical experiments, mostly conducted by Frei Otto himself, and based on models in varying scales.

Otto started with models of the roof at a 1:125 scale. He measured the mechanical forces in the individual wires of the net with gauges he had developed himself. Several fixed cameras recorded both the loaded and unloaded shape of the model for comparative measurements.

As soon as these experiments offered the necessary insight in how these constructions worked and reacted, larger models were built and hand calculations were performed for verification. Therefore, architects and engineers used drawings on a 1:10 scale, resulting in 3.800 sqm of drawings.
References


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