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New Corinthians Stadium in São Paulo

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Summary: Even though the Sport Club *Corinthians* Paulista has one of the most successful soccer teams in Brazil, the club has been waiting for decades for its own stadium. With the FIFA decision that the world cup 2014 will take in Brazil, the Corinthians were able to find sufficient financial support for the new Corinthians Arena. The team of Werner Sobek Stuttgart was selected for the design development of the concrete structure, and for all design phases of the very slender and elegant steel roof structure which spans almost 200 m with a perceptible structural height of 3 m only. The following article describes briefly the stadium design, and explains in detail the structural systems of the concrete structure and the steel roof. The article concludes with an explanation of the construction sequences and the structural analysis.

Keywords: *Stadium, wide-spanning roof, World Cup, Brazil*

ABSTRACT

In 1910, while all soccer clubs in Brazil were for the elite, the Sport Club Corinthians Paulista was founded in São Paulo by five man of the working class. Since then the popularity of the club rose constantly with the club being one of the most successful in Brazil nowadays. With its growing number of fans, the club has played since 1940 in the Paulo Machado de Carvalho Stadium with a capacity of 37,000 spectators only. For games in which this capacity was not enough, the club has been forced to play in the stadium of the rival club – the Morumbi Stadium of the São Paulo FC. From that situation grew the wish for an own soccer stadium with a larger capacity. After the FIFA decided that the World Cup 2014 will take place in Brazil, the Corinthians were eventually able to find sufficient financial support for their stadium project. For Werner Sobek Stuttgart the project began in February 2011, when they were approached by the architects CDCA (Coutinho, Diegues, Cordeiro Arquitetos) with the design intent of an almost 200 m long spanning roof structure having a perceptible structural height of 3 m only (Fig. 1). It was clear from the start, that this design intent demanded a carefully developed structural solution.

The new arena is situated in the township Itaquera – around 15 km away from the city center of São Paulo. It will allow 48,000 spectators to follow the Corinthians games. For the FIFA World Cup games additional seating will be provided – increasing the number of spectators of 65,800.

The stadium consists of a concrete structure and steel roof which covers the tribunes (Fig. 2). The main tribune is in the west of the soccer field. It has a length of 220 m, a maximum depth of 85 m and a height of 57 m. This building houses three underground parking levels and nine above ground levels with shops, lounges, restaurants, and press areas. Compared to the west tribune, the eastern one is relatively small with only three levels above ground. North and south of the soccer field the stands are placed directly onto the surrounding landscape.

The steel roof structure consists of evenly spaced, cantilevering trusses above the west and the east tribunes with a cantilevering length of 58 m. Above the north and south tribunes a 170 m wide-spanning, suspended roof is detailed which ends in the east/west roof structure. This structural concept allows to fulfill the architectural wish of a minimized perceptual height of the roof structure in general, and in particular with a constant edge height of 3 m.

In the following, the key points of the concrete structure are summarized, the structural system of the roof is explained and the erection procedure of the roof structure is discussed.

Fig. 1: New Corinthians Arena (credits: CDCA)

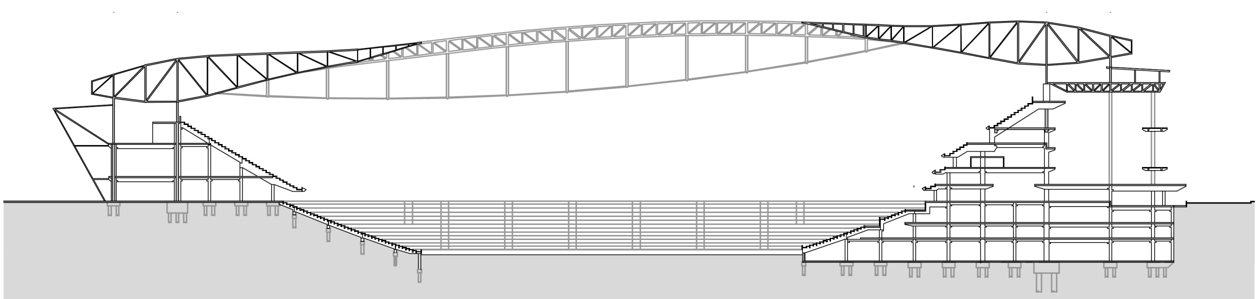

Fig. 2: North-south section of the stadium, left: east tribune, right: west tribunes

CONCRETE STRUCTURE

The concrete structure of the stadium consists of an eastern and a western building supporting the stands and the steel roof structure. The east structure with only three stories is significantly smaller than the west building with three underground parking levels and nine above ground levels. To allow a fast erection sequence, precast elements were used for the columns, the stands and the slabs. Several shear walls transfer the horizontal forces acting on the concrete structure to the ground. A special case are the four H-shaped shear wall cores in the west and the shear wall with a north-south orientatation in the east: into these shear walls the horizontal forces of the roof are transferred (highlighted in red in the Fig. 3).

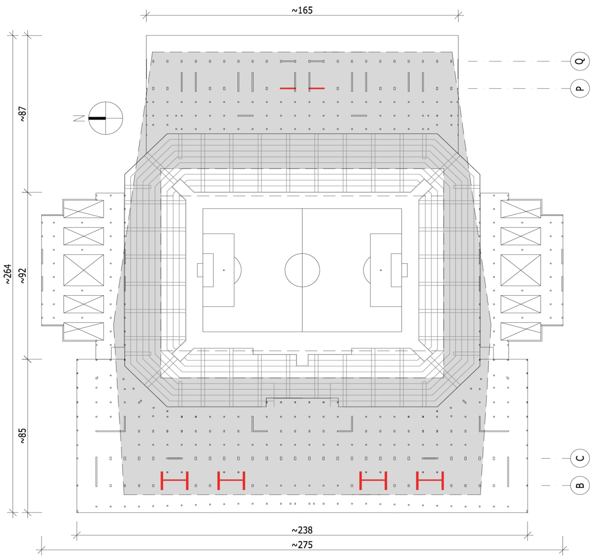

Fig. 3: Top view of the concrete structure (shear walls used for transfer of the roof loads are highlighted in red)

Fig. 4: East tribune during construction

The west building serves as main entrance of the stadium. To allow for an open spatial configuration at the entrance a 25 m high column free atrium hall is situated in the middle of the building (Fig. 5). This large column-free space required a special structural solution for the roof. Instead of using precast beams to support the concrete slabs, a two way spanning steel truss system was developed.

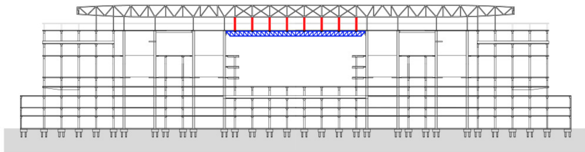

Fig. 5: West building with the centrally located column-free atrium; steel truss system (highlighted in blue) above the atrium to support the roof structure

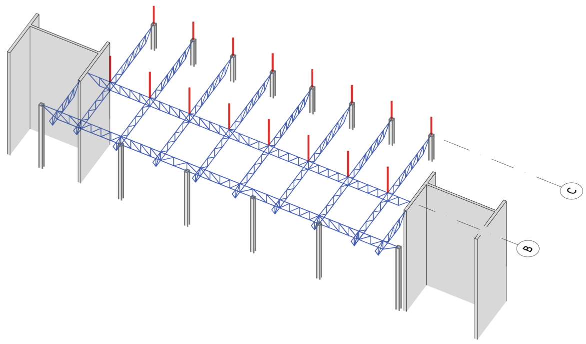

Fig. 6: Steel truss system above atrium hall in the west building (horizontal braces not shown)

Two ~60 m long steel trusses span between two H-shaped shear wall cores and an adjacent column. Perpendicular to these two long trusses, eight trusses, with a length of 28 m each, span to the columns in axis C. These eight trusses are arranged in a spacing of 7.5 m which corresponds to the spacing of the steel roof structure and thus allows the fixation of the steel roof columns in axis B and C (highlighted in red in Fig. 6). Braces between the two perpendicular truss systems stabilize the trusses and transfer occurring horizontal forces into the shear walls (braces not shown in Fig. 6).

STEEL ROOF

The main tribunes, above the west and the east building, are covered by a cantilevering steel structure which is supported by two, 15 m spaced pendulum columns (Fig. 7). The outer edge of the steel structure (e.g. the last 15 m) is designed as a Vierendeelsystem. This was the result of an extensive design study: as this part is being clad with glass, the architects design intent was to keep the supporting structure as visually calm as possible. A study of truss systems showed that the diagonals of the trusses, under a perspective view, lead to a less harmonious appearance. Thus, a Vierendeel-system was chosen for this exposed part of the structure. The remaining steel structure was designed as a truss system. The structural height increases in correspondence with the increasing bending moment from 3 m at the truss tip to about 10 m at the pendulum column which faces the playing field.

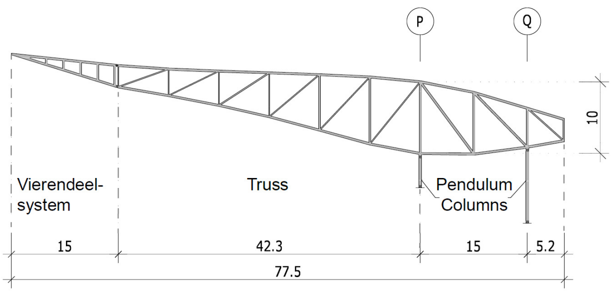

Fig. 7: Cantilevering steel structure above the east/west tribunes

The spacing of the trusses is 7.5 m. The widths of the bottom and the top chord of the trusses are kept constant to 290 mm to allow for a standardized connection of the cladding elements (lower surface: membrane cladding; upper surface: cladding by Firestone using a thermoplastic membrane supported on insulated trapezoidal sheets).

The east and the west tribune are almost 200 m apart. This distance was to be connected by a free-spanning roof structure (Fig. 8). In the course of the structural design it was possible to integrate a composite column within the extents of the west building and to thereby reduce the free span to approx. 170 m.

To maintain also in this part of the roof a visible structural height of around 3 m, a suspended structural system was chosen: a steel truss system is suspended every 14 m by suspension posts with a maximum length of ~ 12 m. The lower ends of the suspension posts are connected by a tension lamella package. By this means the effective structural height of the section was significantly increased and the visually noticeable constant edge roof thickness of approx. 3 m maintained.

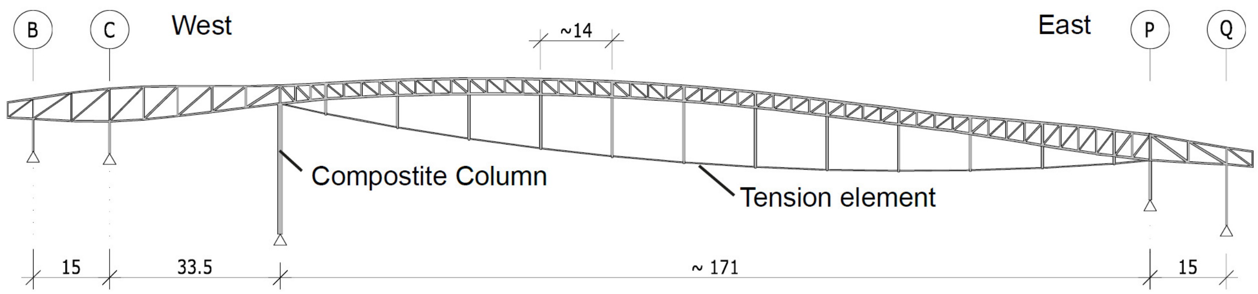

Fig. 8: Section suspended roof part

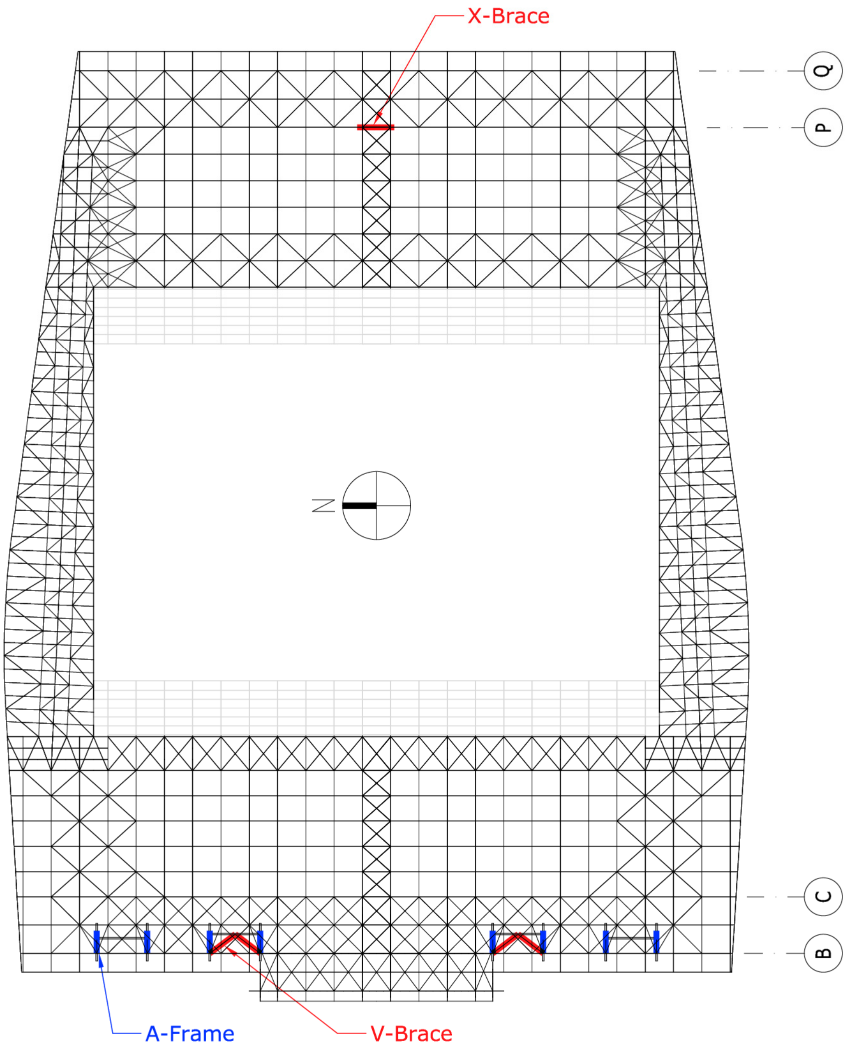

Fig. 9: Top view of the roof structure, elements for horizontal load transfer highlighted

Horizontal load transfer

The outer dimensions of the total steel roof structure are approx. 220 m x 250 m. The temperature changes occurring during the course of the day and the year would cause large forces if the roof structure was restrained. Thus, it was an important design aspect to achieve a statically determinant system for the horizontal load transfer and to therefore allow the roof structure to contract and to expand freely. In Fig. 9 the main elements of the horizontal load transfer are highlighted. In the east-west direction the roof structure is only supported for horizontal loads in the west. Here stiff A-Frames consisting of a vertical column and a diagonal are placed on the H-shaped core walls. In the north-south direction the roof is supported horizontally by one cross brace (X-brace) in the east and two so called V-braces (two diagonals) in the west.

Under design temperature changes the roof extends from its rigid support in the west to the east where a significant movement of the pendulum column top occurs without restraining forces.

CONSTRUCTION SEQUENCE

In coordination with the construction sequence of the concrete structure the construction steps of the roof structure were chosen (Fig. 10). In the first construction step the steel trusses of the east are erected by consecutively lifting two fully assembled trusses as a pair and connecting those to the supporting concrete structure.

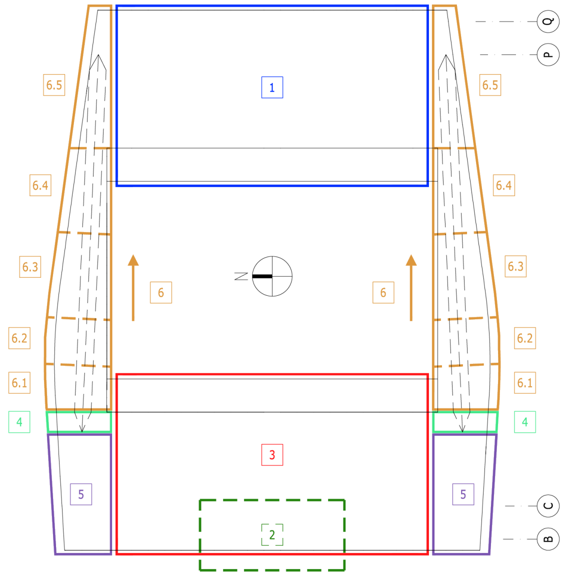

Fig. 10: Construction steps (top view)

The transfer trusses above the atrium hall in the west building are erected in construction stage 2 and subsequently, the truss pairs in the west are installed (step 3). In construction step 4 the roof segments above the composite columns are constructed and in step 5 the adjacent west corner elements assembled. Eventually, the segments of free-spanning roof part are installed in step 6.1 to 6.5. The segments are lifted individually and placed on temporary towers (Fig. 11). Each newly lifted segment is connected to the previously installed roof part. Finally, the east corner roof segments (6.5) are connected to the roof trusses of the east which were the first elements erected. At this point, all roof elements are installed and the temporary towers can be lowered in a stepwise sequence.

CONCLUSION

Stadium designs require carefully engineered structural solutions to allow column-free enclosures with a minimized amount of material used. While most stadiums have a similar enclosure around all four sides of the playing field, the new Corinthians Stadium in São Paulo has two main tribunes and two small side tribunes which have to be sheltered. Thus, a structural solution was chosen which consists of parallel arranged cantilevering steel trusses above both main tribunes and two free-spanning roof elements which connect the two tribune roofs. With this structural approach the architectural design intent of a constant visible roof edge of approx. 3 m could be satisfied and the free-span of 170 m achieved. Like a light-weight disk the roof seems to float above the massive tribune structures.

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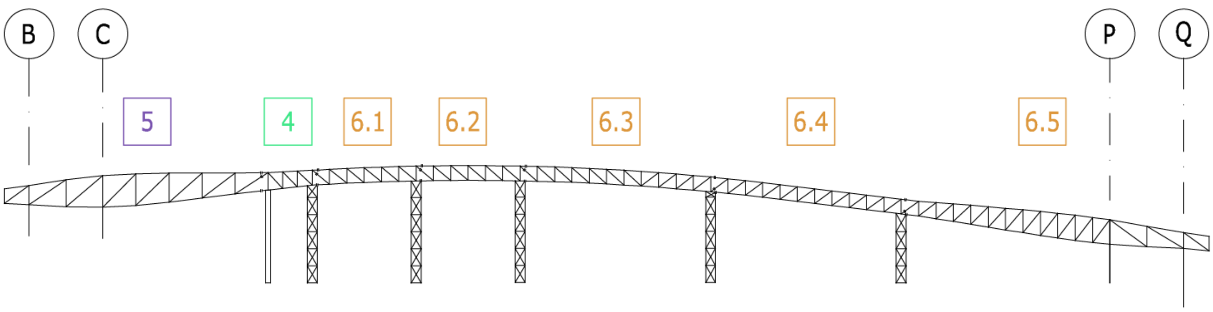

Fig. 11: Construction steps of the suspended roof part (side view)