Zeitschrift: IABSE structures = Constructions AIPC = IVBH Bauwerke
Band: 14 (1990)
Heft: C-52: Football stadiums in Italy

Artikel: Enlargement and covering of Milan San Siro Football Stadium (Italy)
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DOI: https://doi.org/10.5169/seals-22202

5. Enlargement and Covering of Milan San Siro Football Stadium (Italy)

Owner:	*Comune di Milano*
Structural Design:	*Leo Finzi*
Contractors:	*IRSS, Imprese Riunite San Siro leaded by Lodigiani S.p.A.*
Works duration:	*25 months*
Service date:	*1990*

When the Milan Council commissioned the Engineer to draw up plans for the steel and reinforced concrete structures that would be used to extend the San Siro Stadium he had to take into account some basic conditions: the impossibility of structural work on the via Piccolomini side of the stadium; the need for the stadium to be available throughout the entire football seasons, in spite of the construction work; the interdependent assembly of the steel and reinforced concrete structures that would be one above the other; the short time available for the work.

Given the limited space around the stadium it was clear straightaway that the production of the components would have to be as decentralized as possible, i.e. relying on prefabrication. In this way it was possible to have a dozen centres of production working at once, and then bring the prefabricated components together at the stadium site.

The extension structures can be divided into three main parts: the towers, the third ring and the roofing.

The Towers

The towers are of two types. There are 7 «type A» towers: these bear the weight of the third ring alone, at a height of 33.30 m. The four «type B or C» towers are placed at the corners and extend beyond the third ring to support the roof covering at 55.0 m as well.

The «type A» towers are cylinders with a wall thickness of 40 cm and a diameter of 10.3 m. Jutting out of them are the helicoidal ramps. Inside the towers, two intermediate walls that run along side the stairways support the weight of the intermediate landings and of the closing slab at 33.30 m on which the load-bearing beams of the third ring rest. The plinth foundations are 16,5 m in diameter and bear a load of 16000 tons for each tower.

The «type B» or «C» towers are similar to «type A» except that they have an external diameter of 12,76 m and two internal partition walls that are arranged crossways and extended beyond the third ring. Towards the summit this cross becomes the inverted pyramid on which the roofing rests. The «type B» towers have pile foundations supporting 25000 tons for each tower.

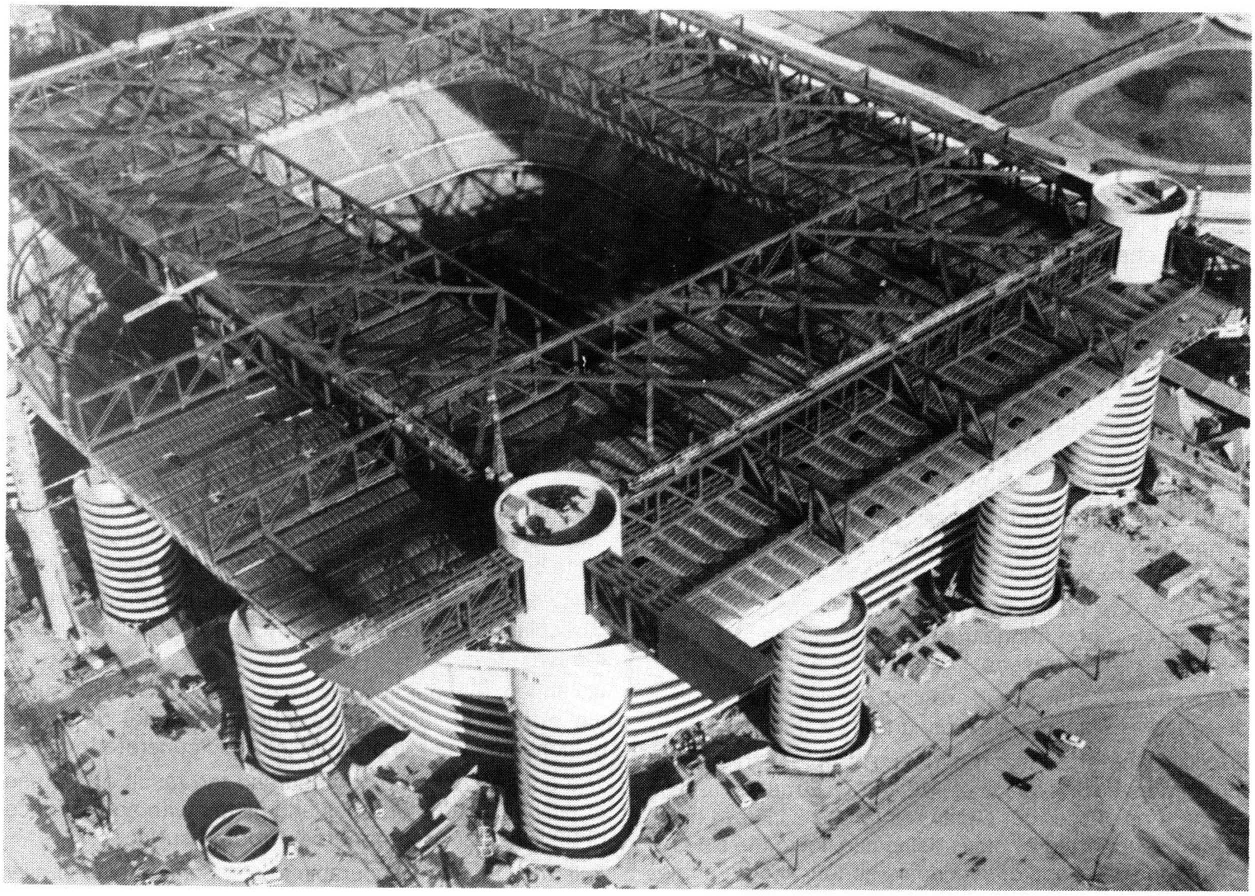

Fig. 1: General view during the erection of the roofing

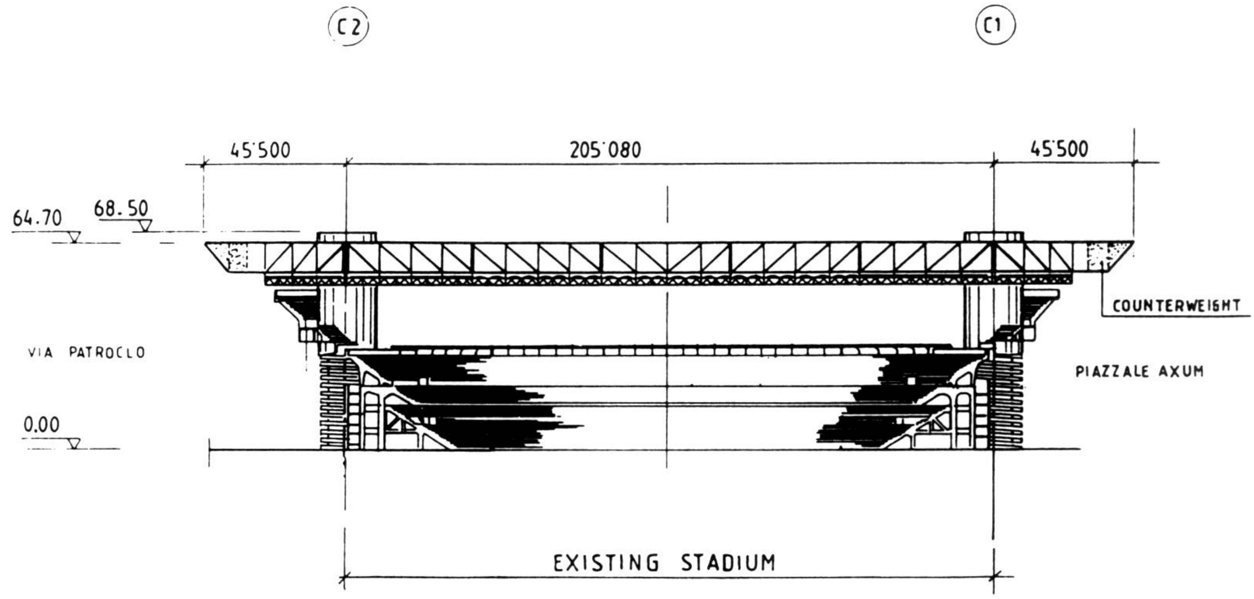

Fig. 2: Longitudinal cross-section

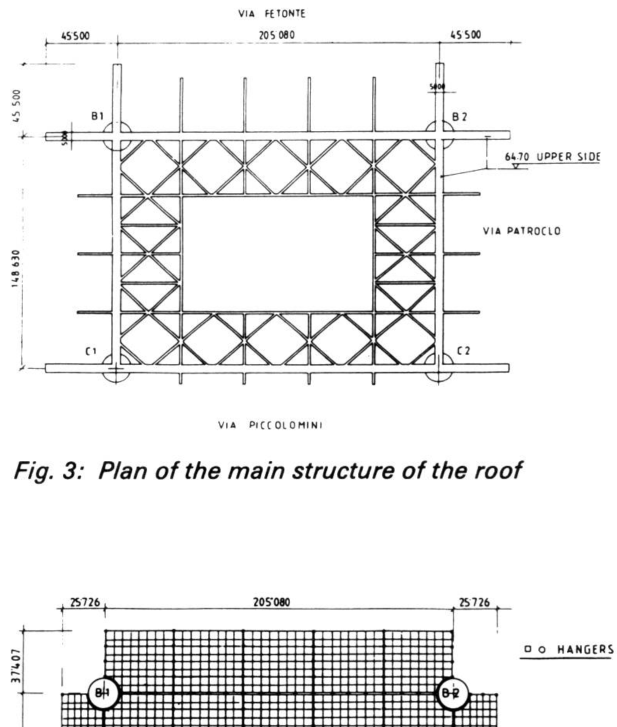

Fig. 3: Plan of the main structure of the roof

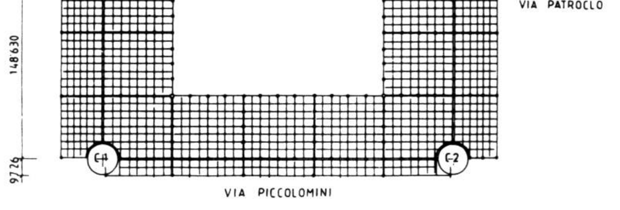

Fig. 4: Plan of the suspended rafts

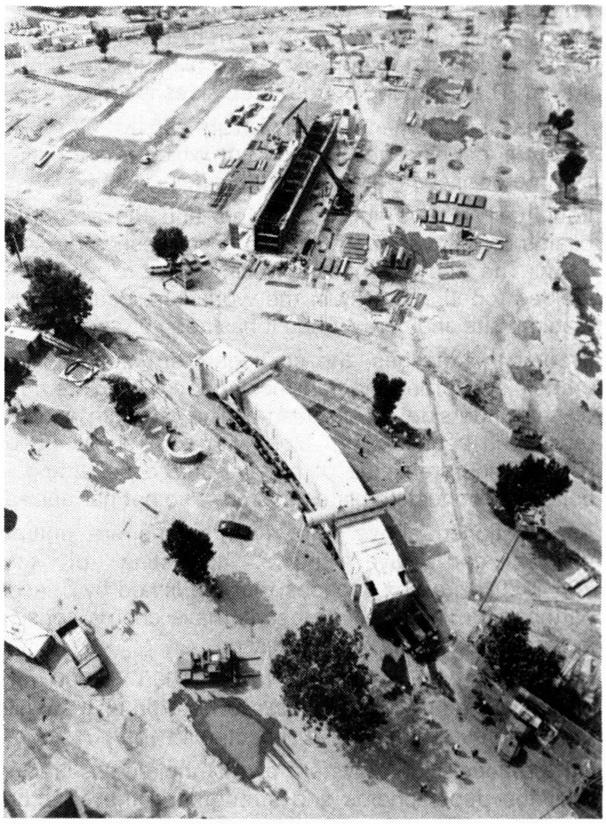

Fig. 5: A prestressed box girder being moved

The Third Ring

The third ring extends around three of the four sides of the present structure the exception being the Via Piccolomini side that leads onto the running track. The load-bearing structure is in prestressed reinforced concrete box beams, section 4,8 × 5,5 m, wall thickness varying from 40 to 90 cm and span varying between 45,9 and 56,7 m. Due to their size, the beams were prefabricated in the area in front of the stadium and lifted into position after the partial pretensioning of the cables.

Their weight varied between 1350 and 1500 tons. On the towers the beams rest on support attachments that permit thermal and viscous expansion. There are also pretensioned tie bars anchored to the top of the tower, which counteract any possible unbalancing of the beams due to their curvature or any uneven distribution of the load they bear. Inside the beams, at intervals of 5 m there are transverse diaphragms which allow the linking of prefabricated pretensioned cantilevers that bear the weight of the floorboard to the box beams. The «floorboard» itself is made up of stepped terraces and aisles both of which are prefabricated in normal reinforced concrete.

To calculate the box beams, spatial models with finite plate elements were set up to test the effect of beam curvature and the way the pretensioned cables acted on the various sections.

Fig. 6: Lifting a main box girder

The Roofing

The roofing covers the third ring and existing stadium entirely, leaving only the pitch uncovered. Structurally this is a grid of lattice beams 9,5 m high which rests on the four corner towers that make a rectangle 205 by 148 m. The overhang on the three sides is up to 45 m.

The maximum dimensions in plan are 295 by 203 m with a central opening of 121 by 73 m which is not placed symmetrically with respect to the sides.

Four main beams link the towers and the secondary beams cross over each other to form meshes of 37 by 41 m. The abovementioned main structure is entirely welded together, partly in the workshop, partly on the stadium site and partly when it has been put into place.

Around the meshes, the secondary structures (called «rafts») supporting the translucid roof covering are hung on the underside of the beams. The rafts are grids of reticulated beams 2.3 m high with a mesh of 4.6 by 5.1 m. They are made of hot galvanized equal angles bolted to connecting plates that are also hot galvanized.

As mentioned above, the main beams are entirely welded and have chords consisting of four 700 × 700 mm box sections that are linked by caisson battens. The intermediate beams have chords consisting of single 1000 × 700 m caisson.

All the uprights are 1000 × 400 or 1000 × 1000 mm. The tensioned diagonals consist of four tie plates while the compressed ones have H-sections.

On the upper side a system of rhomboid cross-bracing links the upper chords and strengthens the structure horizontally. The tips of the overhangs of the main beams are filled with mass concrete to give a ballast of 5600 tons so as to reduce the bending moments at mid-span of the beams and thus reduce the thickness of plate used in the chords less than 40 mm.

The four bearings (two bearings 5000, two 7500 tons) allow the roofing to move as a result of expansion due to heat but do not allow it to move with the wind. The movement is guaranteed by discs of PTFE (Poly Tetra Fluoro Ethilene) on stainless steel surface. The metal framing for the main and secondary structures weighs 10600 and 1900 tons respectively. The weight of the four main beams varies between 1100 tons (for the shorter side) and 2100 tons (for the longer side).

Due to the size of the work and the new technologies being used in its construction systematic checks during fabrication and construction were fundamental.

As well as the normal checking of materials (cement, steel, concrete, etc.) the Italian Welding Institute was brought in from the beginning of the work to check the welding done in the workshop, on site and when the parts had been assembled. They also checked the bolted connections.

Load tests were also carried out on prototypes of the different types of parapets, terraces, aisles, brackets and rafts.

At is was not possible to check load bearing directly, it was decided to equip two of the box beams of the third ring and some of the master beams of the roof with strain gauges so as to compare the changes in tension in them as work progressed with the changes predicated by the calculation models.

(Leo Finzi)

Fig. 7: General night view from outside

Fig. 8: View from the inside of the San Siro Stadium