Conceptual design of two mobile roof structures

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Abstract

The present paper is addressed to the illustration of the conceptual design elaboration of two mobile roof structures, corresponding to:

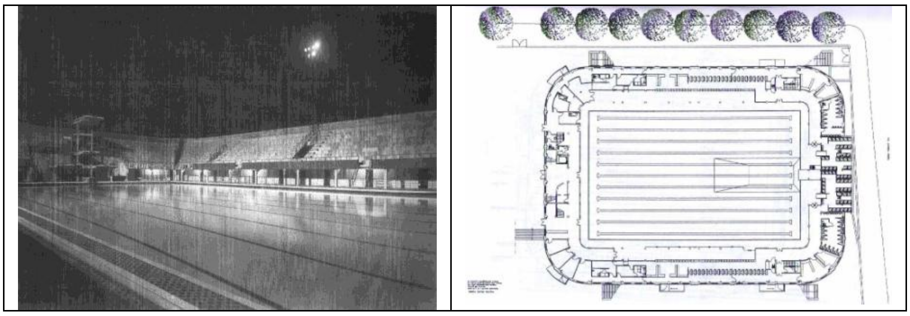
- The existing open-air swimming pool in Bologna.
- The new stadium of Venice;

1 The swimming pool in Bologna

In March 1999, the Municipality of Bologna intended to proceed to a preliminary design regarding the roof covering of the existing olympic-sized swimming pool. This open air facility, named Carmen Longo, was built in 1929 and the existing brickwork construction is protected, under the ethic and esthetic control of the Superintendence of cultural and ambiental values. Therefore, there was necessary to proceed with a special investigation regarding the compatibility between the new structural architecture and the protected existing building.
The variation of state, produced by the new roof on the existing context, was checked by a CAD-3D rendering showing the materials and the real dimensions of the structural elements.

1.1 The actual situation

The sport facility covers an area of around 3000 sqm., with a smoothed rectangular configuration of 68m by 48m dimensions of the sides in plan view (Fig.1).



(Fig.1 The existing building and plan view)

The swimming pool, with dimensions of 50m by 25m, is surrounded by the grandstands and the internal services having a height of 7m from the water level.
The existing structure of the grandstands is formed by parallel double reinforced concrete frames with a relative separation of 2.25m, placed at a constant distance of 7.50m.
From the architectural point of view, only the external brickwork walls have a value to be preserved. Internally, at the contrary, there is not any interesting architectonic or ornamental valuable element.
From the structural point of view a reinforcement of the structures was considered necessary in terms of durability and in order to satisfy the actual loading conditions, considered by the National building code.

1.2 The roof design

The conceptual architectural and structural design of the roof was based, principally, on the following hypothesis and constraints:

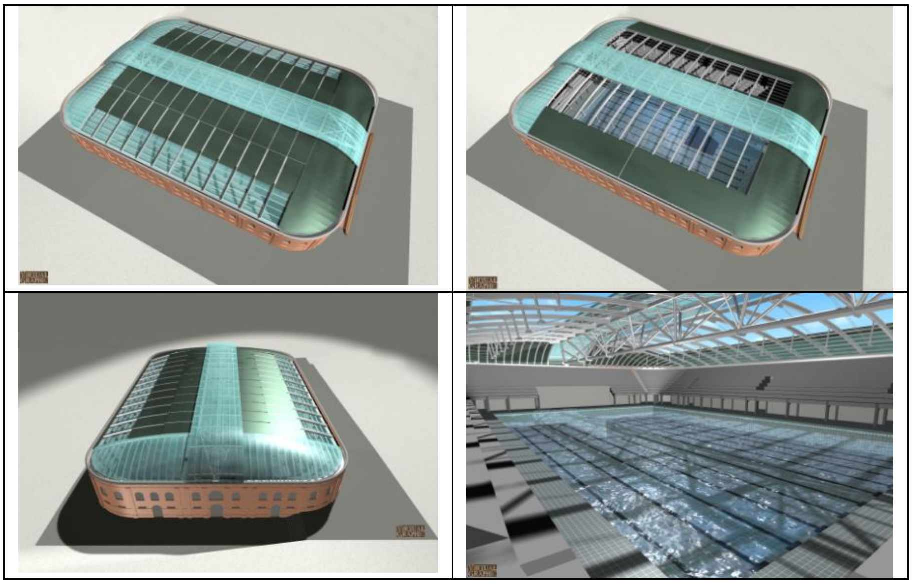
- minimization of the external dimensions of the roof;
- formal , historical and typological compatibility of the roof structures;
- architectonical compatibility between roof material and brickwork;
- partial convertibility of the roof;
- natural lighting and solar energy contribution from the south-east area of the covering.

In order to optimize the above mentioned requirements, the structural system has been conceptually designed considering a typology formed by the following sub-structures:

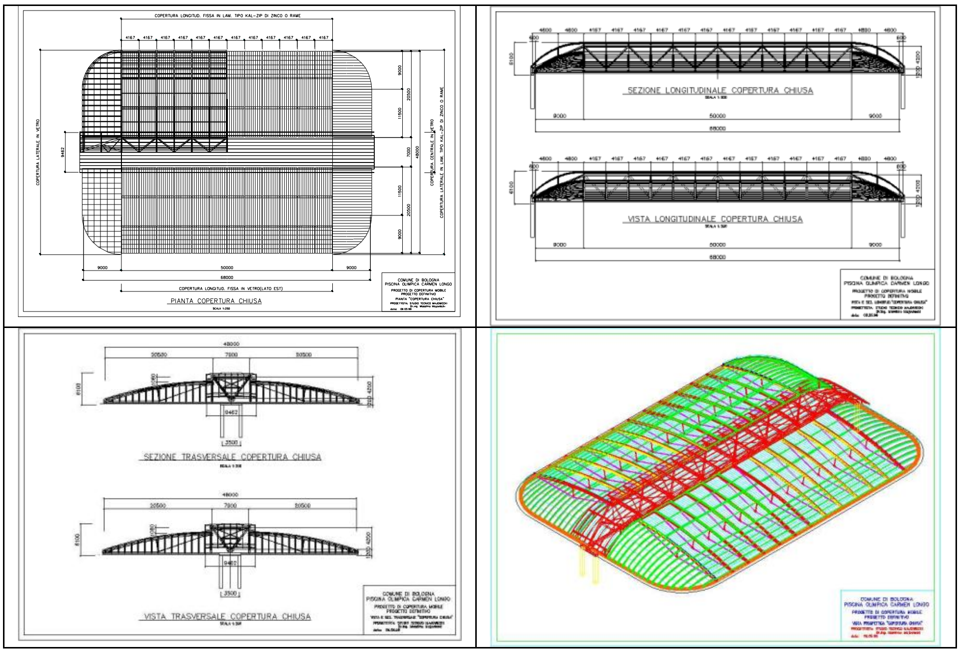
- a longitudinal main structure;
- a system of transversal cable-beam structures;
- a system of mobile covering panels.

Considering the actual carrying capacities of the existing structures and the necessity to minimize the reinforcement works and therefore the intervention in the protected part of the building, a main longitudinal oriented space frame beam has been adopted with a span of 70m and a height of 4m.
The thetraedric standard modular space frame is made by steel 510 (grade C) circular section tubes.

The transversal section of the main beam shows the chord tubes placed in an isosceles triangle of 7m wide and the vertex downward directed. Inside the section, an inspection catwalk is realized including the mechanical system and the zenithal illumination and TV devices.
The main central structure is supported, at the ends, on composite steel-reinforced concrete columns to be realized, with micropile foundations, inside the brickwork gable walls.
Under the two upper chords of the longitudinal beam, a set of transversally oriented cable-beam structures are suspended in correspondence of the joints of the space frame layout with a constant separation of 4m in plan view. The suspension device act as a pendulum, avoiding internal coactive state due to temperature variation and differential settlements; with such a device, the elastic correlation between main and secondary structures is also avoided.
The cable-armed secondary structure, have fixed end restrains in the peripheral part of the existing building corresponding to the column position of the grandstands.
The roof covering is designed to be partially convertible; movable panels will be realized by a sliding mechanism.
The fixed part will adopt structural glass and the mobile part will be realized with rigid panels of insulated metal sheets with an external layer of cooper plates.
The adopted driving mechanism is the wire traction method with a running unit made by a sliding shoe with inox steel plates and PTFE pads fixed with a prevention floating device.
The locking device in the open position will be realized by a lock pin connection.
The opening and closing operations will be monitored with an automatic control system.



(Fig.2 perspectives of the design: open-closed positions)



(Fig.2 plan view, side view and perspectives of the structural design)

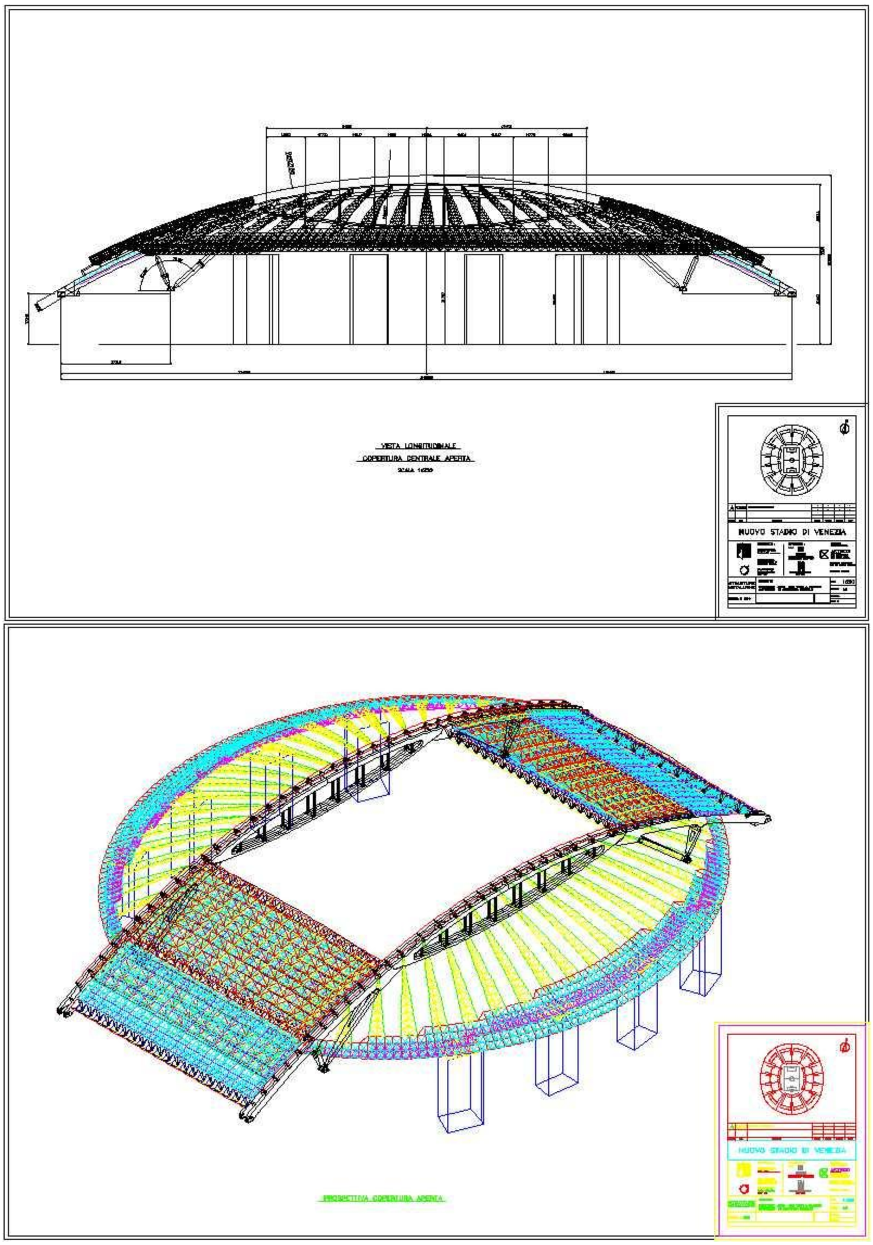
2 The Stadium Marco Polo – Venice

The new stadium of the city of Venice will be covered by a long span structural system with a mobile roof mainly formed by:

- two longitudinally oriented long span arches;
- two lateral shelters;
- a retractable central roof covering;
- a membrane roof covering.

2.1 The longitudinal pseudo-arches

The longitudinal oriented pseudo-arches, separate symmetrically by 90m, have a span of 245m and sag of 57m from the playground level. In reality, exists only the sensation of an arch structure based on the observation of the circular shaped upper chord; the actual mechanical behavior is that of two lateral framed structures and a central simple supported armed beam. In such a way was possible to minimize the structural costs of the main structure; reducing considerably the span and avoiding very expensive works to take the horizontal reaction forces generated by the arch response at a level of 18m above the playground (Fig.3).
The main frame is conceptually designed using steel material and boxed orthotropic cross-section shapes, internally stiffened by diaphragms and ribs.

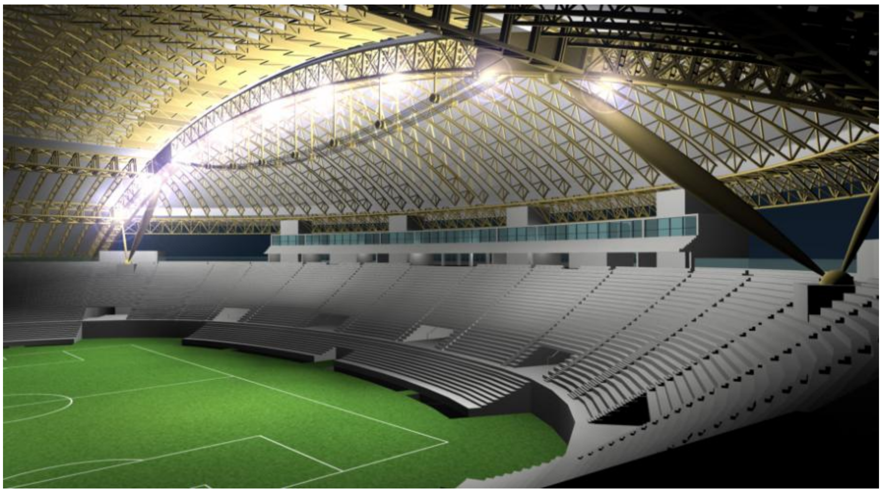


(Fig.3side view and perspective of the roof structural system)

2.2 The lateral shelters

The lateral roof coverings have a geometrical shape of a spherical sector and are made by a double layer space frame, generated by using meridian and parallel circles of the sphere as reference working lines.

The thickness of the double layer is of 2m, constant throughout the sector. The lateral shelters have also the task of stabilizing, out of plane, the main structure.
The shelters are supported: internally, above the upper chord of the main structure and, externally, on discrete points, corresponding to the reinforced concrete staircases.
According to the necessary distribution of the stiffness, the spherical shaped space frame must be more ‘’dense’’ in the external part, where it is necessary to span over 40m between two consecutive staircases. On the contrary, going to the center, the space frame modular frequency must be ‘’lightened’’, in order to minimize the transversal elastic correlation between main-frame and shelters.



(Fig.4-5 Rendering images of external and internal perspective views)

2.3 The retractable central roof

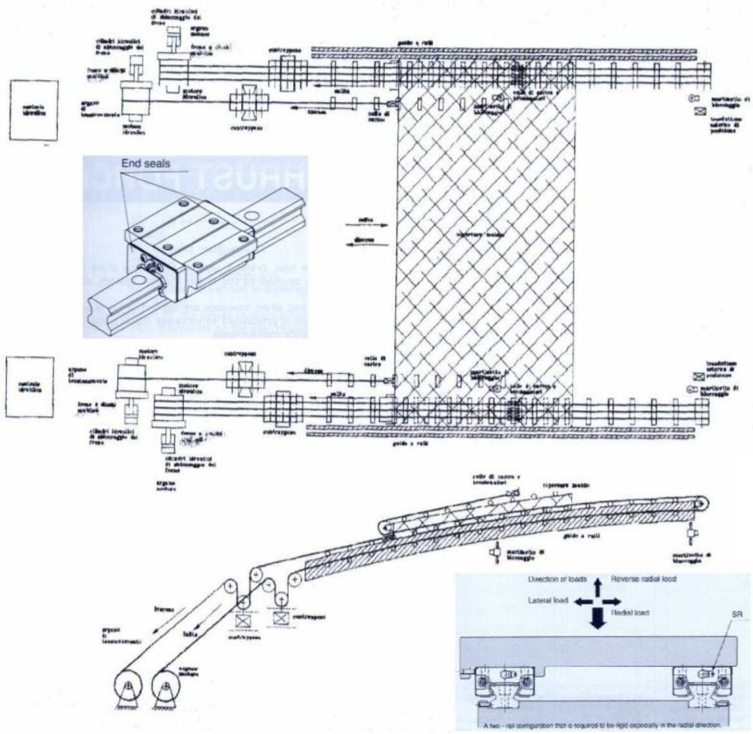
In the central part of the stadium, between the main frames, there are two fixed parts corresponding to the covering of the north and south grandstands. In the central part a retractable roof of 110x90m, made in two pieces, gives the possibility to open and close the playground.The structural typology adopted for the central roofing of the stadium is always a double layer space frame made of circular section tubes.

The mobile sectors have a cylindrical shape with a surface dimension of 55x90m.

The sliding motion system of the retractable roof is obtained using the following constitutive elements of the adopted cable traction method driving mechanism:

- four traction systems (one for every half-side of the mobile roof sector) formed by ropes, pulleys, sliding linear motion guides and tensioning devices;
- eight motors driven winding-drum to which the tensioning cables are wound. Every winding-drum is made by an hydraulic motor and an hydraulic brake system;
- four hydraulic cells giving the oil pressure to the hydraulic system;
- eight pin locking devices positioned on the top of the running guides;
- electronic sensors for the control of the system functioning;
- control commands and blocking devices.

The figure 6-7 shows, schematically, the motion system.



(Fig.6-7 Motion system)

2.4 The membrane roof covering

The roof covering of the fixed parts of the stadium is realized by steel microhole prepainted metal sheet with an external prestressed membrane of reinforced polyester fiber, coated by PVDF.
Only a simple layer of a prestressed doubly curved membrane of translucent material will cover the central mobile part of the roof.

3 Aknowledgements

The architectural design of the stadium has been elaborated by Studio Arteco of Verona and the Building contractor is Impresa Mazzi S.p.A. for the owner Marco Polo S.p.A.
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