TEMA

Technologies
Engineering
Materials
Architecture

Journal Director: R. Gulli

e-ISSN 2421-4574

Vol. 6, No. 2 (2020)

Issue edited by Editor in Chief: R. Gulli

Cover illustration: The west grandstand of the Flaminio Stadium in Rome, by P.L. and A. Nervi.

Editorial Assistants: C. Mazzoli, D. Prati

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e-ISSN 2421-4574
Vol. 6, No. 2 (2020)
Year 2020 (Issues per year: 2)

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TEMA: Technologies Engineering Materials Architecture
Vol. 6, No. 2 (2020)
e-ISSN 2421-4574

THE USE OF “STRUCTURAL PREFABRICATION” IN THE FLAMINIO STADIUM BY PIER LUIGI AND ANTONIO NERVI. A TECHNICAL-CONSTRUCTIVE STUDY AIMED AT FORMULATING GUIDELINES FOR A FUTURE CONSERVATION PLAN

TEMA Technologies Engineering Materials Architecture
e-ISSN 2421-4574
Vol. 6, No. 2 - (2020)

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DOI: 10.30682/tema0602b

Highlights

The recovery and conservation of buildings of the 20th century have highlighted the necessity to adopt different methodologies, techniques, and tools from those applied in traditional restoration.
The guidelines, which serve as a basis for future conservation work on the Flaminio Stadium (built in Rome for the XVII Olympics in 1960 and now protected as a cultural asset), stem from a methodology based on a precise reconstruction of the various phases of the project, including its construction, as well as a critical analysis of the original and current physical elements of the Stadium.

Abstract

The paper highlights the specificity and originality of the solutions adopted by Nervi in the construction of the Flaminio Stadium (Pier Luigi and Antonio Nervi, 1957-59), as well as his talent as a designer and engineer. The text presents both a summary of the research carried out on the terracing and the canopy of the Stadium (built using “structural prefabrication”) and draws attention to the research methodology, of which this study is a part. The research was funded by the Getty Foundation with the aim of formulating guidelines for the future conservation project of the Stadium.

Keywords

Pier Luigi Nervi, Flaminio Stadium, Structural prefabrication, XX Century, Rome.

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1. INTRODUCTION

The recovery and conservation of 20th century buildings have highlighted the necessity to adopt different methodologies, techniques, and tools from those applied in traditional restoration. More precisely, these differences encompass working procedures beginning from cognitive analysis through to intervention.

The methodology followed in traditional restoration is analytical when assessing the state of deterioration and the work to be carried out, deductive when defining the technical choices and methods of intervention, and repetitive when applying consolidated practices. This methodology does not apply to 20th century architecture because each work is unique, especially the technological and construction aspects that are often closely connected to the building’s architectural significance. While restoration work has to be considered part of the building’s life span and therefore requires a philological-conservative approach, for the works of the 20th century it is necessary to carry out meticulous, accurate and sophisticated cognitive investigations. Furthermore, the restoration must be invisible, even when it involves the development of new construction solutions to resolve existing technical deficiencies.

This methodology was used as the basis for our research for the guidelines "Developing a conservation management plan for the Flaminio Stadium by Pier Luigi and Antonio Nervi in Rome, Italy: an interdisciplinary approach", which was selected in 2017 by the Getty Foundation in Los Angeles as part of the program 'Keeping it Modern'. The research − promoted by the Dipartimento di Ingegneria Strutturale e Geotecnica of the Sapienza University (Rome), the Pier Luigi Nervi Project Association, and Do.Co.Mo.Mo. Italy, in agreement with the Municipality of Rome − enabled us to further our knowledge of the Stadium. A fact-finding study focusing on the noteworthy parts of the Stadium, together with an analysis of the historical documentation in the CONI Archive (Rome), the CSAC Centro Studi e Archivio della Comunicazione (Parma) and the MAXXI Centro Archivi di Architettura (Rome), produced the research results which lead to the development of the guidelines for the conservation project.

To illustrate the methodology used in the research, we have provided a brief account of the study of the characteristics and construction of the terraces and the canopy. The results of this study have both a knowledge value which furthers our understanding of a historical event in Italian engineering and a operational spin-off which is not merely descriptive in nature. In this way, when the interpretation of the work is able to grasp the unique characteristics and, above all, can focus on the specific way in which the construction took shape − thus defining the architectural expression − the method of conservation can be adapted to the level of transformation which is compatible with the preservation of architectural values.

Fig. 1. *The Flaminio Stadium.*

2. THE CONSTRUCTION OF TERRACES

The Flaminio Stadium was designed and built by Pier Luigi and Antonio Nervi (1957-59) for the XXVII Olympics in Rome (Fig. 1 and Fig. 2). On April 4 1957, the examining commission for the tender competition (that had been announced by the National Olympic Committee (CONI) in July 1956) awarded the contract to the firm Nervi & Bartoli. Five other companies had participated, with projects submitted by architects specialized in sports buildings design such as: Cesare Ligini and Dagoberto Ortensi, Sergio Bonamico, Enrico Mandolesi, Pio Montesi, Enrico Lenti. Nervi's proposal won because it was functionally efficient, aesthetically acceptable, and was the most economical: only 810,000,000 lire. Work began on July 1 1957 and was completed within 18 months. On the morning of March 18 1959, the Flaminio Stadium was inaugurated by Prime Minister Antonio Segni.

The form and architectural structure of the Flaminio Stadium resulted from Nervi's inspirational invention of a construction system for the stands that was as effective as it was simple. This system of "structural prefabrication" was a process that Nervi used repeatedly, and "consisted of building a resilient complex by linking together prefabricated elements and making them statically binding". As these words suggest the structure, although made up of assembled parts, should not betray the monolithic nature of the organism which for Nervi was "the most characteristic property of reinforced concrete structures […] and was also the one from which its most brilliant and specific static solutions were born" [1]. Nervi realized most of his domes with structural prefabrication: breaking down the surface into small pieces to be built on-site and reassembled to form a single solid structure.

Fig. 2. *The west grandstand.*

The structural prefabrication not only allowed Nervi to realize complex or otherwise unachievable structures, but it also enabled him to reduce construction time and costs by creating finished products that did not require further cladding. In fact, the burden of the formwork was practically eliminated because a substantial part of the structure was constructed from a limited number of molds that could be reused many times.

Structural prefabrication, however, demanded a project construction site that was “more difficult and delicate […] with very few established points of a general or theoretical nature”. It “must fundamentally be based on experience, on similarities, and above all on a *practical imagination* that includes all the phases of processing, transport, and assembly so that each can be defined with sufficient accuracy” [2].

In the case of the Stadium, structural prefabrication also served to rationalize the site and solve problems that would not have otherwise been possible using traditional methods. The construction planning − which Nervi had tested and used in other projects − was essentially a series of 92 reinforced concrete supporting frames, cast on site, with a “covering” (in this case the cavea of the Stadium) made of prefabricated elements, from which the terraces and the canopy were made.

When preparing the competition project, Nervi came up with a basic-element from which the entire *cavea* could be constructed: a hollow step with a rectangular trapezoid section. Each face of the step had a specific function: the vertical faces were the supporting beams; the horizontal face, the seating; the slanting face, the component which collected rainwater. Nervi patented this system even before completing the competition project [3] (Fig. 3).

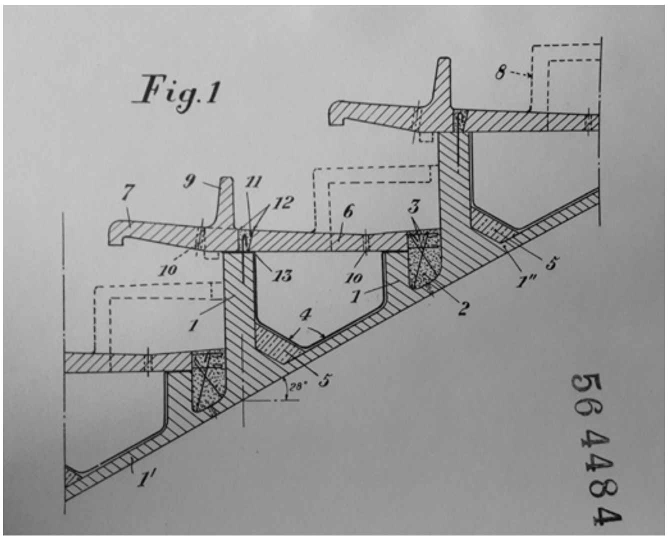

Fig. 3. *P.L. Nervi, Patent n. 564484, January 12 1957.*

Nervi identified three principal problems concerning the construction of the terraces. The first was the waterproofing. If the grandstands were made of load-bearing reinforced concrete steps, “it becomes very difficult to cover the water-repellent layer above with cement-based plasters, because it would be impossible to make them adhere effectively […] to the supporting structure”. The problems persisted even when the steps were built on an inclined slab because the waterproofing layer covering the slab “could lead to slippages of the steps on the underlying support structure”. Then there was the problem of the rainwater, which could not be allowed to run down the terraces. The final concern was the visibility of the playing field: to make it optimal, it was necessary to increase the slope of the steps gradually. This could be achieved by maintaining a constant lift and increasing the tread as it approached the playing field, but this would have reduced the capacity. Alternatively, it could be realized by keeping the tread constant and progressively increasing the lift as it moved away from the playing field, but this would have increased the height of the seat, which, “for the comfort of the spectator”, should remain constant.

To resolve these problems, Nervi’s patent proposed a step made of two prefabricated components. One had a U section which rested on the supporting frames of the stands, and “had a static function of collecting and conveying water”. The other, covered and supported by the first, “constituted the tread and the seat”. The U-shaped elements − once bonded both reciprocally and with the supporting frames (through small concrete casting that incorporated the protruding bars) − were waterproofed to the extrados before mounting the tread seat. In this way, the first problem was solved, and the rainwater runoff down the terraces was also avoided (as the water that collected on the tread was removed through a hole that delivered it to the U-shaped element). From there, it was conveyed to a second hole that disposed of it in a sheet metal tube, visible at the intrados of the terraces. Finally, Nervi achieved a constant seat height by simply using a seat protruding from the step. In this way, it uncoupled its height from the position of the tread.

Nervi knew that for the solution to be economically viable it had to be restricted to a limited number of typical-elements which could be repeated many times and the enveloping shape of a Stadium *cavea* did not guarantee that the selection of the pieces would be limited. It is, therefore, reasonable to think that Nervi initially focused on the geometry of the stands in order to make it as compatible as possible with the steps of his invention. In fact, the cavea, symmetrical with respect to the east-west axis, had an elementary geometry: four planes, inclined towards the sides of the playing field, and four cone-shaped connecting surfaces, at the corners. There was, however, an unavoidable geometric complication. The terrace planes had different extensions; hence their upper sides were at different heights, which meant the cone quarters did not align with the circular arc. Nervi, therefore, chose an easily traceable crooked line: which was the intersecting line of the conical and cylindrical areas that had a vertical axis not coinciding with the cone axis. The result was a toping line that appeared to be continuous, flowing, and harmonious. From the outside, it made the Stadium look “less bulky”, and from the inside, it removed “the viewer from the feeling of being in a closed environment” [4] (Fig. 4).

Despite the simplification of the geometry of the whole, the typical-elements of the steps were numerous. There were straight pieces used for the seating area of the east and west grandstands, the standing area and the parterre of the north and south grandstands, and the seating area of the west parterre (Fig. 5).

In addition, there were the curved pieces of the corner terraces, which had different lengths and curvatures. Above all, there were many special pieces, both curved and straight, such as those near the upper edge of the conical areas intersecting the crooked top beam, which were triangular or trapezoidal; those in the vicinity of the *vomitoria*, to the ascending and descending stairs, to the expansion joints, to the curved perimeter of the north and south parterres, and the areas reserved for the journalists and authorities. In addition, almost all the types were tripled because the inclination of the terraces (both flat and conical) was not constant but passed from 28 to 30 to 32° to allow for perfect visibility of the playing field.

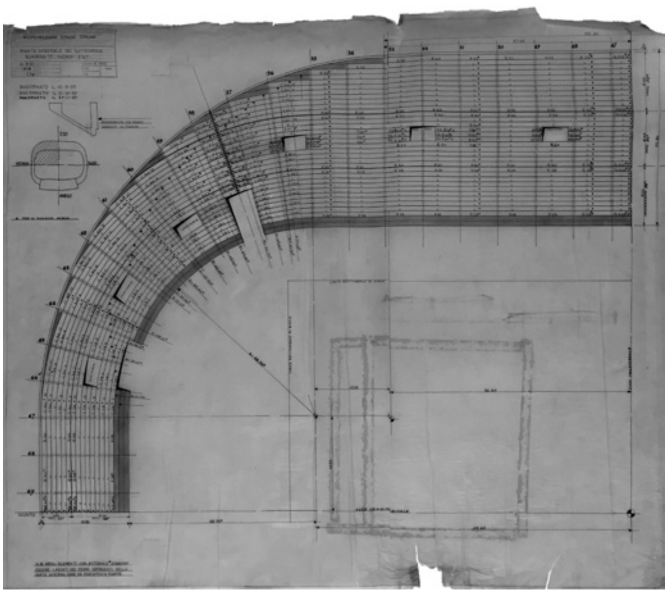

Fig. 4. *Northeast quadrant of the Stadium.*

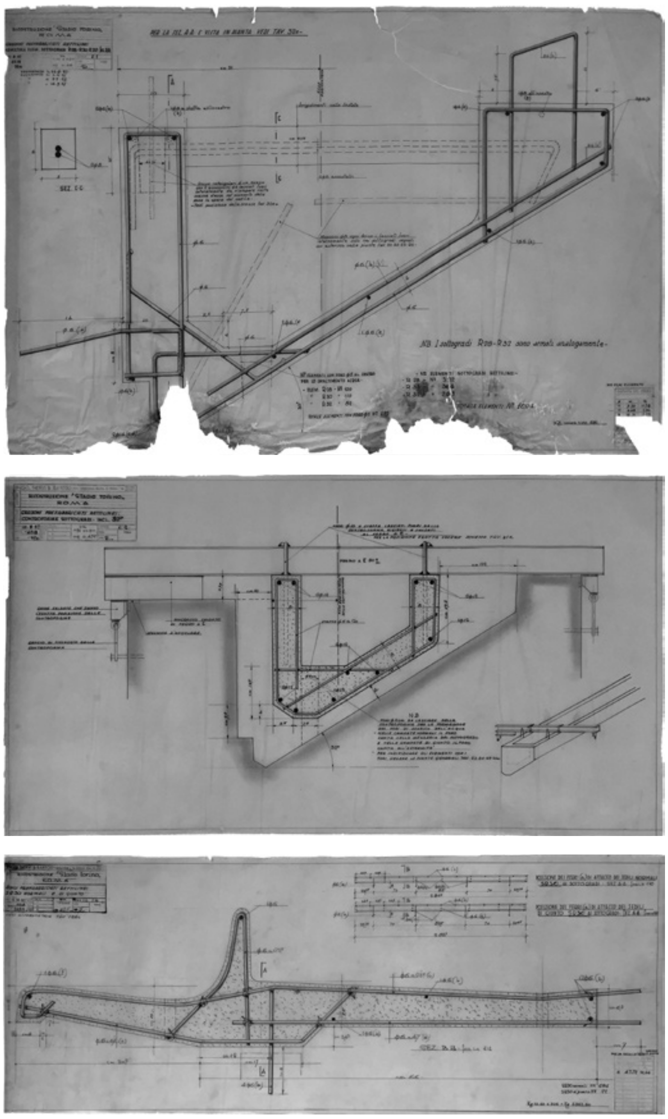

Fig. 5. *The prefabricated steps: U-shaped reinforcement element; fixed and counter-mold for U-shaped element; straight seat element.*

Aware of how delicate and difficult the process was, Nervi, even before working on the planning and structural design of the supporting structures (foundations and frames), was keen to plan and start the prefabrication site of the steps immediately.

When making the risers (finished on both sides), he used a fixed mold (the "*forma a terra*") to shape the intrados, and a removable concrete counter-mold to shape the extrados (Fig. 5). On the construction site, molds and counter-molds of different shapes and sizes were available: their number was calculated in relation to the elements to be made for each type. There was an identical assortment regarding the tread elements, which were both seats with a small backrest (Fig. 5) and stepped components for the standing room.

To give an idea of the variety, it suffices to say that the rectilinear risers, the simplest ones, not only belonged to three different families according to the inclination of the stands, but they also had to be supplied in different lengths − 536 centimeters or 2/3, 1/2, 1/3, 1/6 of this measure − depending on whether they were the base-pieces or the special pieces in proximity to the *vomitoria*, the ascending and descending steps, the expansion joints. There were also secondary variants for each type which dealt with the water-draining outlets, the closure or otherwise of the heads of the risers, and the different reinforcement and positioning of the protruding bars. Finally, further differences were envisaged when the elements, instead of being supported, were cantilevered, such as those on the sides of the vomitoria and the expansion joints − because in this way the tubes became disposable formworks for suture castings, with which real reinforced concrete beams were made. Despite these complications, the prefabrication site managed to produce an average of 35 elements a day, for a total of 7652 pieces (Fig. 6).

Fig. 6. *The construction site: on the ground the prefabricated elements of the steps.*

3. THE CANOPY

The prefabrication of the canopy elements presented fewer problems as there were only 88 pieces, and the typical-elements were only two: rectangular, 14.30 meters long, 1.425 meters wide (4 per span) and 1.2 meters high at the joint; and a piece of the same length, but with a plan in the form of a sector of an annulus, to cover the curved end parts of the west grandstand. Once assembled, their V-section produced an elegant pleated surface perforated with numerous, small circular apertures. The two faces of each component, delimited above and below by ribs, were not flat surfaces but hyperbolic paraboloid ones. Two transverse stiffening joists joined the upper ribs, preventing deformation of the components (Fig. 7).

The canopy as a whole was made up of two parts: the portion formed by the prefabricated components and a rear concrete platform resting on the extensions of the corbels of the supporting frames, and in front, on twenty-two slender struts of steel tube filled with concrete.

In the competition project, the canopy was resting on tubular steel uprights, but the covering elements had a tube section, very similar to those of the canopy of the semi-circular pavilion of the Fiera di Milano (1952). The tubes, envisaged in *ferrocemento*, were five per span and 14.6 meters long closed at the top by thin hollow brick and concrete casting. The whole had a height varying from 45 (at the free end) and 110 centimeters (at the embedded end). The wavefront was hidden by a tall front-band. The rear platform, cast on-site, was made up of a 5 centimeters slab and a ribbed extrados: in this way, a closed box section with a height varying between 90 and 110 centimeters was realized.

The shape of the canopy in the final design remained substantially unchanged, but the shapes of the prefabricated components became V-shaped and were made in that form.

The procedure for the construction of the canopy components was different from that of the terraces; they were, in fact, of *ferrocemento*. A steel grid of small-diameter bars was used to support three to four layers of thin steel mesh, on which the cement mortar was smoothed with a trowel, creating layers only 3 centimeters thick and ribs of 10-15 centimeters on the side.

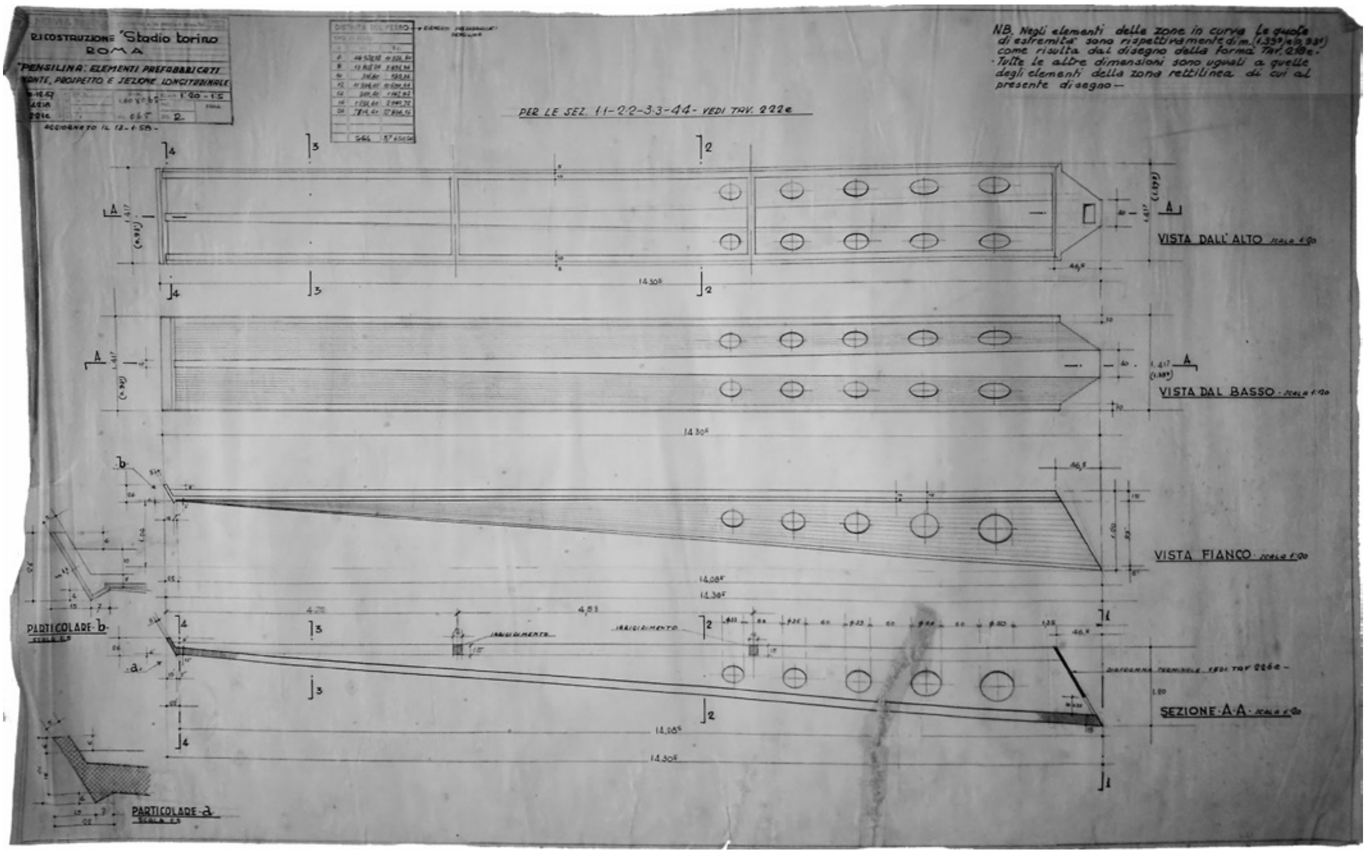

Fig. 7. Ferrocemento *element*.

In May 1958, Nervi developed an apparently slightly different solution in which the static structure of the roof was more clearly expressed. It entrusted the traction induced by the inclined strut to a reinforced concrete tie-beam, separated from the roof, which behaved like a simple resting structure (Fig. 8). It was a brilliant solution that was reproduced in the Swindon Stadium project (1963-66).

4. "COSTRUIRE CORRETTAMENTE"

The site set up by Nervi for the construction of the load-bearing structures used a hybrid construction process that saw the coexistence of structural components made on site of prefabricated elements, and of finishing parts (made in situ) for the margin of the *cavea* (crowning of the stand, lower ring, border of the *vomitoria*). The immediate goals, unavoidable for a construction company such as Nervi & Bartoli, were certainly those of reducing construction cost and time. However, in the case of Nervi, these aims were not separated from the need to obtain a convincing formal result. Indeed, for Nervi, the correctness of the formal outcome was somehow guaranteed by the effectiveness of the construction process itself. This was also the case of the Stadium, where there was an inseparable bond between technical invention, construction method, and the formal result.

Fig. 8. *The west grandstand.*

The pre-eminence that Nervi gave to the structural fabric over the rest of the construction is demonstrated by the fact that no element of the supporting structure was kept hidden, even in circumstances when revealing its presence did not seem significant. Furthermore, Nervi proposed to sandblast the concrete of the frames to enhance the surface texture, a treatment he had recently used for the UNESCO site in Paris (designed by Marcel Breuer and Bernard Zehrfuss). Nervi advised CONI: "the purpose of blasting was not to clean the surfaces of the reinforced concrete […] but to highlight the formwork design by removing the grout veil on the treated surfaces that made them uniform. In fact, all the exposed reinforced concrete works carried out before sandblasting was adopted, having remained rough as after disarming and without any treatment, have clean but less lively surfaces than those sandblasted at the Flaminio Stadium" [5].

The areas under the stands (dressing rooms, swimming pool, and gyms) followed the geometry of the cavea, developing in a continuous ring that occupied a strip of the covered area. Purposely, therefore, the geometry of the spaces did not come into conflict with the geometry of the structure. Even the walls were subtle, almost neutral, spreading out in single surfaces, which unequivocally showed their secondary role as infill for the spaces between the frames. The same can be said of the windows that, in the form of large windows or strips, always developed from one frame to another (Fig. 9). This planning can also be seen in the details (always very simple, apart from some elements such as the steel staircase of the swimming pool) and fell within the established construction tradition of those years, which drew on repetitive solutions with a limited number of variants.

The Flaminio Stadium is an example of the "*costruire correttamente*" pursued by Nervi, that identified a static-construction system, which then became the heart of the project. This way of working led to an "essential" architecture which is apparent in most of Nervi's work, and bases its value on the economy of forms and, when necessary, the materials that show with truthfulness and sincerity the way it was built, which is the case of the Stadium.

Ultimately, one could describe the Flaminio Stadium in the terms Nervi used to describe the requirements that an architectural work must possess: "it must be a stable, unified, resistant organism, in accordance with its environment and with the functions that it must perform, balanced in all its parts, clear in its support structures and its technical elements, and at the same time capable of giving that indefinable emotion that we call 'beauty'" [6].

5. CONCLUSIONS

The structural prefabrication site that Nervi set up for the Flaminio Stadium was not dissimilar to those used in other projects. Only an experienced and well-tested firm like Nervi & Bartoli could have undertaken such an enterprise that was not – at least for the variety of prefabricated pieces to be prepared – comparable to others. It was essential that the firm, in order not to risk increasing the cost and lengthening the construction time (already limited), carefully planned out the form and specific components of the

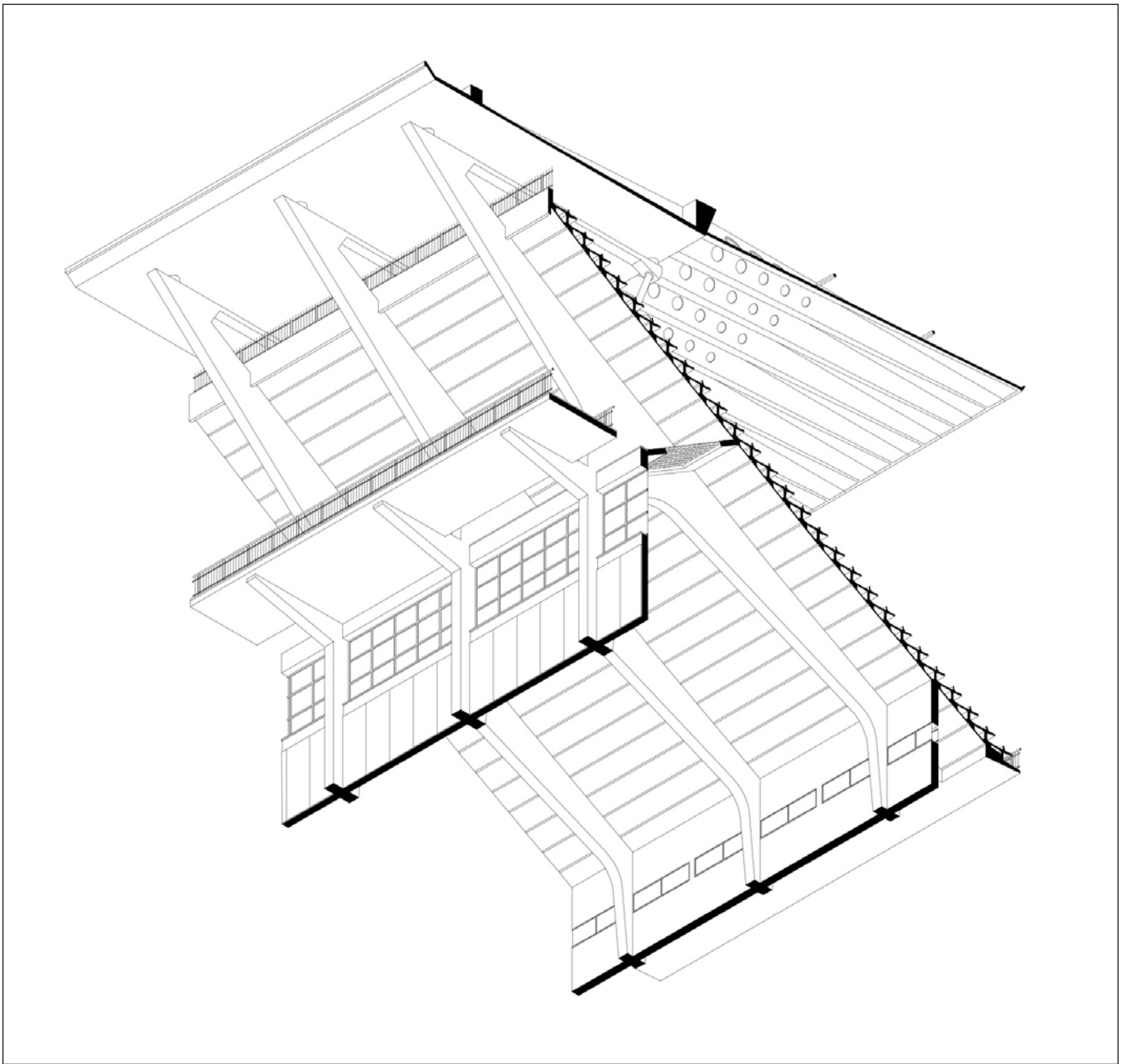

Fig. 9. *Guidelines: axonometric view of west grandstand (authors' drawing).*

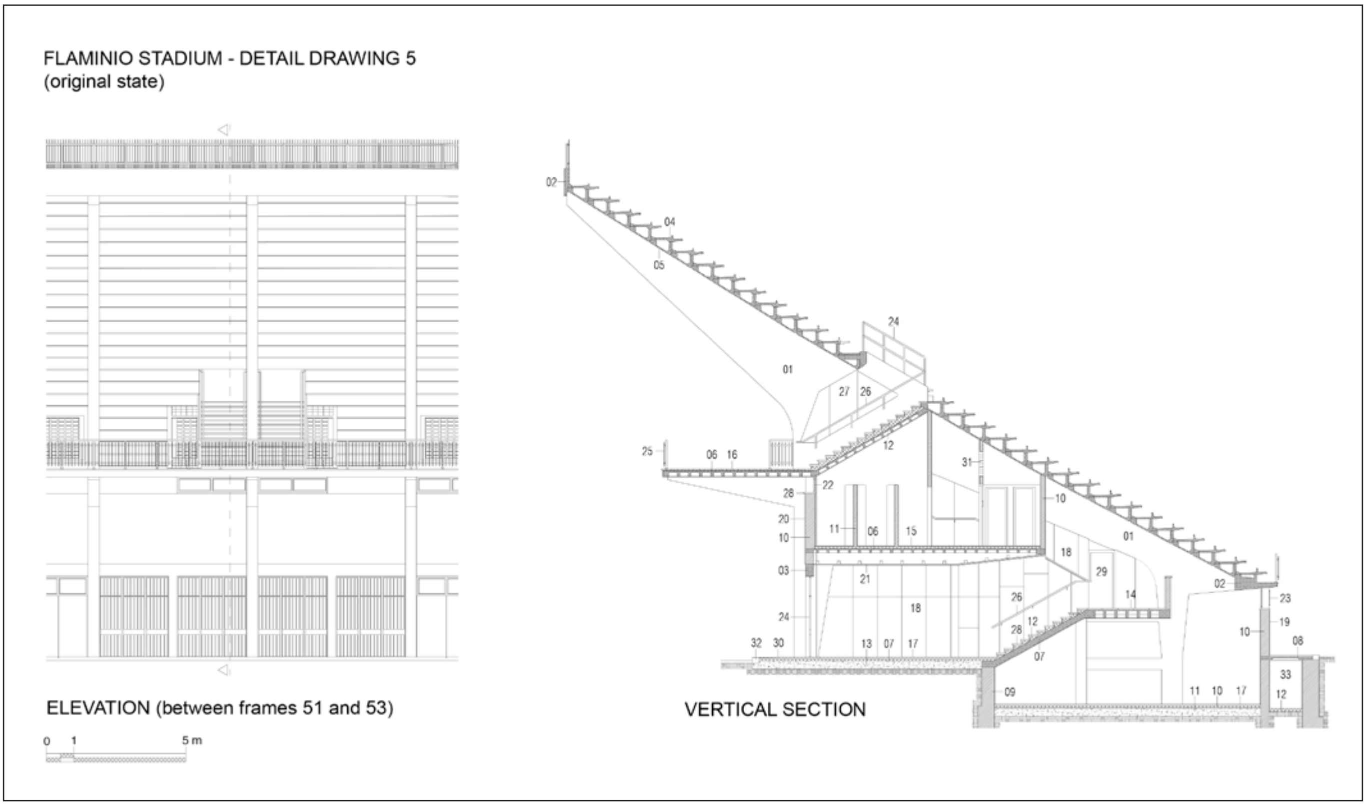

Fig. 10. *Guidelines: detail of the original state between frames 51 and 53 (authors' drawing, with D. Chiarello and T. Valentini): 01. Exposed concrete frame - 02. Exposed concrete edge beam - 03. Exposed concrete beam - 04. Precast concrete seat - 05. Precast concrete riser - 06. Hollow brick and concrete floor - 07. Concrete floor - 08. Low hollow brick and concrete floor - 09. Tuff stone wall - 10. Brick wall - 11. Perforated brick wall - 12. Concrete layer - 13. Drainage layer - 14. Travertine slab floor - 15. Gres tiles floor - 16. Concrete tile floor - 17. Rubber floor - 18. Rough travertine slab cladding - 19. Small travertine plank cladding - 20. Plaster - 21. Suspended ceiling - 22. Window with 'ferrofinestra' frame - 23. Steel mesh grate - 24. Steel gate - 25. Steel railing - 26. Steel handrail - 27. Safety glass plate - 28. Travertine slab - 29. Plywood door - 30. Asphalt layer - 31. Perforated brick screen - 32. Travertine edge - 33. Interspace.*

building to be used together with a thorough study of both the manufacturing methods and the assembly of the parts. Only Pier Luigi Nervi could have taken on and managed such a demanding undertaking.

Today the Stadium is abandoned, and its future is uncertain. The reconstruction of the phases of the project, which include: the construction site, the analysis of the original physical structure of the Stadium (for example, those relating to the terraces and the canopy), and the analysis of the subsequent additions are indispensable steps in formulating the conservation plan. This is the objective of the research project within which our study is placed.

In the guidelines, the analysis and project planning documents relating to the individual building parts are flanked by drawings of the "parts", necessary to clearly describe the architectural and construction specifics of the Stadium (Fig. 12). These two documents are both a concise tool for making the defining elements of the Stadium better known and an operational tool for the implementation of the conservation project.

In particular, the study recognizes the grandstands as a unitary body which despite their present "fragility" must be preserved, not only in appearance but also in their original form, as an authentic testimony of the specifically devised and unique construction system. Consequently, the guidelines for the supporting structures provide not only for the restoration of the Stadium's original features, eliminating the additions and all the subsequent cladding, but also for the philological restoration of the prefabricated elements (still largely present), and the integration of those that are missing or severely deteriorated. This "fundamentalist" position did not, however, prevent us from recommending a preliminary solution for one of the most severe construction problems − that of the rainwater collection and disposal − which allowed for effective, reversible, supplementary or replacement technical solutions (if more effective) than those identified by Nervi.

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