Fit Structures. The Representation of Bridge and Viaduct Design in the Work of Silvano Zorzi

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Abstract

This paper presents the results of an investigation into the use of graphic representation in the design of bridges and viaducts within the work of Silvano Zorzi, a central figure of the twentieth-century Italian School of Structural Engineering. The study was carried out within the framework of the SIXXI research project – XX Century Structural Engineering: the Italian Contribution *(ERC Advanced Grant, PIs: Sergio Poretti, Tullia Iori).*
Its aim is to highlight the role of drawing as a means of making visible the internal logic of the designed structure and, in particular, the coherence between form, structural behaviour, and construction process. The analysis is based not only on the available literature but, above all, on documentation preserved in the Zorzi Archive at the Politecnico di Milano and in numerous other archives belonging to clients and construction firms. Through these materials, the essay investigates how Zorzi, as a structural designer, employed representation –from the preliminary sketch to the executive detail– not only as a critical tool for control, used to describe and validate technical solutions, but also as a means of expressing the logic, at once rational and aesthetic, that governs structural form.

Keywords: history of structural engineering, infrastructure, viaducts, building sites, reinforced concrete.

Introduction and state of the art

Silvano Zorzi (Padua 1921 - Milan 1994) is one of the foremost masters of the Italian School of Structural Engineering. Within its history –reconstructed as part of the *SIXXI* research project [1]– he stands out for his identity as an engineer-designer, one who conceives and draws structures, particularly bridges, with essential lines: works designed at the scale of the landscape and harmoniously integrated into their environment. To achieve the extraordinary formal quality of his works, he exploited the full potential of construction materials, dedicating himself from the outset to reinforced concrete, and, in particular, to its prestressed version. In this way, he created elegant structures with slender profiles that span rivers and roads with spans seemingly incompatible with the dimensions of their piers and decks [2].
This paper proposes an enquiry into the use of graphic representation in relation to some of his most significant works, based on largely unpublished graphic and photographic material preserved in the Zorzi Archive at the Politecnico di Milano, and in numerous other archives of clients and construction firms, as well as on the existing bibliography concerning the engineer's work. The analysis developed in this article is limited to the design of bridges and viaducts, which represent the most significant part of Zorzi's professional activity [Zorzi 1981; Iori, Capurso 2019] and focuses on the connection between graphic representation, static conception,

and construction logic. The latter aspect, in particular, has not been specifically examined in the scientific literature. In the executive drawings, one can thus see the evolution of Zorzi's approach to infrastructure design over the various phases of his long career, highlighting the role of graphic representation as a means of making visible the design logic of the structure, and particularly the coherence between form, structural behaviour, and construction process.

Design and construction

For the protagonists of the Italian School of Structural Engineering, drawing played a role intimately connected with construction and with their inventions. Pier Luigi Nervi (1891-1979) used it not so much to represent the final result as to explain to the workers of his company, Ingg. Nervi e Bartoli, how to produce in practice the thousands of small elements of his original construction system, based on structural prefabrication and ferrocement, with which he assembled the magnificent domes that made him famous throughout the world. The drawings of Riccardo Morandi (1902-1989) went into such detail on the positioning and locking of prestressing cables, with loops and sinuous curves, that one could almost perceive their tension already on paper, as later in his distinctive cable-stayed frames. Sergio Musmeci (1926-1981), for his part, found it difficult to represent in plan, elevation and section his 'formless forms', which rejected known typologies and were born first as soap bubbles, then as physical models, and only in the end were transposed onto the drawing sheet.
And in Zorzi's case?
In what way did the control and verification of structural form afforded by graphic representation enable his practice, and later his company In.Co. - Ingegneri Consulenti, to ensure the high technical and formal quality of his works?
In 1983, the journal *Casabella* published an article written by Zorzi himself on the elevated road for the state highway Pontebbana, introduced by a commentary by Giacomo Polin (1956) [Zorzi 1983]. To accompany his presentation effectively, Zorzi included five cross-sections of bridges (fig. 1) –simple, schematic sketches– illustrating the direction of his formal and technological research in viaduct design: from the most conventional prefabricated beams on massive, constant-section piers, through increasingly light and essential solutions, to the minimal monolithic plate, with a section smoothly merging into the pier, the very solution chosen for the Pontebbana viaduct. However, it is not the sketches that dominate this unusual article in a learned architectural journal, but the technical drawings: road layouts, profiles and gradients, construction sections comparing the ordinary solutions forming the basis of the tender with those later designed and realised by Zorzi, and above all, construction schemes illustrating ingenious site procedures made possible by the use of innovative equipment. Alongside fine photographs of the site and the completed work, these drawings fill the pages, bearing witness to both the contemporary architectural culture's interest in structural conception and the intimate connection between graphic representation and construction in Zorzi's practice.
Thus, by analysing not so much the conceptual sketches as the working drawings developed by his highly skilled partners –from Giorgio Macchi (1930-2023) to Sabatino Procaccia, Lucio Lonardo and Aldo Muller– who co-signed numerous projects with Zorzi and accompanied his name in presentations published in specialist journals, it becomes clear that Zorzi's graphic production must be considered inseparable from that produced by his studio and, later, by In.Co.

Bridges in the landscape

Forced to abandon his studies during the Second World War, Zorzi took refuge in Switzerland, where he became a pupil of Gustavo Colonnetti (1886-1968) and later graduated at the end of the conflict. He was thirty-five when, together with the construction firm Rizzani, he won the design-and-build competition for the first major bridge of the Autostrada del Sole – the structure crossing the river Po at Piacenza, in the locality of Mortizza (fig. 2). Completed in March 1959, the bridge is a simple structure: sixteen reinforced-concrete beams, each with a span of seventy-five metres, prestressed using the BBRV system imported from Switzerland, simply resting on the piers.
The construction drawings describe in meticulous detail the geometry of the piers and beams and the arrangement of the prestressing cables, but the dossier also includes an overall perspective view of the bridge, certainly prepared by a studio collaborator. These graphic studies allow verification of the visual relationship between the structural parts –piers and girders– and of the overall effect produced by the succession of equal spans, while the riverbank vegetation in the background is only lightly suggested.

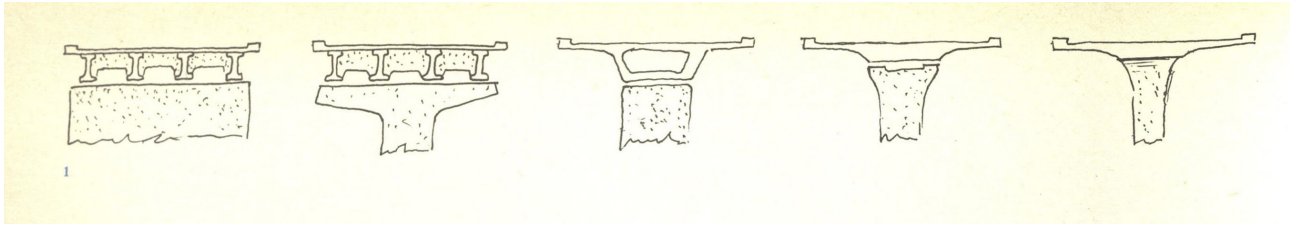

Fig. 1. Schemes of cross-sections for viaducts (Historical Archive of the Politecnico di Milano, Silvano Zorzi Collection, Milan).

Fig. 2. Bridge over the river Po, working drawings. Perspective view (ANAS Historical Archive, Cesano).

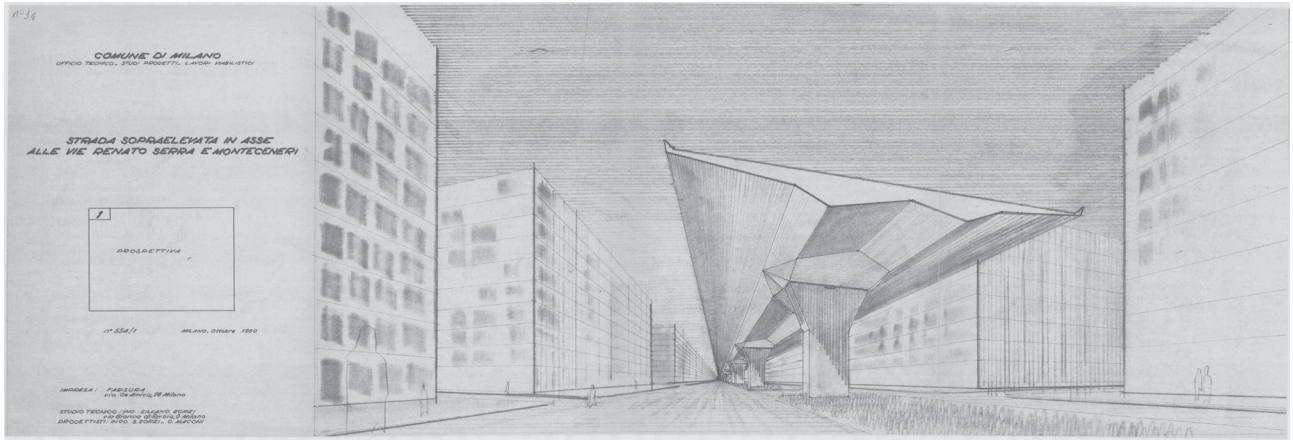

Fig. 3. Elevated road along viale Renato Serra and viale Monte Ceneri, working drawings. Perspective view (Municipal Archive of Milan, Technical Infrastructure Department, Milan).

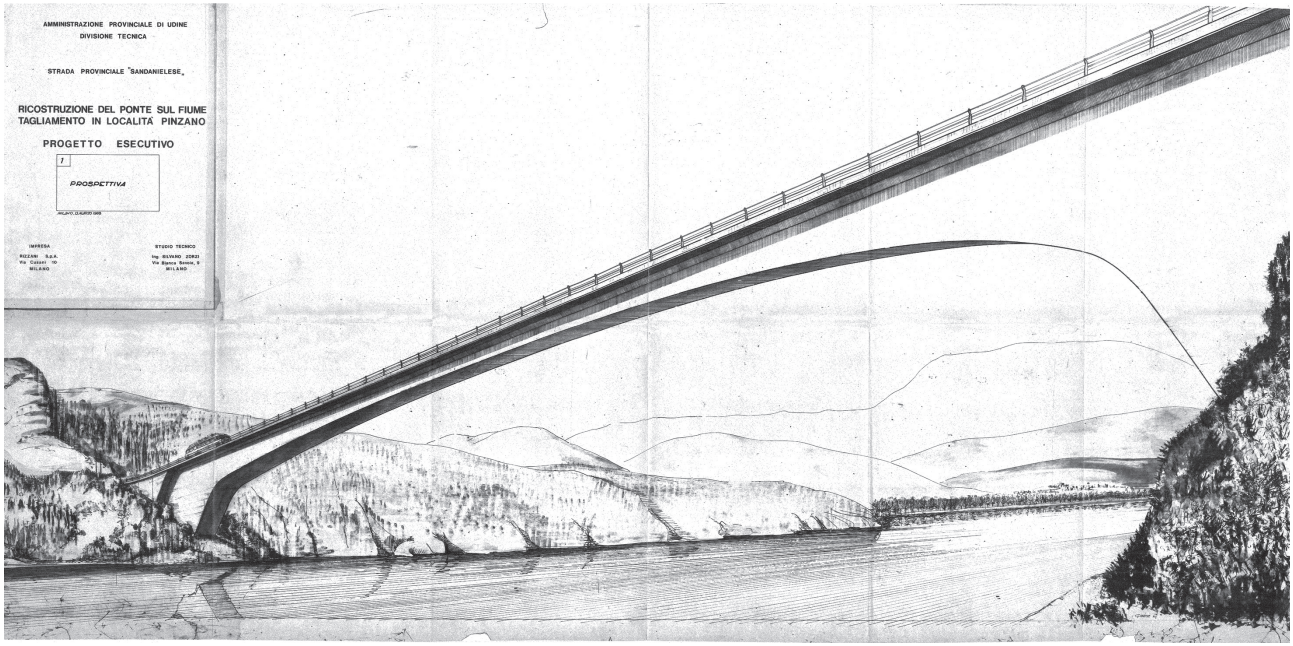

Fig. 4. Bridge over the river Tagliamento at Pinzano, working drawings. Perspective view (In.Co. S.p.A. Historical Archive, Rome).

The frequent use of perspective views, perhaps required by contracting authorities for project assessment, also reveals Zorzi's attention to verifying the soundness of his formal solutions. Perspectives were therefore prepared by the Studio and later by In.Co. for public selection procedures; they often depict low-angle or lateral viewpoints, foreshortened and close-up. The perspective accompanying the executive drawings of the elevated roadway in Milan between viale Renato Serra and viale Monte Ceneri (1960) emphasises the articulated composition of the surfaces of the pier and of the underside of the deck (fig. 3) and introduces a refined plan view showing the arrangement of the timber formwork boards, whose imprint would economically be left visible. This work was conceived not only to carry vehicular traffic along its deck but also to be viewed from below, at pedestrian level. The perspective that opens the executive dossier for the bridge over the Tagliamento at Pinzano (1968-1969), updating the version presented for the design competition, analyses the perception of an observer standing on one bank of the river and highlights the elegance of the portal-arch line (fig. 4).

A perspective view at the opening of the dossier was also chosen to illustrate the visionary project for the bridge of Guayllabamba (1968), prepared for submission to the competition called by the Ministry of Public Works of Ecuador for the *Carretera Panamericana Quito-Tulcán*, and developed in collaboration with Lonardo (fig. 5). The bridge was conceived as a stretched ribbon of prestressed reinforced concrete, only thirty centimetres thick, suspended between the two banks, three hundred metres apart, shaped to the geometry of a catenary with a small sag. Its behaviour was then described in the other drawings –plan, elevation, and section– included in the competition dossier. According to these graphical studies, which represent with convincing realism a structure probably impossible to build, the deck, formed by sheathed cables subsequently grouted to constitute both reinforcement and prestressing tendons, was to be completed in segments, cast using a

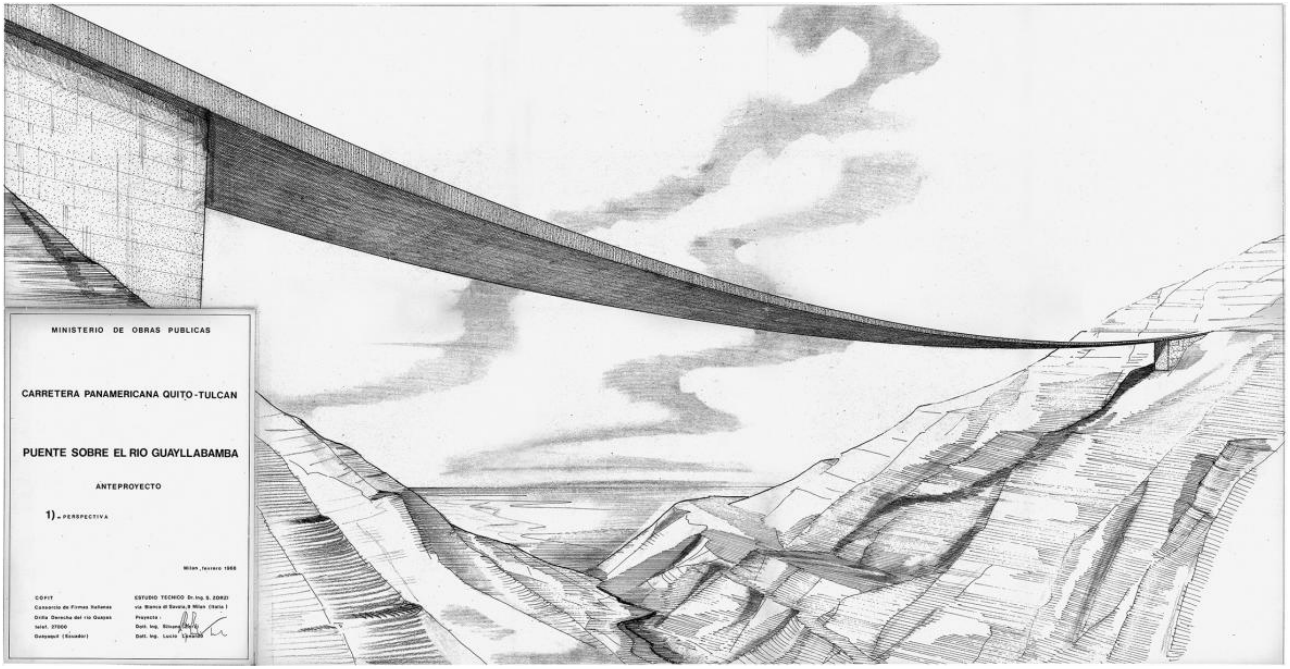

Fig. 5. Bridge over the river Guayllabamba, competition project. Perspective view (Historical Archive of the Politecnico di Milano, Silvano Zorzi Collection, Milan).

special centring and later prestressed transversely [Capurso, Martire 2017, pp. 98-115].
Thus, perspective drawings of bridges –far from common in the archives of structural engineers– emphasise, through deliberate chiaroscuro and shading, the edges and boundaries, enhancing the graphic essentiality of the works, often reduced to a few juxtaposed elements. They resemble presentation drawings of a lamp or a bookcase rather than those of a functional and 'brutal' work such as a viaduct.

Drawing for calculation and assembly

In Zorzi's work, drawing also served as a tool to support analytical calculation. In 1961, for the completion of the route of the Autostrada del Sole, he designed two further bridges, this time arches, both over the Arno and both built by the Astaldi company, at Incisa and at Levane.

For the first bridge, he combined two portal arches in prestressed reinforced concrete, each with a span of 104 m, constructed on spectacular scaffolds of Innocenti tubes. The analysis of stresses was conducted through the plotting of influence lines of the hyperstatic unknowns, using the method of the ellipse of elasticity (fig. 6). The calculations were developed analytically, but their graphic representation allowed a verification of the coherence and consistency of the values, which was also useful for the approval of the design by the competent authorities. The verification of the foundations, moreover, was carried out using a genuinely graphic method, through the funicular polygon. This mixed approach to calculation, both analytical and graphical, would be adopted by Zorzi throughout his career, reappearing in the dossier for the Gorsexio viaduct in Liguria, built in the mid-1970s.
The bridges at Incisa and Levane were among the last arch bridges built for an Italian motorway route. The reasons are

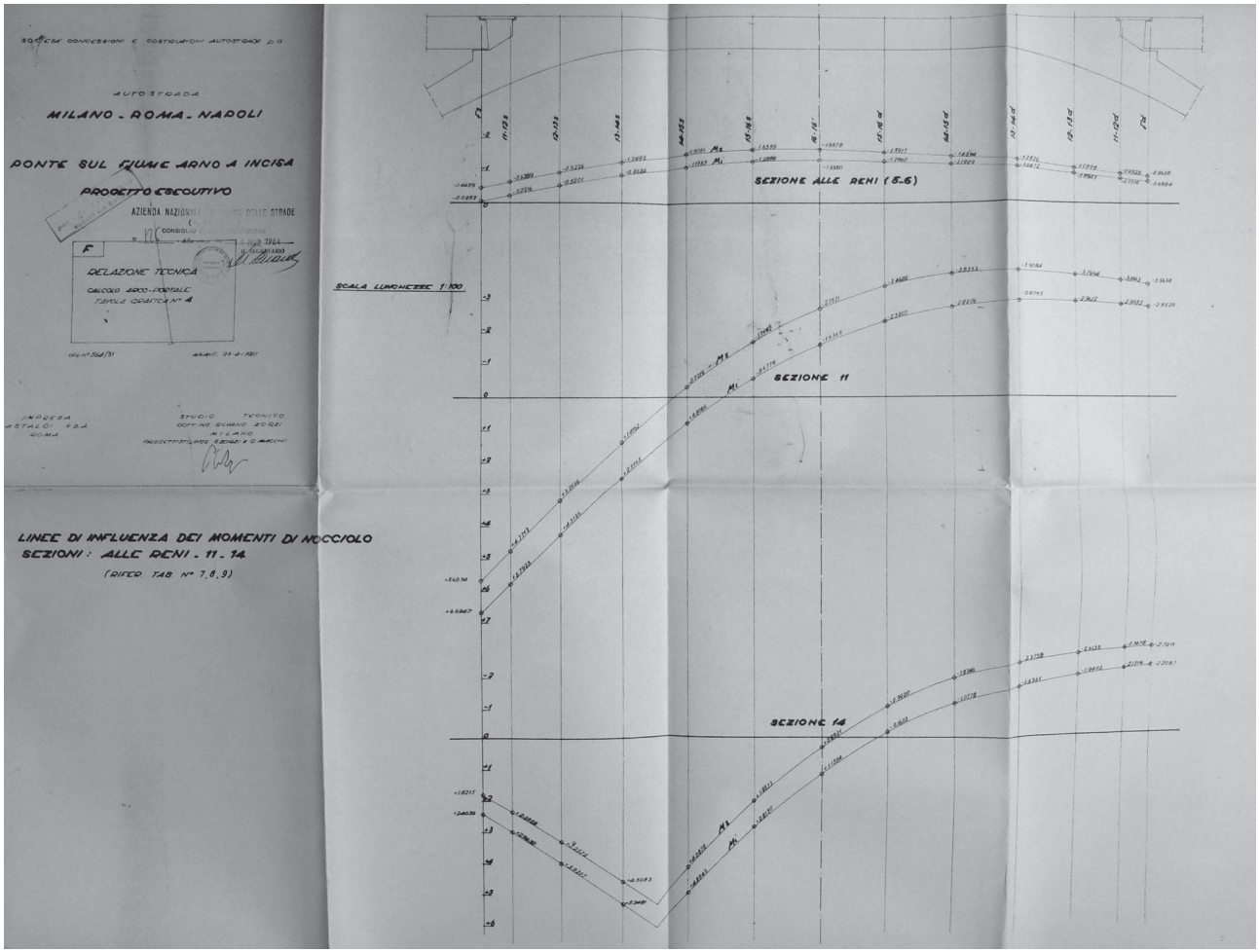

Fig. 6. Bridge on the Autostrada del Sole at Incisa. Calculation of influence lines, diagram (ANAS Historical Archive, Cesano).

numerous: new anti-seismic regulations discouraged thrusting structures; the Superintendencies for Cultural Heritage began to consider the arch bridge too 'intrusive' in the landscape and demanded more abstract, linear and slender solutions; the rising cost of labour made the erection of centring increasingly expensive; and finally, Italian public-works policy demanded ever faster construction schedules and greater site productivity. The artisanal character of the final years of large arch bridges thus gave way to the need to construct ever more rapidly a great number of viaducts for the motorway sections granted in concession during the 1960s and built throughout the following decade.

The emergence of this new type of viaduct, with tall piers and continuous decks, did not find Zorzi unprepared.

Fig. 7. Bridge on the Autostrada del Sole at Incisa, under construction (In.Co. S.p.A. Historical Archive, Milan).

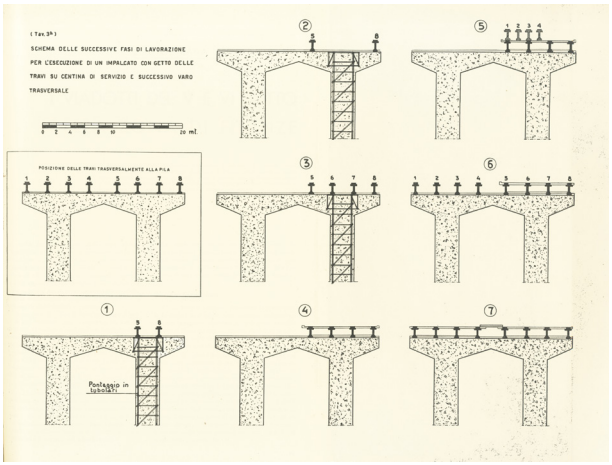

Fig. 8. Bridges on the Autostrada del Sole at Mugello, construction phase diagram (SIXXI Archive).

Rather than merely adapting to the new production requirements, the engineer devoted himself to inventing new construction procedures. In his projects, the methods of assembling the structural elements –which would form the decks of the viaducts– assumed a central role.
During the 1960s, Zorzi was also an active disseminator of technical knowledge, giving invited lectures and writing articles for specialist journals such as *Autostrade* and *L'Industria Italiana del Cemento*. In illustrating the construction techniques adopted for the Mulinaccia, Bellosguardo, Baccheraia, Goccioloni I and Goccioloni II viaducts on the Autostrada del Sole (sections V and VI of the Florence area, 1959-1960), the engineer used, alongside site photographs, graphic diagrams evidently derived from the project drawings, which communicated both the structural characteristics and the innovative erection procedures employed (fig. 8).
Thus, beyond depicting the arrangement of the reinforcement, the prestressing cables, and the shape of the cable-head housings within the beams, drawing was also used to illustrate the 'sequence of elementary operations for the launching' of the viaduct beams. Two distinct versions were developed for different parts of the infrastructure: one foreseeing a prefabrication yard with transport on trolleys, and the other involving casting of the beams on a service centring supported by the already completed structures, followed by transverse launching – an invention by Zorzi and the construction company to overcome the lack of space for setting up a prefabrication yard.

Drawings for mobile workshops

Prefabrication might seem, at first glance, to leave little room for design or for research into the expressive potential of structural form. During these years, however, Zorzi devoted himself to reinventing the construction site, managing to design new masterpieces [Zorzi 1968]. Distinguishing himself from his contemporaries, Zorzi declared: "The work to be realised must indeed be the most functional, but at the same time it must also take shape as a harmonious and lasting insertion into the environment and constitute a vision that is satisfying in itself" [Zorzi 1981, pp. 11-12]. Only by rationalising and industrialising the construction site could Zorzi recover, within this new context, the quality and flexibility of in-situ casting, which he was unwilling to abandon. He thus introduced into Italy two special machines, imported from Germany but adapted for Italian construction: the self-advancing centring and the launching girder.

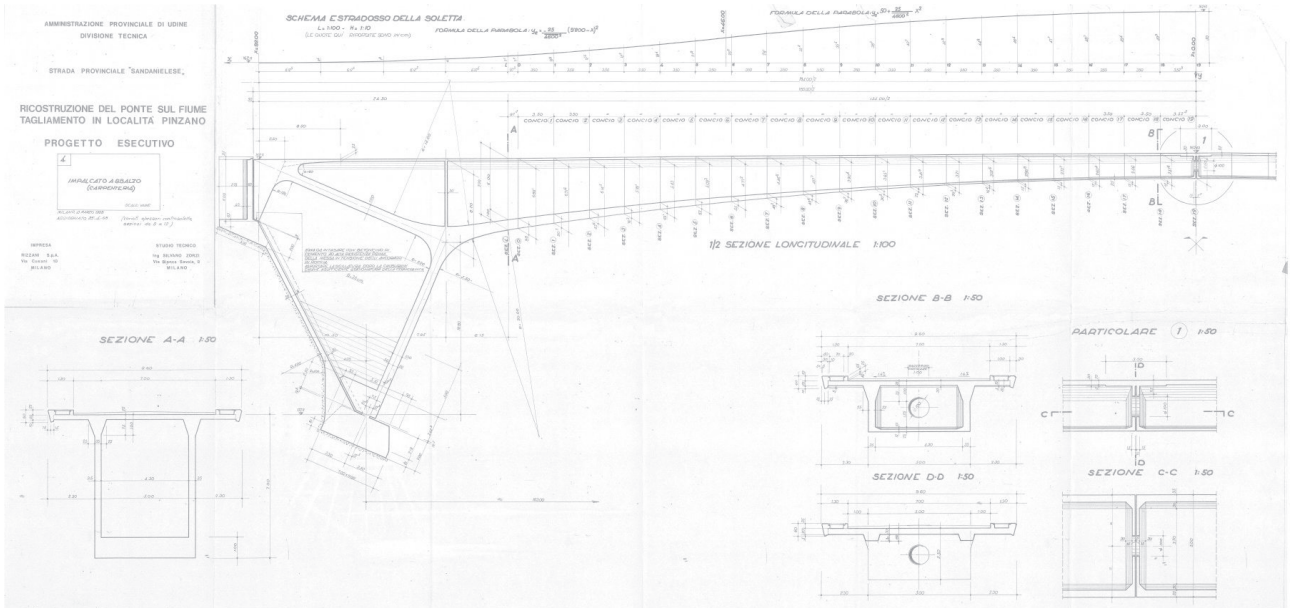

Fig. 9. Bridge over the river Tagliamento at Pinzano, working drawings. Cantilever deck, longitudinal section of formwork (In.Co. S.p.A. Historical Archive, Rome).

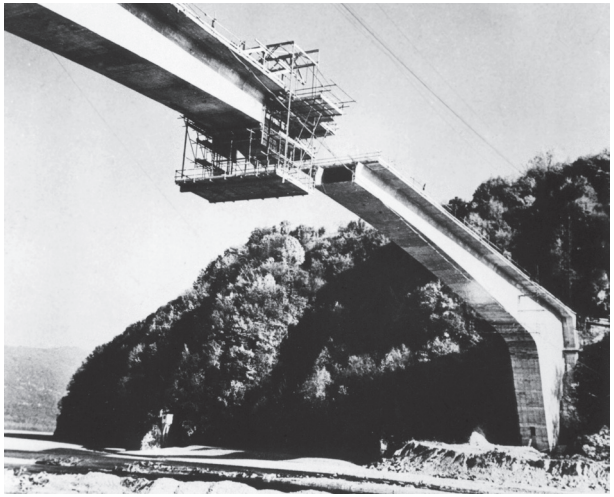

Fig. 10. Bridge over the river Tagliamento at Pinzano, under construction (Historical Archive of the Politecnico di Milano, Silvano Zorzi Collection, Milan).

Fig. 11. Gorsexio viaduct at Voltri on the Voltri-Alessandria motorway (Historical Archive of Cooperativa Muratori & Cementisti C.M.C., Ravenna).

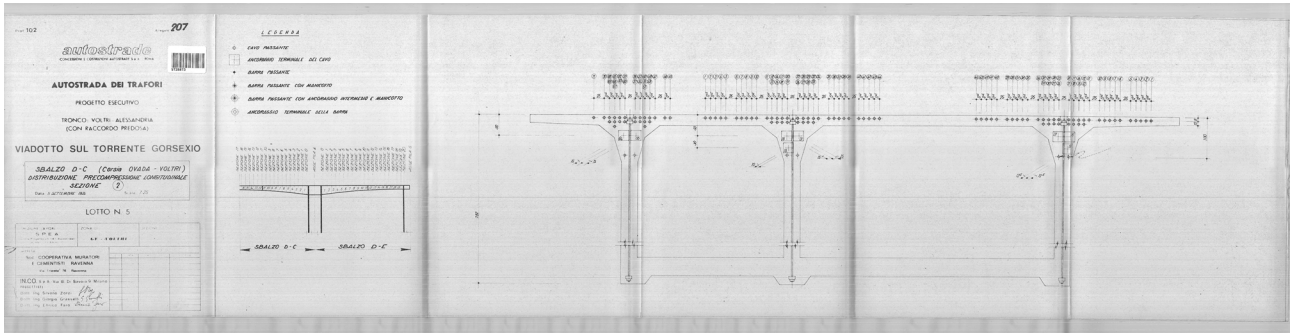

Fig. 12. Gorsexio viaduct at Voltri on the Voltri-Alessandria motorway. Working drawings, cross-section (Historical Archive of Cooperativa Muratori & Cementisti C.M.C., Ravenna).

The first was a small, covered, mobile workshop, resting on the heads of the piers and sliding forward from one pier to the next [Blandino 2014, pp. 104-113]. Its use was advantageous when the piers were all identical, as in urban viaducts and elevated roads built outside city centres. In these cases, too, the elevated roadway was conceived like a portico: the intrados had to be beautiful, since it was to be appreciated from below. Zorzi was skilled at designing slender, sculpted piers that stood at the centre of a deck slab opening in cantilever, thinning elegantly toward the edges. For the construction of such works, among which the Teccio viaduct at Cadibona on the Turin-Savona motorway (1974) stands out for its audacity, Zorzi's office was involved not only in architectural and structural design but also in defining the operation of the machines themselves. The drawings, developed in collaboration with specialist firms, analysed and validated the assembly and advancement schemes of the equipment used, which became crucial to the successful execution of the works.

With the launching girder, by contrast, Zorzi built bridges using the 'little by little' technique. Unlike the unitary image of the completed structure, the working drawings had to specify the size of the segments to be cast –designed so that they could be supported by the construction machine until the concrete reached sufficient mechanical strength– as well as the type and layout of the prestressing bars, by then almost always of the Dywidag type. Zorzi adopted launching girders for the first time in 1967, for a series of viaducts along the Azzurra motorway in Liguria, from Genoa to Rapallo, and later for the aforementioned bridge over the Tagliamento at Pinzano (figs. 4, 9, 10). The analyses in elevation, plan and section show the distinctive constructive solutions defined by Zorzi: the careful modelling of the concrete members, the point-by-point layout of the bars, the special devices devised to obtain the hinges at the crown of the bridge, and the three-hinged configuration that ensured the structure's exceptional line. Using the same technique, he built the deck of the Gorsexio viaduct (figs. 11, 12), one of his final masterpieces. Rising on vertiginous piers with lamellar sections, the definition of the construction phases demanded sustained effort from the studio's draughtsmen: twenty meticulously detailed sections were needed for each half-span to describe the exact position of all devices required for prestressing – through cables, anchorage systems for continuous bars, with couplers or intermediate anchorages, and terminal anchors whose position varied continuously within the beam. This minute and refined technological design reveals Zorzi's persistent attempt to preserve in his works his distinctive minimalist character and the structural, constructive, and figurative lightness typical of his design approach.

Zorzi was aware of the anachronism of his position. At the beginning of the 1980s, when issues of formal quality and the environmental permanence of works remained unresolved in Italian infrastructure projects, he remarked that the responsible designer –one who cared for the essential expression of structure and its proper execution– in a "climate of great competitiveness and in the face of mostly inattentive clients", would, unfortunately, "often find himself alone" [Zorzi 1981, p. 35].

Conclusions

The analysis of project representation in the work of Silvano Zorzi reveals how drawing served as a critical device capable of making visible the intimate connection between structural logic, construction process, and formal quality. In the design of bridges and viaducts, the graphic documents do not merely record technical solutions; rather, they embody a design approach that integrates calculation, the definition of assembly procedures, and the perception of the structure as an object situated within the landscape. In this sense, Zorzi's graphic production stands in continuity with the tradition of the Italian School of Structural Engineering, while also representing an original evolution of it – one oriented towards reconciling the demands of industrialised construction with a sensitivity to the relationship between structural form and its environmental or urban context.

Project representation in Zorzi's practice should therefore be understood not only in terms of technical experimentation but also as the construction of a visual language, new within the panorama of Italian infrastructure design, and based on affinities with the world of industrial design. His work further demonstrates how, in the best tradition of post-war Italian engineering culture, representation cannot be reduced to mere transcription but constitutes a genuine instrument of invention, control, and communication of structural form.

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Notes

[1] On the research project SIXXI – XX Century Structural Engineering: The Italian Contribution (ERC Advanced Grant 2011. PIs: Professors Sergio Poretti and Tullia Iori), see: https://www.tulliaiori.com/SIXXI/. On the Italian School of Structural Engineering and its masters, see the series SIXXI – Storia dell'ingegneria strutturale in Italia, edited by S. Poretti and T. Iori, published by Gangemi between 2014 and 2020.

[2] For the profile of Silvano Zorzi as a structural designer and for his professional career within the broader history of twentieth-century Italian engineering, see Iori, Poretti 2015 and Iori, Capurso 2019.

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