Structural consolidation
Reinforced concrete lining
Supporting works in preparation for excavations

Lanuvio (RM), Italy

60% Architecture

40% Engineering

10% Geology - Geotechnics

Subcontractor: ETS S.r.l.
Contractor: Sveco spa
Contracting Authority:
RFI Rete Ferroviaria Italiana
Works designed:
Structural consolidation Reinforced concrete lining
Supporting works in preparation for excavations
Place of realisation of the works designed:
Rome-Formia railway line
Period of provision of the service:
2018-2019
Value of the works designed:
€ 3,030,000.00

DESCRIPTION OF THE SERVICE PROVIDED

This technical description refers to the executive design for the seismic upgrading of the brick arch viaduct on the two-track Rome-Naples railway line at kilometre 35+492, in the municipality of Lanuvio (Rome).

The viaduct had 5 brick arches, the middle one crossing the Piastranello stream.

The bridge was 75.00 m long and 10 m wide.

The round arches had span of 12.00 and radius of 6.00 m and were all the same height. They were built in earthenware bricks and lime mortar, with arch structure about 70 cm thick.

The tapered piers had above-ground height varying from 2.99 m to 9.46 m and all had the same rectangular cross-section at the base of the arch of 2.00 x 9.60 m.

The completely buried abutments consisted of a brickwork and lime mortar cladding and a core of cemented agglomerate, with a total (longitudinal) thickness of 2.50 m.

The work was completed by 4 brick and lime mortar wing walls, two on the Rome side and two on the Naples side abutments, which were more than 50% buried.

Current condition

PHASES

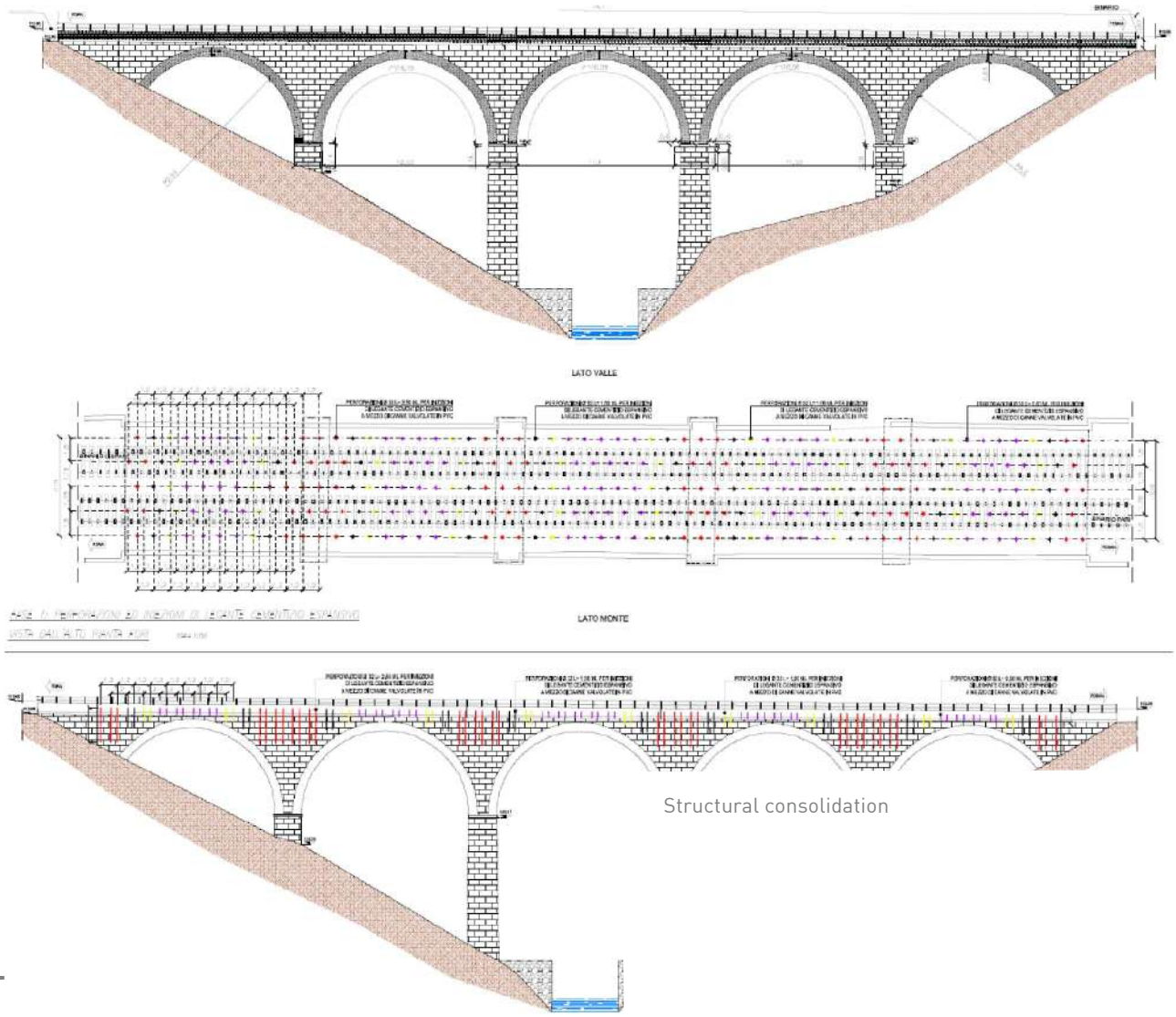
The works to be carried out are subdivided into two phases:

Phase I Works (Consolidation)
Phase II Works (Structural)

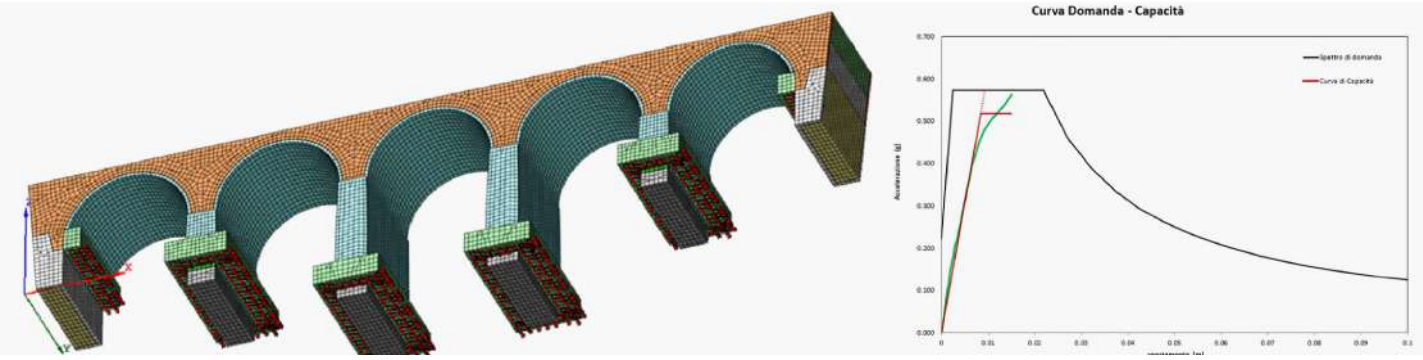
PHASE I

The consolidation works were designed to enable the railway line to remain in operation during the period prior to the structural works, in view of the rapid deterioration of the structures.

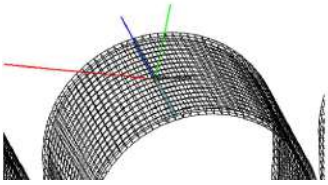
Through boring of a series of holes at the track bed height, in the spandrels, on the arches themselves and on the piers of the bridge, the intention was to fill the cavities behind the facing by injecting cement and epoxy resin binder, which would also improve the waterproofing of the brickwork structure of the bridge.



Structural consolidation

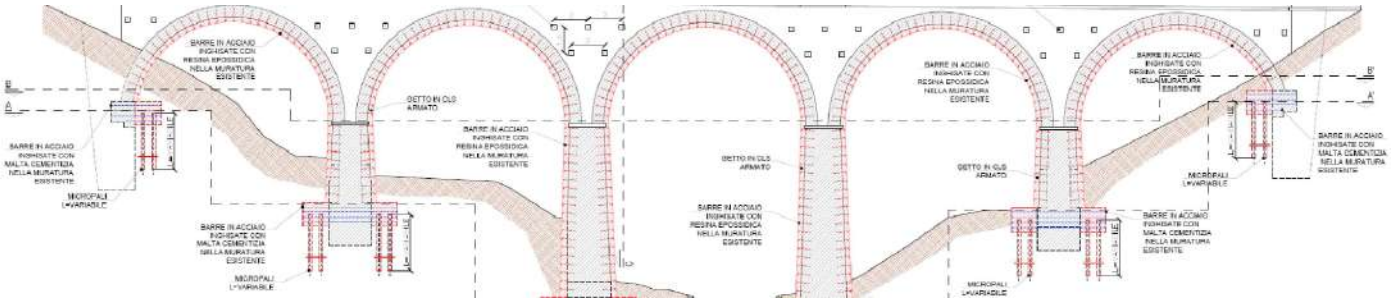


FEM modelling

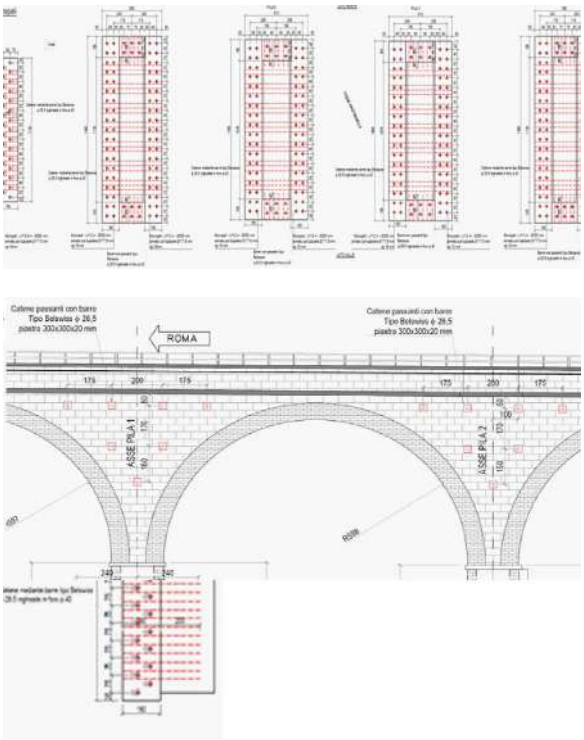


Meccanismo di collasso indagato	Gruppo di spinta	ANTE OPERAM			POST OPERAM - FASE 1			POST OPERAM - FASE 2		
		PGA_D	PGA_C	IR	PGA_D	PGA_C	IR	PGA_D	PGA_C	IR
Meccanismo globale longitudinale	Gruppo 1	0.222g	0.146g	0.66	0.222g	0.164g	0.74	0.222g	0.305g	1.37
	Gruppo 2	0.222g	0.113g	0.51	0.222g	0.164g	0.74	0.222g	0.241g	1.1
Meccanismo globale trasversale	Gruppo 1	0.222g	0.157g	0.71	0.222g	0.180g	0.81	0.222g	0.230g	1.04
	Gruppo 2	0.222g	0.15g	0.68	0.222g	0.153g	0.69	0.222g	0.289g	1.30
Meccanismo locale del timpano		0.222g		-	0.222g		-	0.222g	0.288g	1.56

Verification of section for lining



Complete works

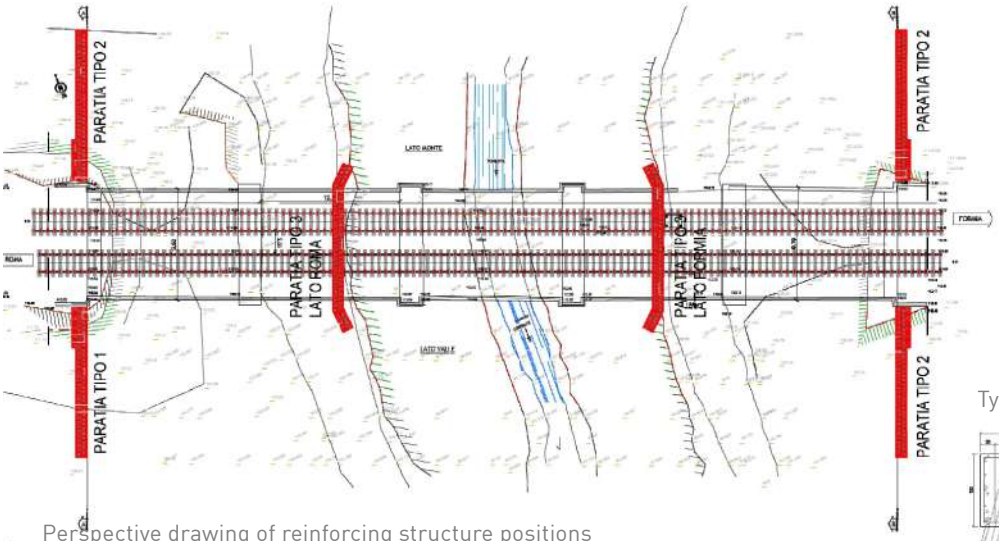


Local works

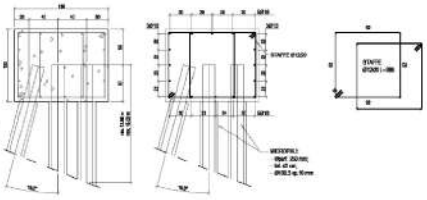
PHASE II

The structural works in Phase II were intended to improve the bridge's safety in case of earthquake by upgrading its total and local resistant capacity.
The resistant capacity of the bridge's arches and substructures was improved by constructing a reinforced concrete lining 30 cm thick with two layers of dia. 20 mm/20 cm bars running both lengthways and transversely. This lining was cast on site onto the intrados of the arches and connected to the original brickwork structure by means of nine dia. 20 mm metal pins per square metre. The resulting composite reinforced concrete masonry structure was able to absorb any actions transmitted by the seismic event.

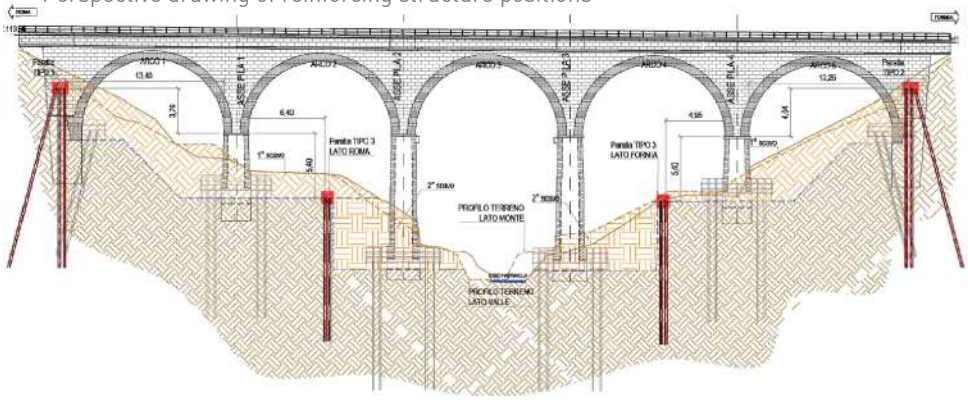
Ground plan of reinforcing structure positions

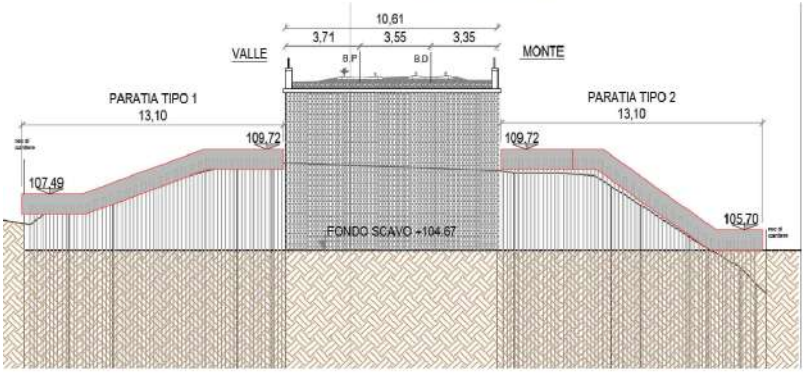


Typical formwork and rebar layout

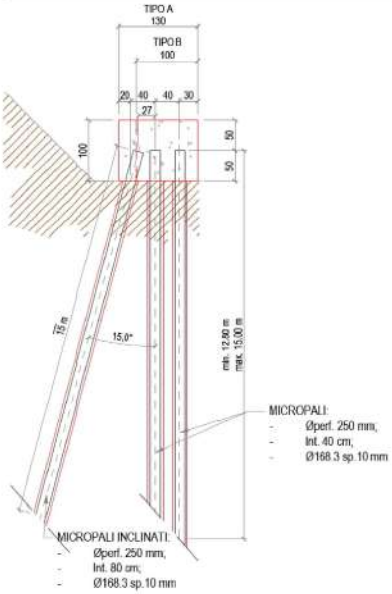


Perspective drawing of reinforcing structure positions





Typical perspective drawing along abutment



Typical cross-section

The resistant capacity of the foundations, on the other hand, was increased by creating subfoundations on all the vertical structures, consisting of a reinforced concrete beam resting on micro-piles along the front wall of the abutments and around the entire perimeter of the piers. This beam had cross-section of 1.65x1.90 m for the piers and 1.90x1.65 m for the abutments, while the micro-piles were arranged in two parallel lines, with borings dia. 250 mm, length 10 m, reinforced with tubular S355 steel bars having diameter 177.8 mm and thickness 16 mm.

To improve the bridge's resistance in specific points, ties consisting of Belswiss steel bars dia. 26.5 mm anchored on both sides to metal end plates were inserted in the spandrels.

The distance between the ties varied between 1.70 m and 2.00 m; they were 0.50 m below the top of the spandrel, while the end plates measured 300 x 300 x 20 mm.

To improve the bridge's local resistance, ties consisting of steel bars anchored on both sides to metal end plates were inserted in the spandrels.

The bridge's seismic vulnerability was assessed by calculating the lowest Risk Index (IR) value of all the possible statically and kinetically permissible mechanisms for the structure.

The risk index describes the ratio between the maximum peak ground acceleration and the acceleration required in the limit state considered, derived from the elastic response spectrum, or the design value (in our case, we assessed the ULS).

Various methods and calculation models can be used for this evaluation. For design purposes, a non-linear static analysis was performed for the global failure mechanisms, with a kinematic analysis for the local mechanisms.

SUPPORTING WORKS IN PREPARATION FOR EXCAVATIONS

Since the reinforcing structures were to be installed close to the abutments and the piers, it was necessary to ensure safety during the excavations and during the construction of the foundation beams, and also to allow the passage of the heavy plant necessary for the work around the piers. The decision was taken to use concrete micro-piles cast on site, having diameter of 250 mm and uniformly reinforced with tubular steel dia. 168.3 and 10 mm thick.

The size of the top beam varied depending on whether the row of piles was double or triple, but it was still reinforced with bars dia. 16 and brackets dia. 12.

The design work was therefore subdivided by the three types as follows:

- **TYPE 1 REINFORCING STRUCTURE**

  reinforcing structure of micro-piles Ø250 mm with length variable from 15.0 m to 12.80 m. The cross-section of the top beam varied but in all cases it was at least 130x100 cm (TYPE A) and 100x100 (TYPE B). It extended along the downstream escarpment on the Rome side for about 13.10 metres with the depth of the trench varying between 5.05 m and 2.8 m. The micro-piles were 0.40 m apart, with 0.40 m between rows. The third row of micro-piles was inclined at 15° to the vertical.

- **TYPE 2 REINFORCING STRUCTURE**

  Reinforcing structure of micro-piles Ø250 mm with length variable from 15.0 m to 11.0 m. The cross-section of the top beam varied depending on whether there were two or three rows of micro-piles but in all cases it was at least 130x100 cm (TYPE A) and 100x100 (TYPE B). It extended along the downstream escarpment on the Formia side for about 13.10 metres with the depth of the trench varying between 5.05 m and 1.0 m (upstream on the Rome side) and 5.3 m and 1.3 m (upstream and downstream on the Formia side). The micro-piles were 0.40 m apart, with 0.40 m between rows. The third row of micro-piles was inclined at 15° to the vertical.

- **TYPE 3 REINFORCING STRUCTURE**

  Temporary reinforcing structure of micro-piles of Ø250 mm, with length 12 m. It consisted of two rows with a top beam of 100x100 cm. It extended for about 14.70 m underneath arch 2 (Rome side) and arch 4 (Formia side) to allow work on the foundations of piers 2 and 4 respectively. The depth of the trench varied between 6.50 m on the Rome side and 6.30 m on the Formia side.

PROJECT TECHNICAL SPECIFICATIONS

Structural consolidation Reinforced concrete lining
Supporting works in preparation for excavations

PROJECT DATA:

Contractor: SVECO S.p.a.
Contracting Authority: RFI Rete Ferroviaria Italiana
Produzione Roma S.O. Ingegneria e Tecnologie
Place: Lanuvio (Rome)
Type of Project: Transport, Retail, Restyling
Award: A.Q.493/2017
Period of provision of the service: 2018-2019
Status: Completed
Area of Site: 55,000 m2 approx.
Buildings: 600 m2

PROJECT MANAGEMENT:

Project Manager: Ilaria Rizzello
Architectural Design: Marco Terracciano
Design of Structures: Ilaria Rizzello

PROJECT TEAM:

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Matteo Biagio Di Prima
Luca Terrile

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