Seminario Internacional de Puentes
AMIVTAC - PIARC

CAMPECHE 2018

A BRIDGE OVER THE PO RIVER

a design for enviromental sustainability

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On April 30, 2009 a span of an old reticular steel bridge, connecting two important regions (Lombardy and Emily), suddenly collapsed after the abundant rains that had swollen the river to 23 ft above its usual level, causing the subsidence of two masonry piers and strongly increasing the stress state of some joints already stressed for fatigue.

Some cars still running on the deck fell into the rubble, luckily enough nobody died, but, as a consequence, a large and very economically active part of the country was cut in two.

……….. but

as often happens with stories that start with an unfortunate event, what followed turned out to be one of the most innovative bridge projects, now regarded as a leading example not only in Italy.

In fact

ANAS (Italian Road Administration) decided
not to repair the old bridge because of
- high corrosion and fatigue problems in a large part of the old reticular steel deck
- need to adapt the road to current traffic volumes and loads
- need of a wider hydraulic section to reduce the risks associated with large river floods

but to build a new bridge,
only saving the old historical masonry piers, giving the task of designing the bridge to mca
(mele consulting associated) in collaboration with the technical offices of the Administration.

The design input was clear:

INNOVATION → architecture → structural concept → enviromental aspects

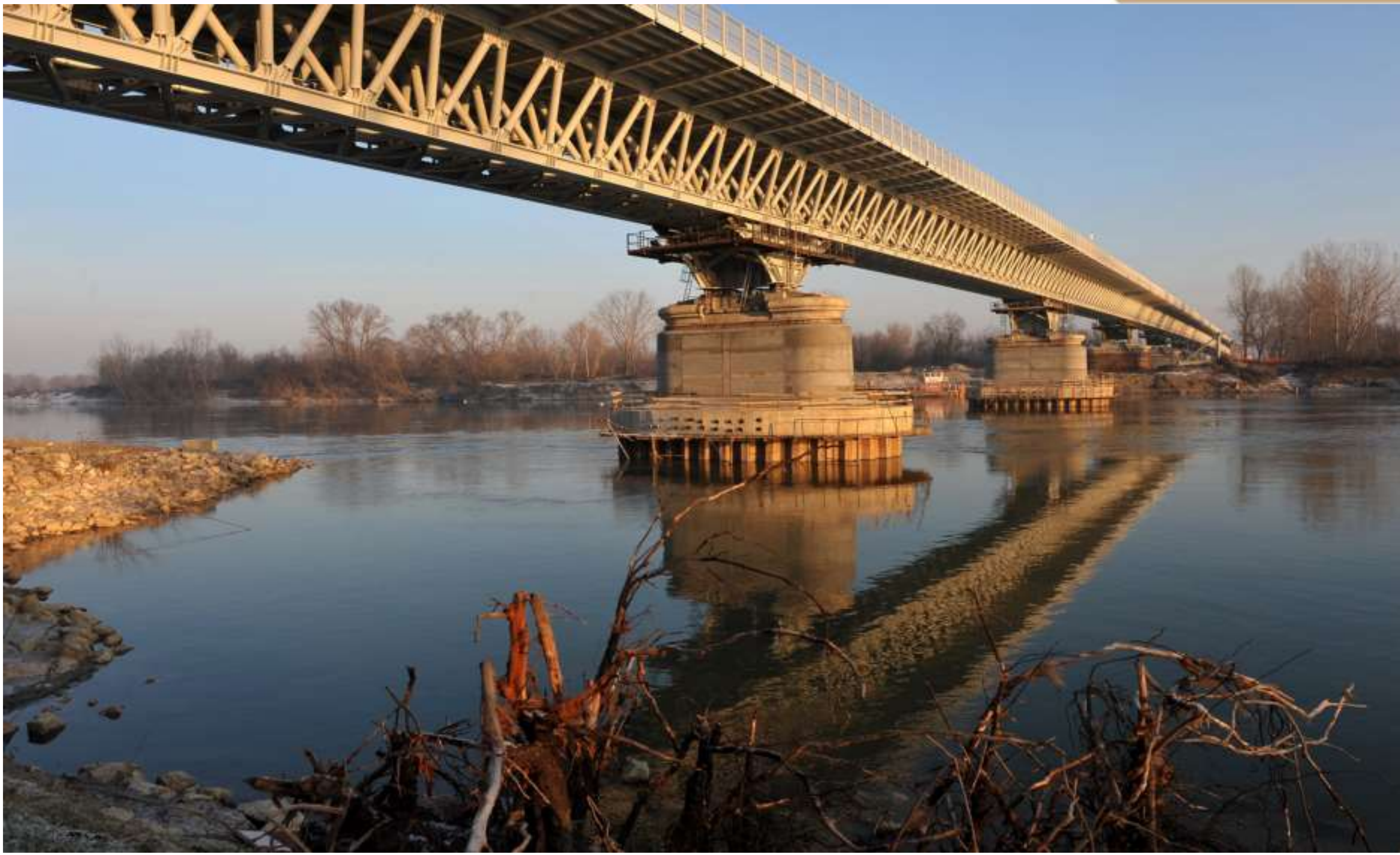
SAVING OF HISTORICAL PIERS

LARGEST PLATFORM AND HYDRAULIC SECTION

HIGH DURABILITY

TIME EFFICIENCY FOR DESIGN AND CONSTRUCTION

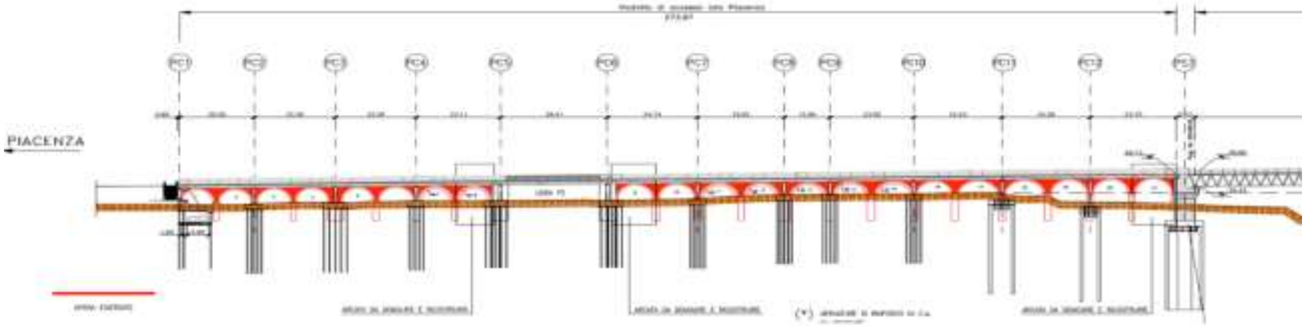
and the output was



General Characteristics

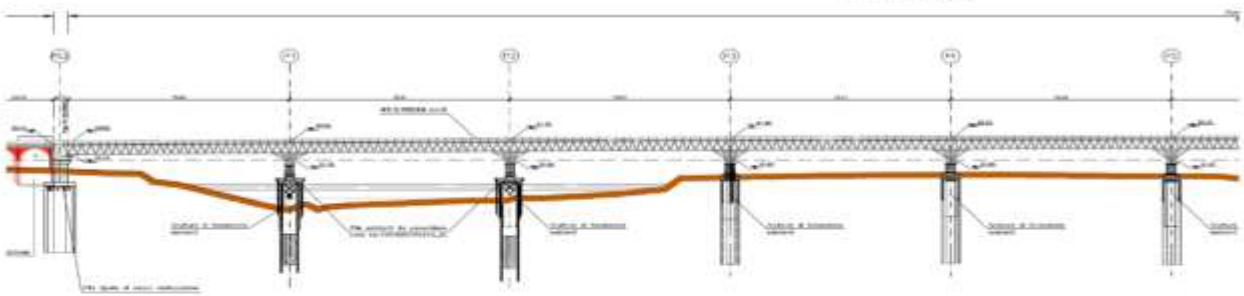
- 11 spans of about 75 m for a total lenght of 800m
- a platform 15,35 m wide with a 1 m sidewalk, a 3 m cycle lane and 2 traffic lanes made of an orthotropic steel plate
- the deck is a continous steel grid truss girder 4,50 m high
- steel capitals 3,5 m hights on the masonry pillars, rigidly connected to the deck 3D truss girder
- plus an approach viaduct 280 m lenght that is not subject of this presentation

PROSPETTI

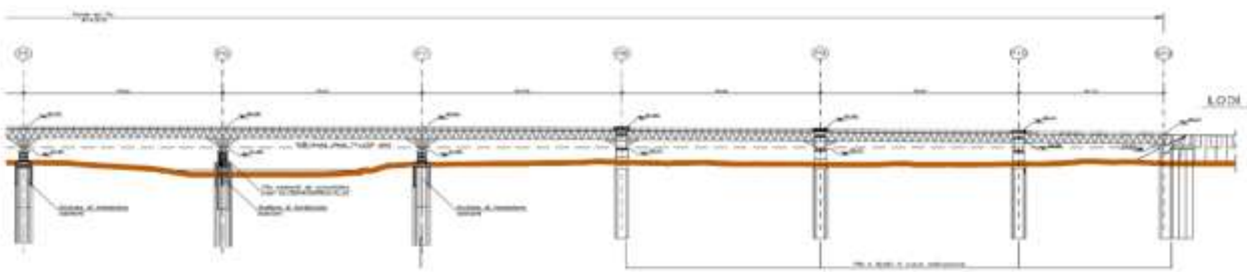


Viadotto di accesso lato Piacenza

PROSPETTO 1:500



Ponte Po: prospetto da PS3 a P5



Ponte Po: prospetto da P5 a SP2

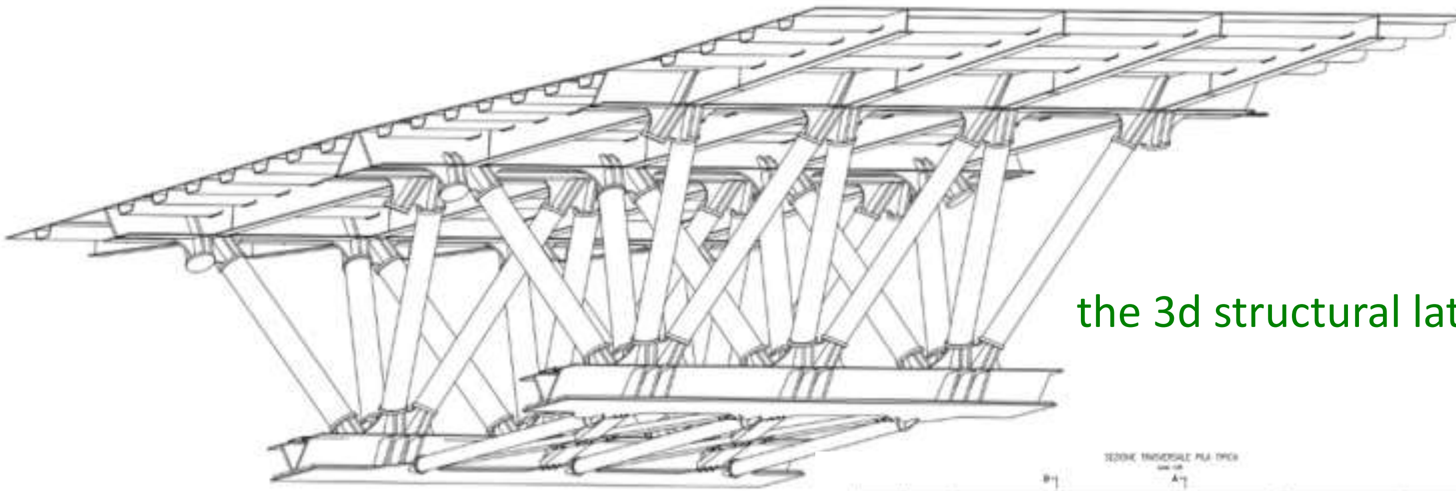
The Architectural Concept

- the shape of the bridge has sprung from the will to preserve the characteristics of lightness and transparency of the reticular structure of the old bridge.
- a reticular structure was therefore proposed,
- but reinterpreted in a modern way with a spatial conception of the lattice
- an undoubtedly original type for a bridge
- with the almost total elimination of bolted joints and the use of tubular profiles with a circular section.

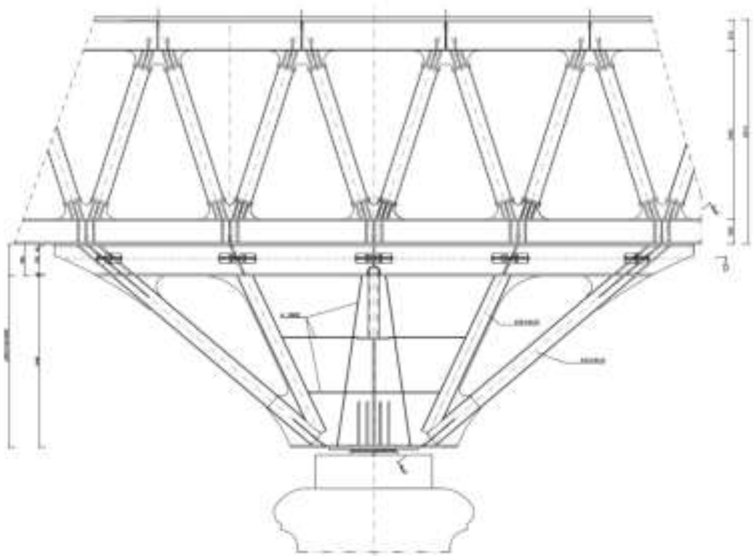
The strustural Design

Concept

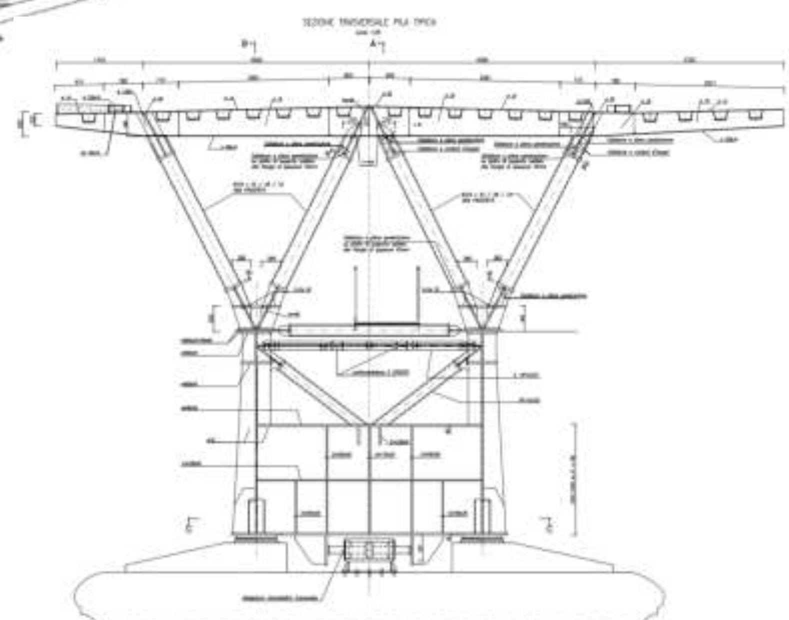
a three-dimensional latticed structure (a 3D grid) where
the traditional distinction among main beams,
secondary beams and diaphragms disappear
because each structural element play
a multi-functional role



the 3d structural lattice



a longitudinal view on the pillar



a cross section

Hydraulics

- The old deck had a height of 8 meters.
- Reducing the height of the deck truss girder to 4.5 m (only one twentieth of a span light) and placing capitals of 3.5 m height on the piers, the hydraulic section was increased by about 22% at the river bed and about 80% in the floodplain area, where the greatest problems occurred in the event of floods.
- This certainly puts the structure in safe conditions even in case of extraordinary floods

Seismic Resistance

Reference life of the bridge 75 year

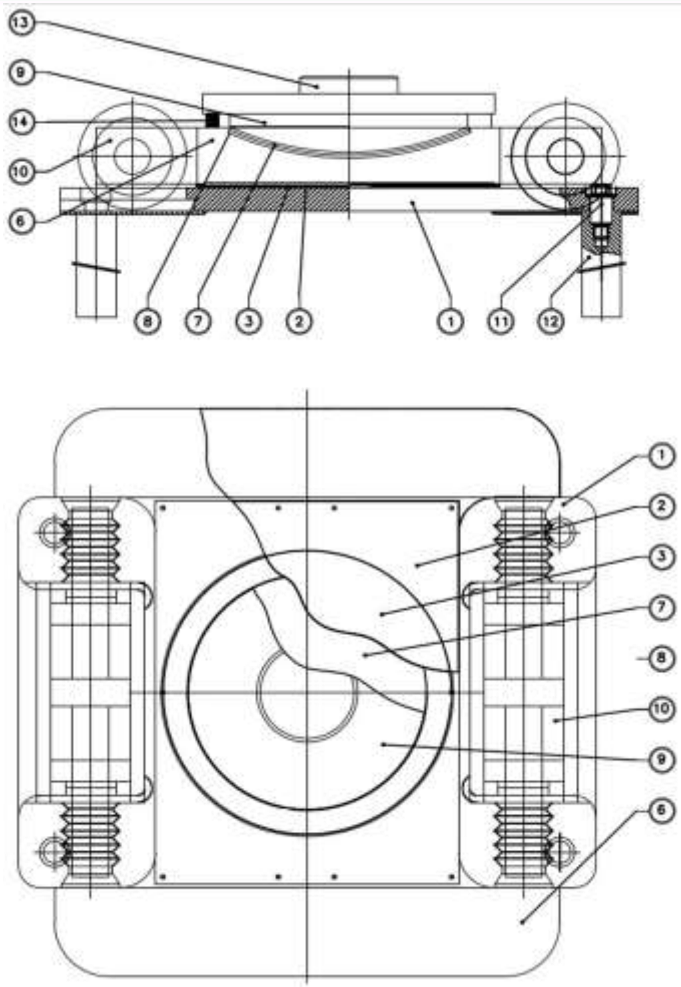
Return period of the earthquake → 75 y SLD

→ 712 y SLU

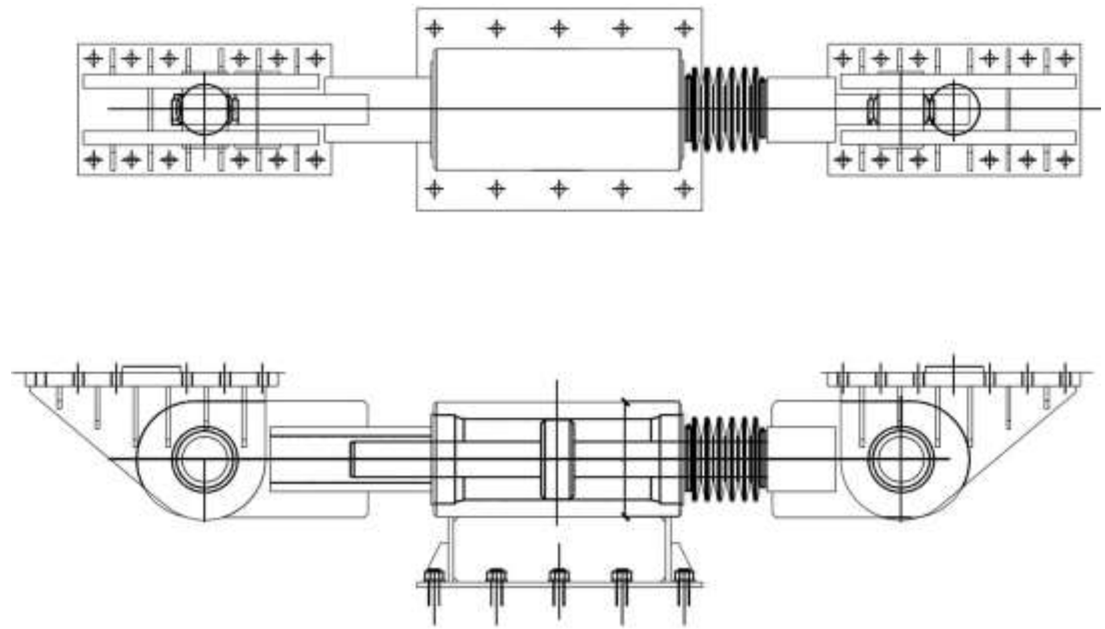
Longitudinal seismic forces: greatly reduced thanks to the use of viscoelastic dissipative devices incorporated in multidirectional supports and transferred only to the bridge abutments

Transverse seismic forces:

- SLDs are given to the piers
- the surplus ones (until the SLU's) are cut thanks to the adoption of dissipative devices similar to those adopted for the longitudinal forces and arranged between the support devices



multidirectional bearings and longitudinal dissipative devices

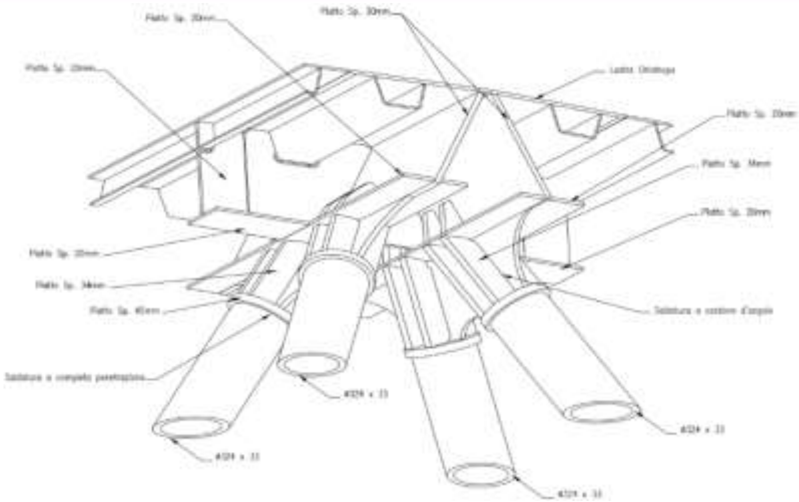


transverse dissipative devices (between bearings)

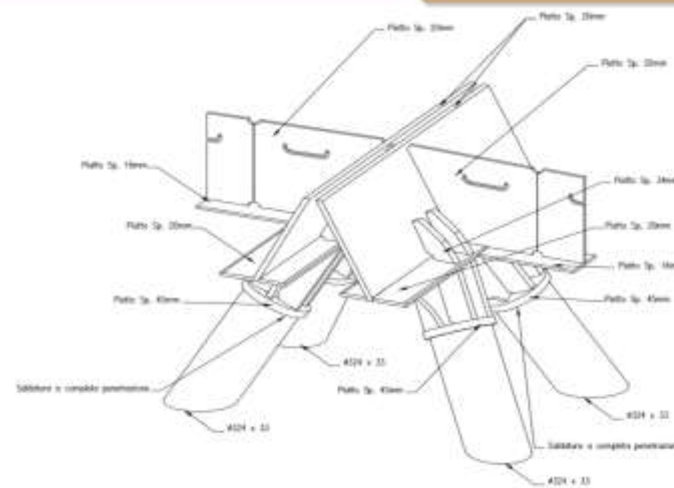
Fatigue

- Every detail of the steel structure has been designed looking for a satisfactory compromise between aesthetic quality and resistance to cyclic loads
- the number of guaranteed cycles has been increased to $5x10^6$ with the highest fatigue load,
- thus achieving an unlimited life span

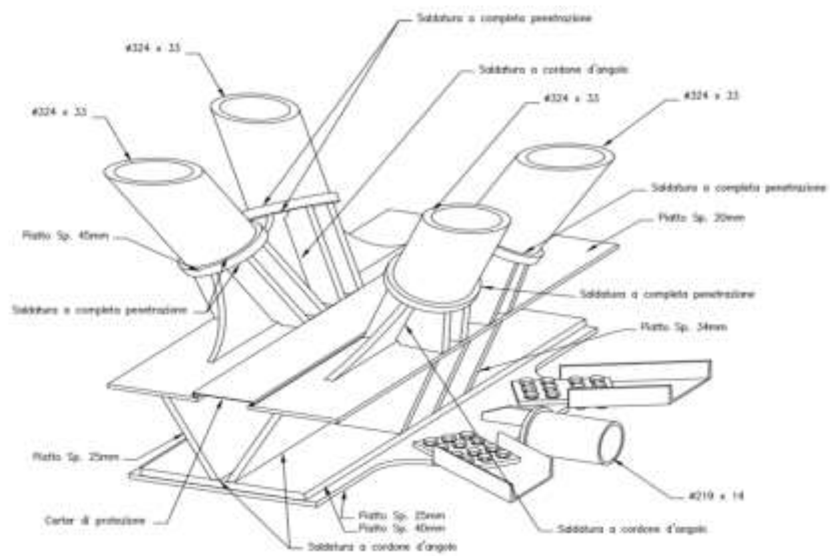
Of particular delicacy was the design of the joints among the tubular profiles



upper external joint

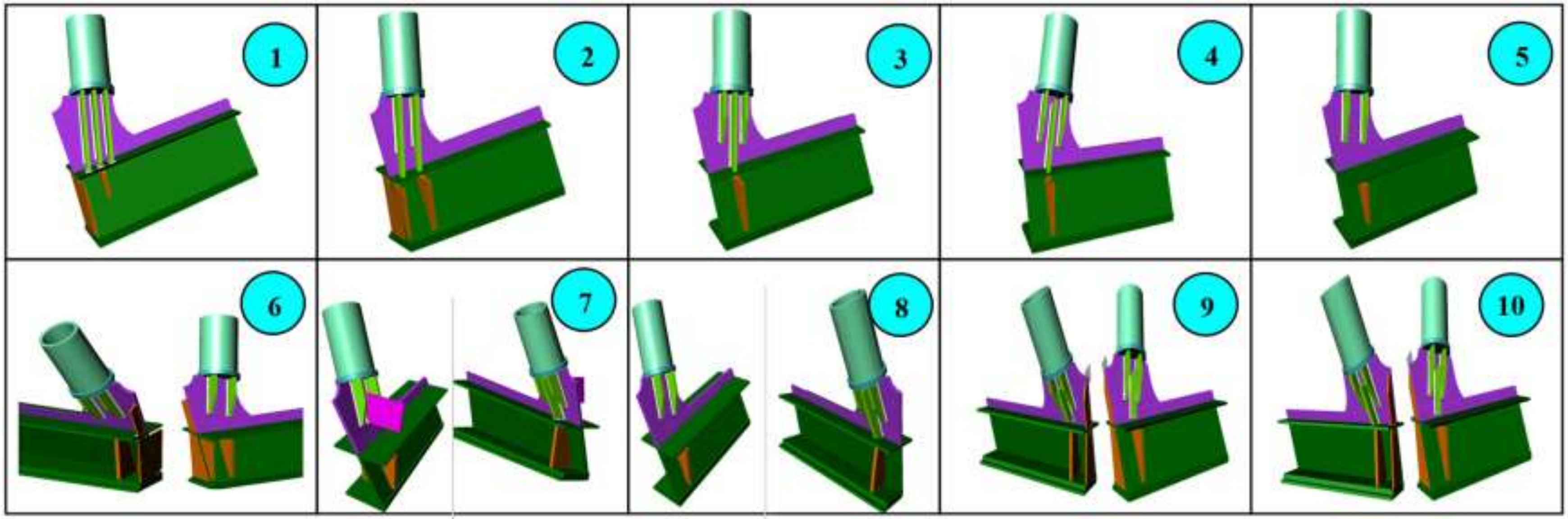


upper internal joint



lower joint

For the lower joints, subjected to the most critical fatigue conditions, 10 different solutions were compared to optimize statical performance and constructive simplicity

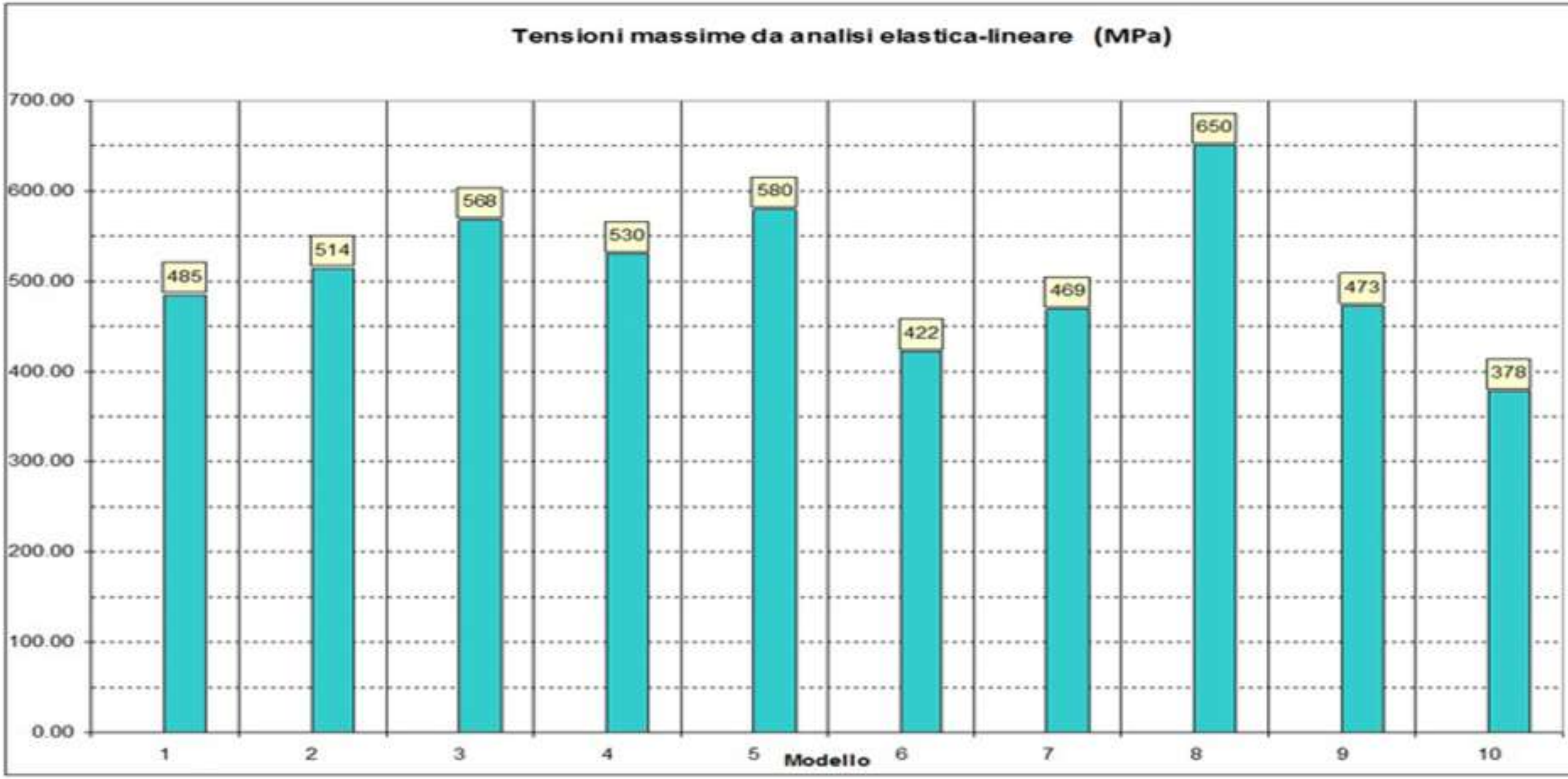


analyzing the static resistance, the fatigue resistance and the deformability in the elastic and elastoplastic fields

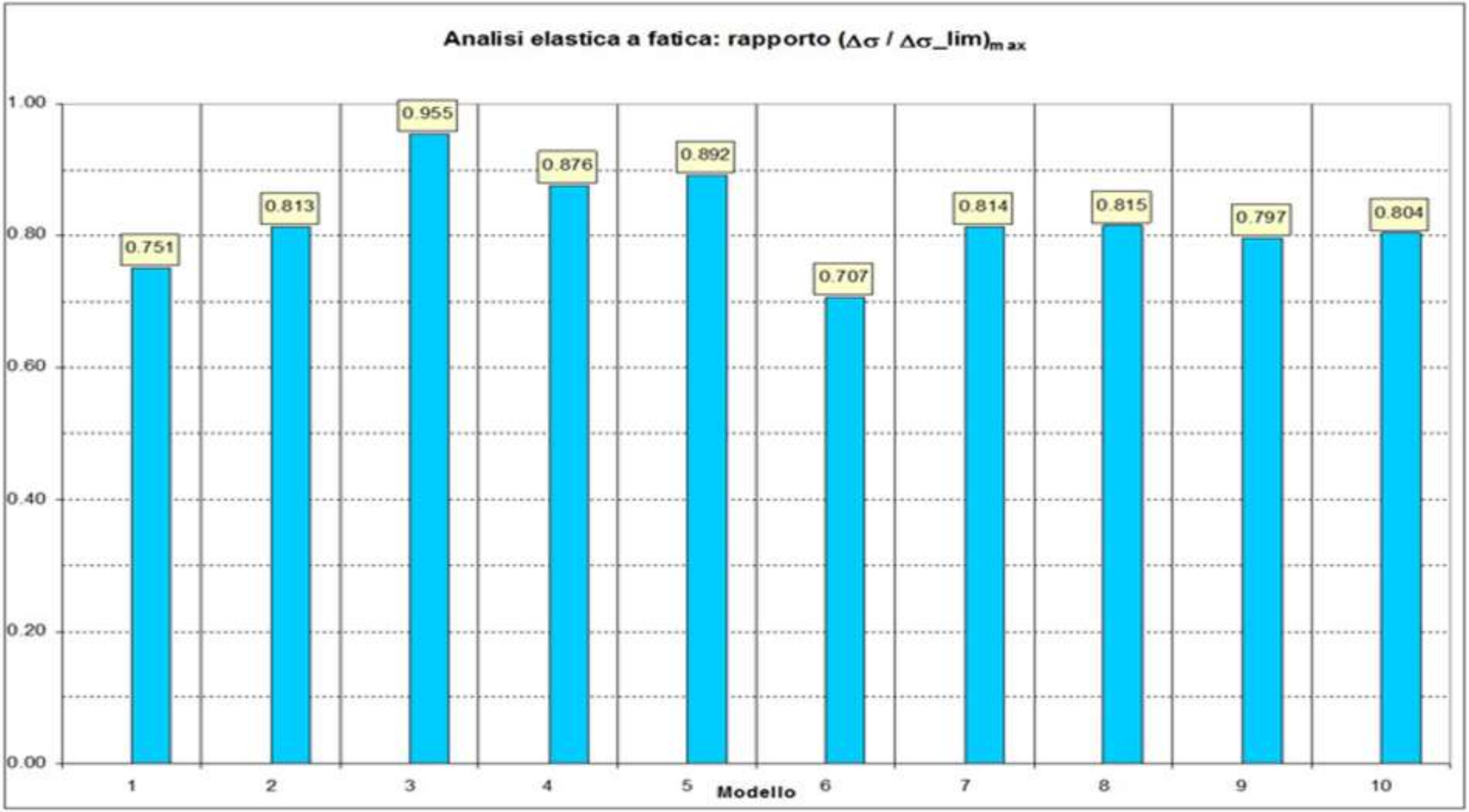
at the end choosing the detailnumber 6 as the best one

VERIFICHE DI RESISTENZA

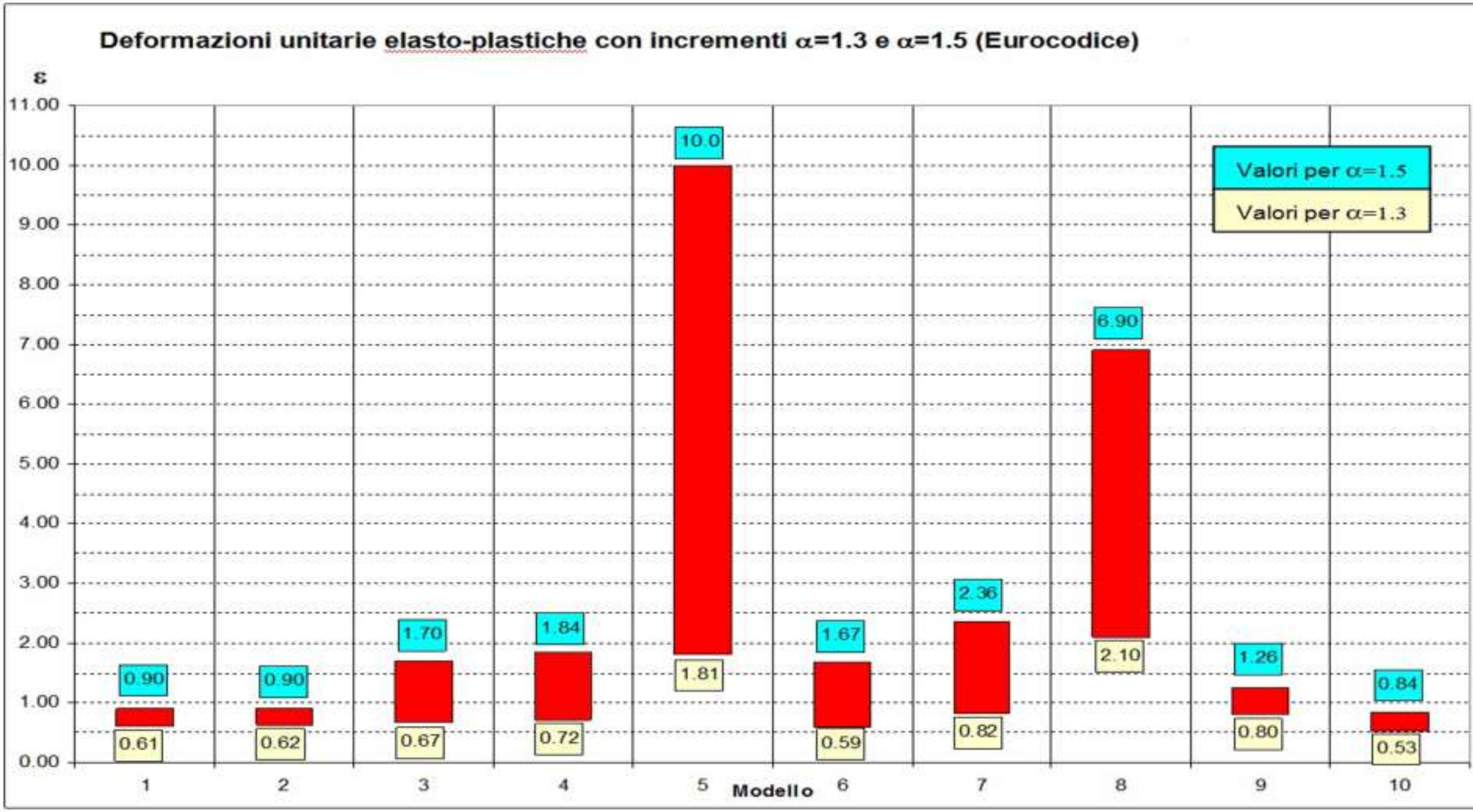
Analisi elastica lineare



resistance


Analisi elastica a fatica: rapporto (Δσ / Δσ_lim)max
1.00
0.80
0.60
0.40
0.20
0.00
0.751
0.813
0.955
0.876
0.892
0.707
0.814
0.815
0.797
0.804
1
2
3
4
5
6
7
8
9
10
Modello

fatigue



elasto-plastic deformability

Durability

Durability has been assured

- with the typological choice of the steel profiles and avoiding any possible stagnation of water
- adopting perfectly sealed deck joints
- adopting welded joints for the primary connections
- with a hot galvanizing treatment for the tubular profiles or closed section elements composed of welded steel plates
- with a zinc metallization process for the lower currents and the corresponding joints
- providing two special painting cycles for the platform plates, three for the others elements, and two more for the restoration works in site

with the result of raising the interval of extraordinary maintenance cycles to values between 50 and 70 years

Masonry Pillars and Foundations

- Masonry structures of the piers were reinforced injecting resins and cement grouts
- Only for two particularly damaged piers foundations were reinforced inserting micropiles with a diameter of 30 cm

Enviromental Sustainability Design
(last but absolutely not the least)

The design solution was compared with two other possible alternatives, namely:

- a steel box deck in ribbed plates
- a solution similar to the one chosen but with non-galvanized tubes and traditional painting cycles

comparing both the economic and environmental costs over the entire useful life of the structure.
The economic evaluation, conducted with the LCC (Life Cycle Cost) analysis criterion, showed substantially comparable results.

The environmental one was not simply qualitative (enviromental friendly) but analytical (enviromental efficient), i.e. conducted with LCA (Life Cycle Assessment), evaluating the impacts on the life cycle starting from the production of the materials used up to the end-life taking also in account the residual values of the structure (*from the cradle to the grave*).

The impacts considered were only the ones due to the global warming potential (GWP) that is the accumulatyion of greenhouses gases in the atmosphere, undoubtely the most relevant in the construction sector and in particular for the bridges, both quantitatively and for the induced effects, in comparison with other impacts ((photochemical ozone creation potential, POCP, acidification potential, AP, eutrphication portential, EP).

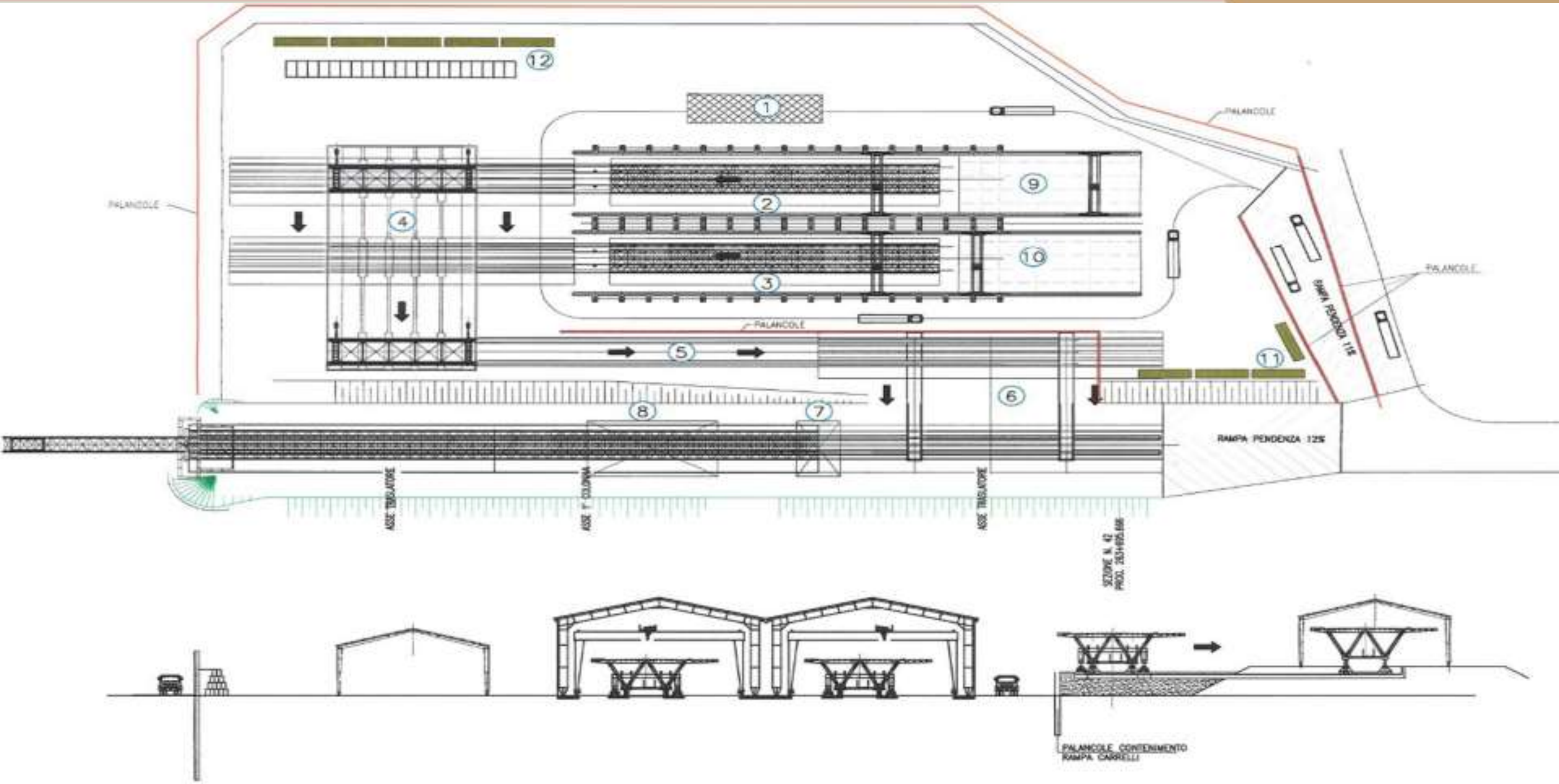
So the LCA was evalueted considering the GWP of any substance produced in the process in terms of an equivalent GWP of carbon dioxide (CO_2).

It thus resulted that the chosen solution had emission values of at least 10% less than the other items compared.

This neglecting two important factors

- the tubes used came from steel scrap,
- the steel coming from the demolition was largely (about 40%) used for the production of high quality non-welded tubular profiles and used in the construction of the new bridge.

The project also encluded the constructive modalities of a large part of the structure (except for the orthotropic panels of the platform and the connecting nodes of the tubulars), creating in site a real steel workshop in the floodplain area on the right bank of the river consisting of five sheds (three fixed and two mobile) organized with an assembly line logic



in the first the reticular web panels were assembled,
in the second and third ones two a half deck span were assembled at a time

then each one was carried on the elevated launching ramp with a sistem of rails

and here in the fourth shed was joined to the structure already built and in the second one metallization and painting were carried out, proceeding finally to the launching of the roller conveyors positioned on the capitals placed over the piers

Times and costs

Steerl weight	8,000 tons	(6,600 for the main bridge + 1,400 for the approach viaduct)
Cost	€ 42 millions	(about $ 60 millions)
Times	7 months	for preliminary and final design, demolition and construction of a temporary floating steel bridge
	11 months	for the bridge construction

In order to celebrate with this realization the first 150 years of the Italy unification

Awards

★ Demolition Award 2010

★ “*Mega-Demolition*” documentary by the National Geographic Channel 2011

- *“Bentley Certificate of Achievement”* 2012 for “*Innovation in Bridges*”

- EPD (Enviromental Product Certificate) 2015
  1st big infrastructure in the world

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in ordine ai lavori di ricostruzione del ponte strada statale n. 9 via Emilia
dal km 262+392 al km 263+487, tra San Rocco al porto (LO) e Piacenza
NEW BRIDGE ON THE RIVER PO
with regard to the reconstruction of the bridge public road no. 9 Via Emilia from km 262 + 392 to km 263 + 487, between San Rocco al porto (LO) and Piacenza

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VALIDA FINO AL:	xx-xx-2018
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Thanks !!!