UNIVERSITY OF NIŠ

Faculty of Civil Engineering and Architecture

Design and Calculation of Cable-Stayed Bridge

Diploma Thesis

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Task

Design a **pedestrian concrete bridge** over the river Nišava in Niš, according to the conditions defined by:

- cross section of the regulated river channel (waterways)
- site plan (location plan)
- technical solution for the bridge substructure

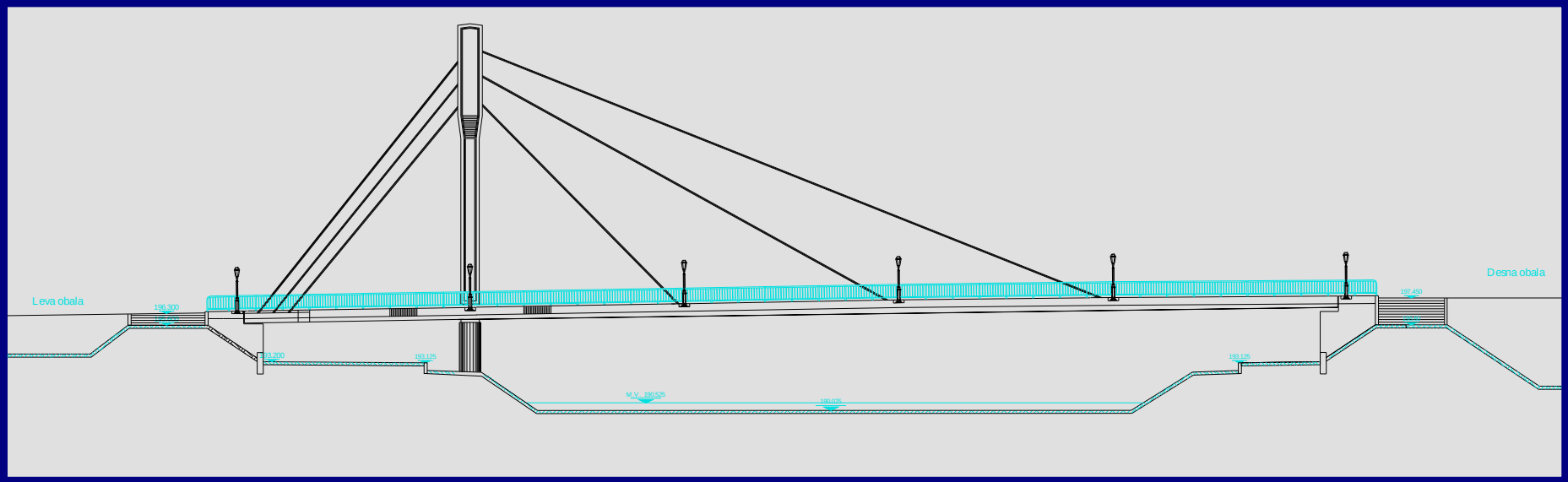
- Technical data:
  - span of the bridge: **70.0 m**
  - available deck width: **4.0 m**
  - free height above the flood flow: **0.70 m**
  - installations on the bridge: electrical installations for bridge illumination
  - material of the deck: **reinforced concrete, prestressed**

Content of the presentation

- Task
- General data of the bridge
- Description of bridge structures
  - superstructure:
    - girder
    - pylon
    - stay cables
  - substructure
- Analysis of bridge structures
  - static analysis
  - dynamic analysis
- Some details
  - reinforcement plans
  - assemblage of main girder

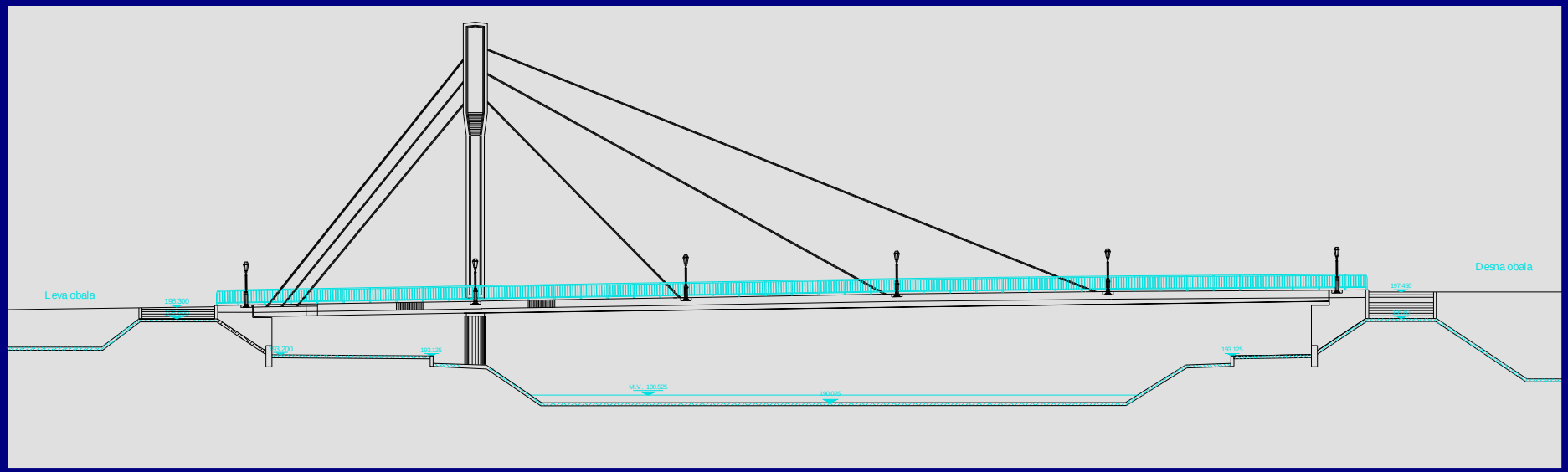
General data of the bridge

- According to the given conditions and the accepted concept of precast superstructures the bridge is designed as a **cable-stayed beam**, with two spans 14.0+56.0=70.0 m
- The superstructure of the bridge consist of: prestressed concrete deck with 3+2x3 stay cables and one pylon placed on the left river flood plan.
- Finished road level is set low in the bridge zone; to respect the conditions of free opening above the flood flow, the designed solution has small constant height of the deck: 77.0 cm between the finished road level to the bottom surface of the structure.
- The bridge is of constant height along the whole span



General data of the bridge

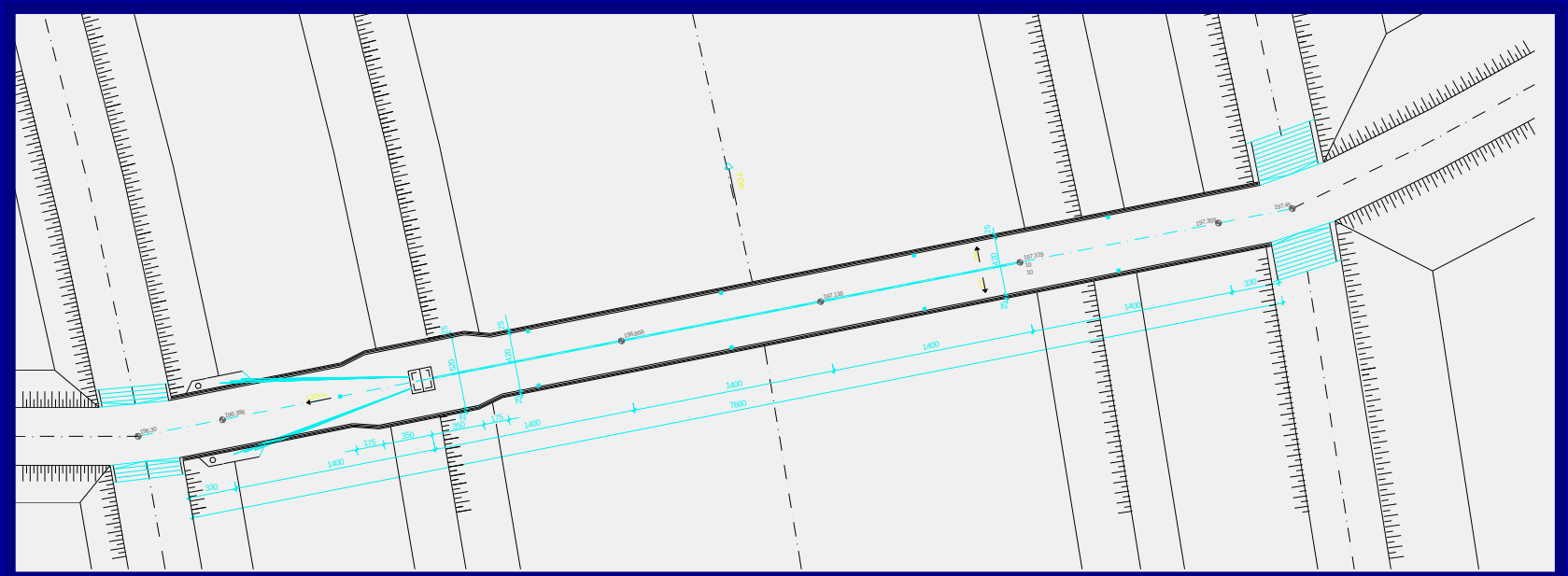
view of the bridge: upstream side



- Beside the functionality, strict vibration's and stability conditions, the aesthetic appeal of the bridge was important design constraint.
- Finished road level is straight and inclined longitudinally towards the left river bank (i=1.37%)

General data of the bridge

plan of the bridge

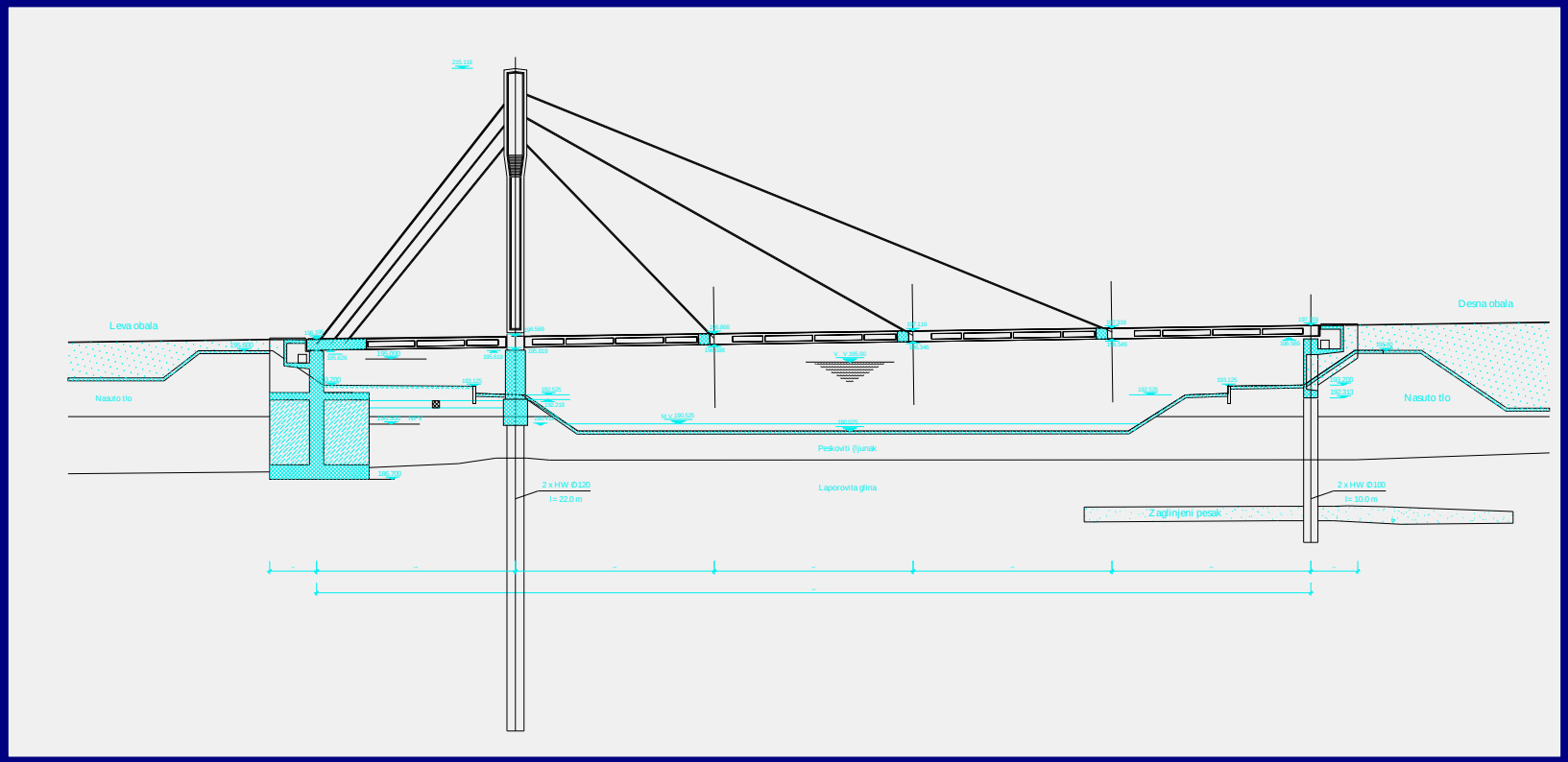


- The center line of the bridge is straight, while the center line of the river flow in the bridge zone has curvature of 400.0 m in radius, and intersects the center line of the bridge almost perpendicularly.
- The deck width is 4.2 m, with both side lateral inclination of 2.0 % from the center line
- Free profile is 2x2.0/2.5 m along the whole span - passing beside the pylon or stay cables.

Description of bridge structures

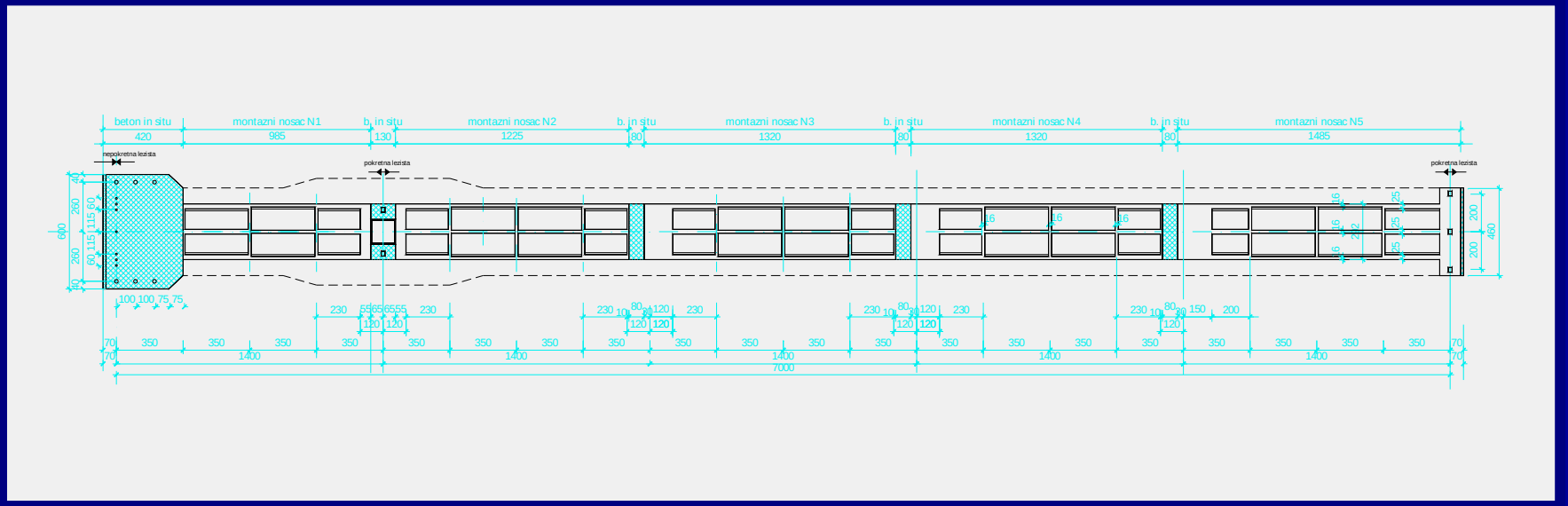
superstructure: **girder**

- Spanning structure:
  - prestressed concrete girder (C 45), boxed cross section.
  - formed of precaste segments, 14.0 m of length.
  - the height of the girder is constant along the span, with 73.0 cm in the center line, and 68.5 cm form the bottom edge of corona to the bottom surface of girder (intrados)



Description of bridge structures

superstructure: **girder**

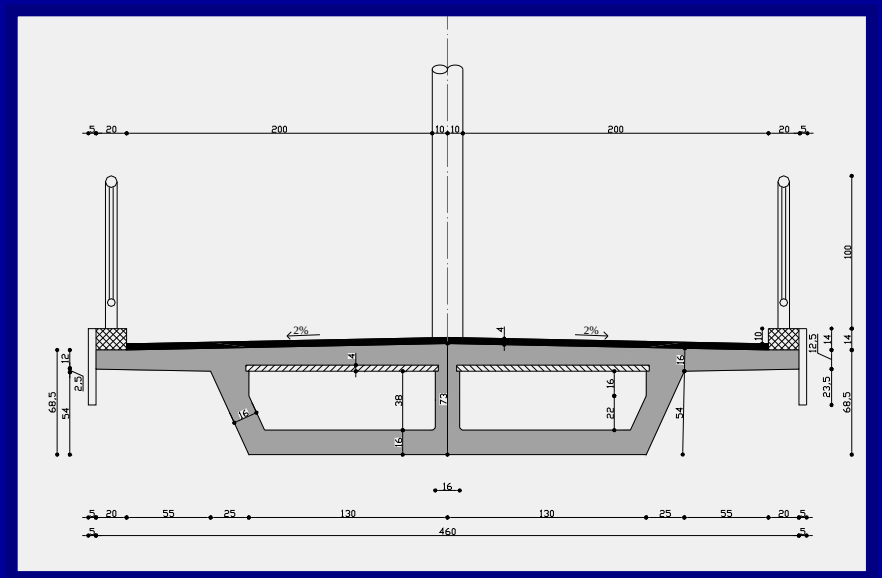


- The part of the girder at the left pier, 0.7+3.5 m long, is cast-in-situ solid deck.
- The cross section of the girder is of shape of trapezium, consisting of two chambers, bordered by the upper deck, two side ribs and one middle rib (in the center line of the bridge).

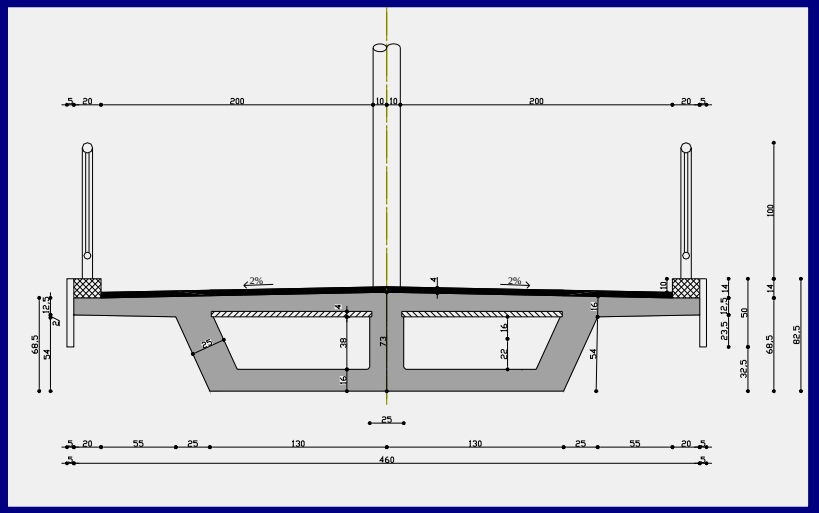
Description of bridge structures

superstructure: **girder**

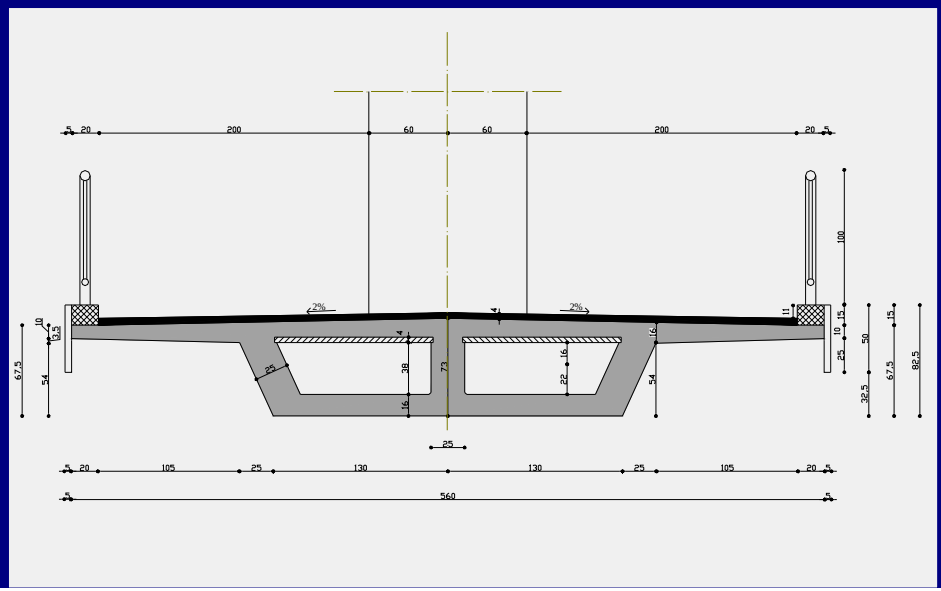
- Cross sections of the girder :
  - section in the span



  - Section in the support zone

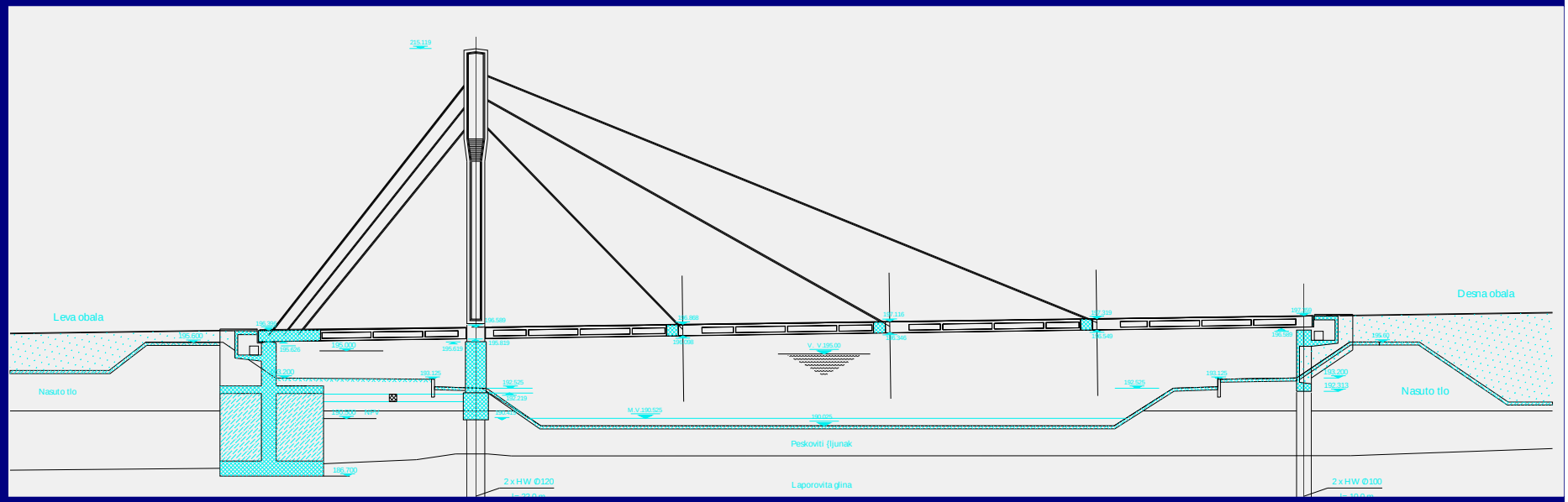


  - Section in the pylon zone



Description of structures

superstructure: **girder**

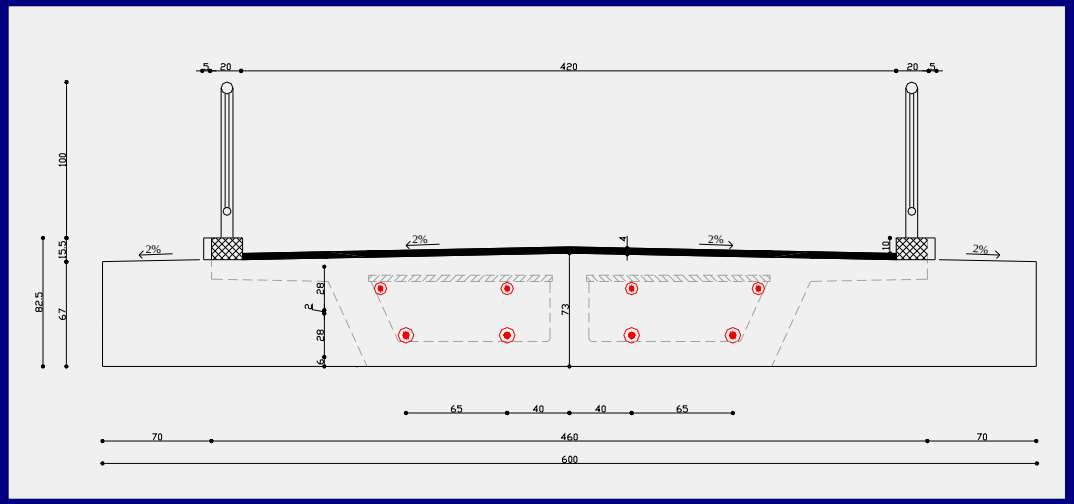


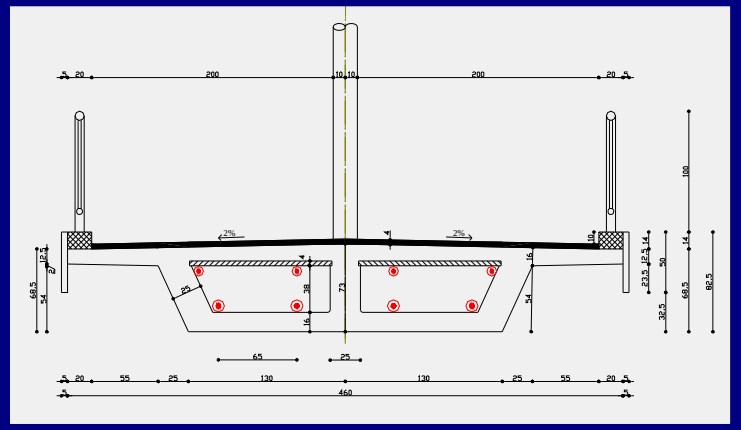
- Transversal girders:
  - main stiffener plates in the load bearing zones are 240 cm width.
  - secondary stiffeners, in the main span, are 16 cm width
- Bearing pads:
  - Fixed end bearings are placed on the left shore pier, designed as prestressed linear hinges (pin joints)
  - Free end bearings (in direction of bridge's center line) are placed
    - on the foundation pier of the pylon - elastomer, type NAL_b 200/250/41
    - on the right shore pier - elastomer, type NAL_b 200/250/107

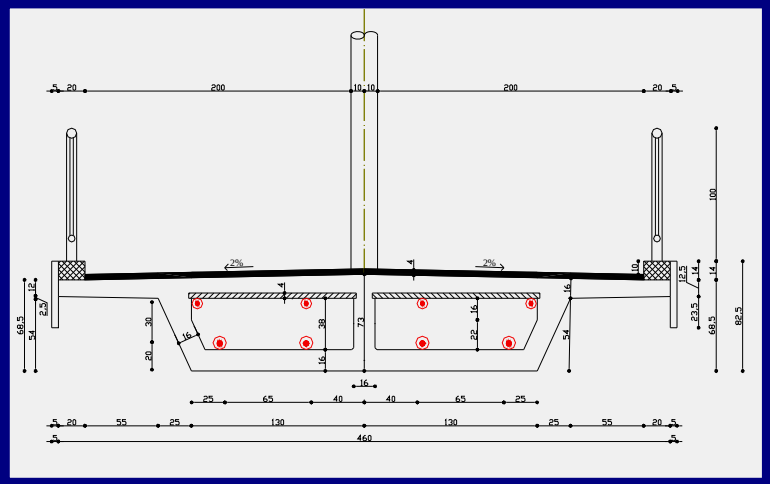
Description of bridge structures

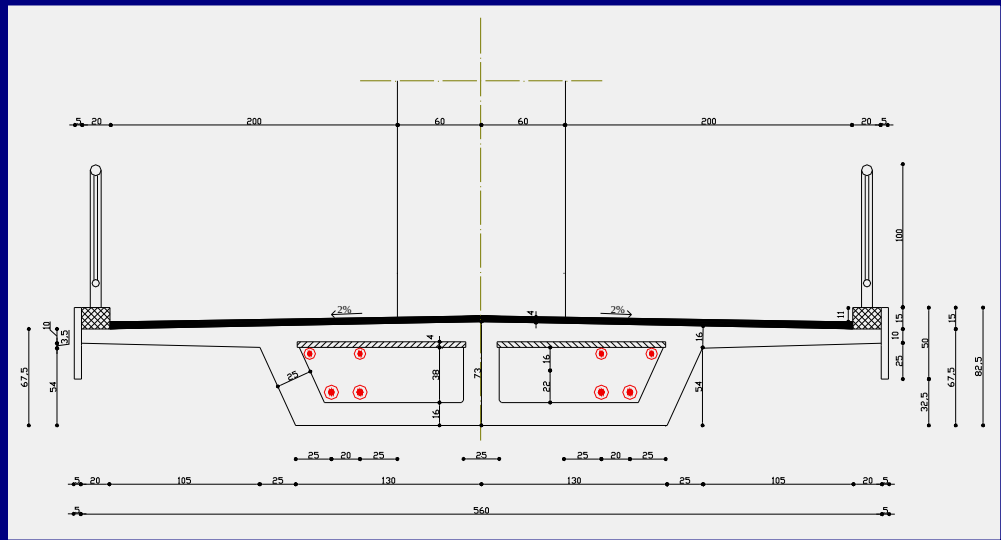
superstructure: **girder prestressing**

- After assemblage of the parts of main girder, the girder is made longitudinally continual by means of longitudinal prestressing of cables:





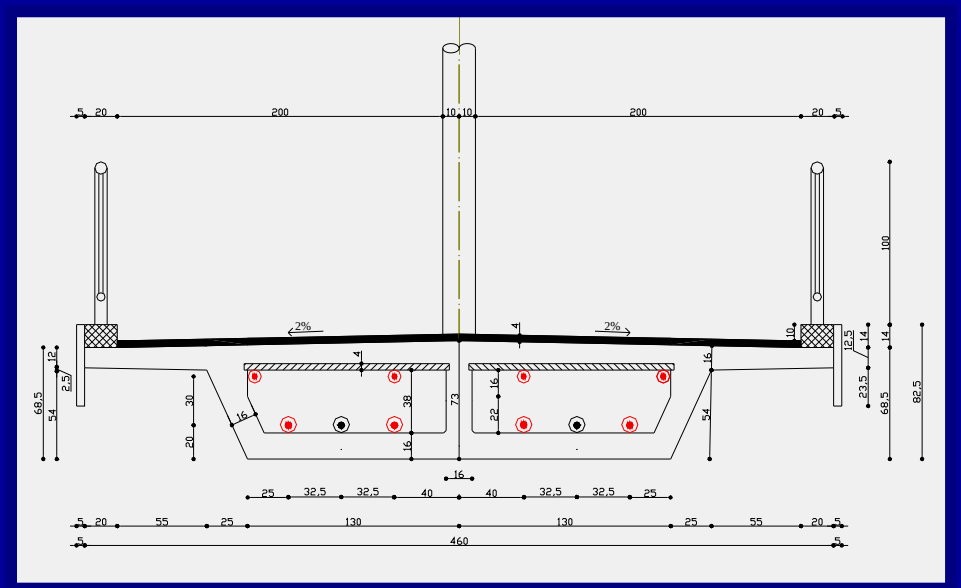


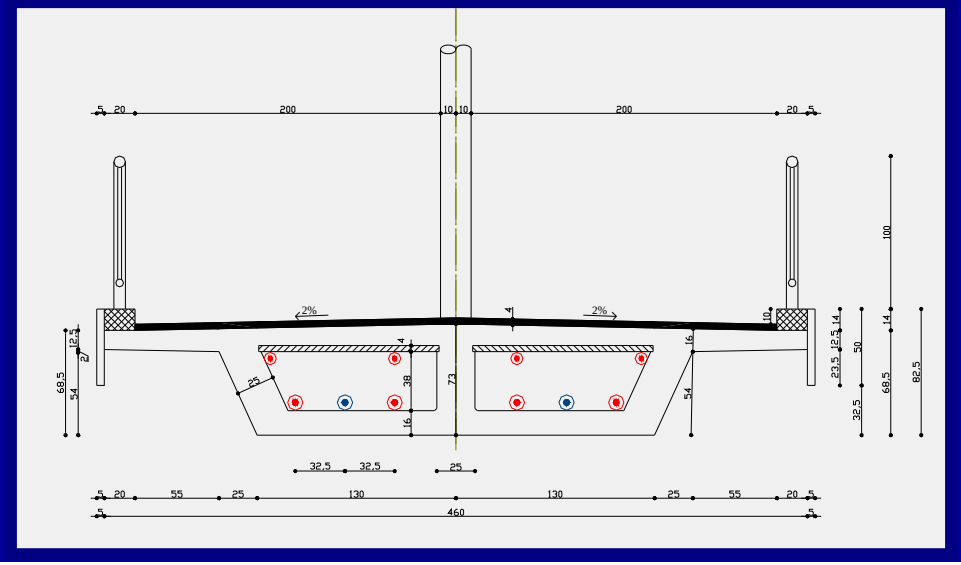


Description of bridge structures

superstructure: **girder prestressing**

Cross section of the main girder in IV i V field

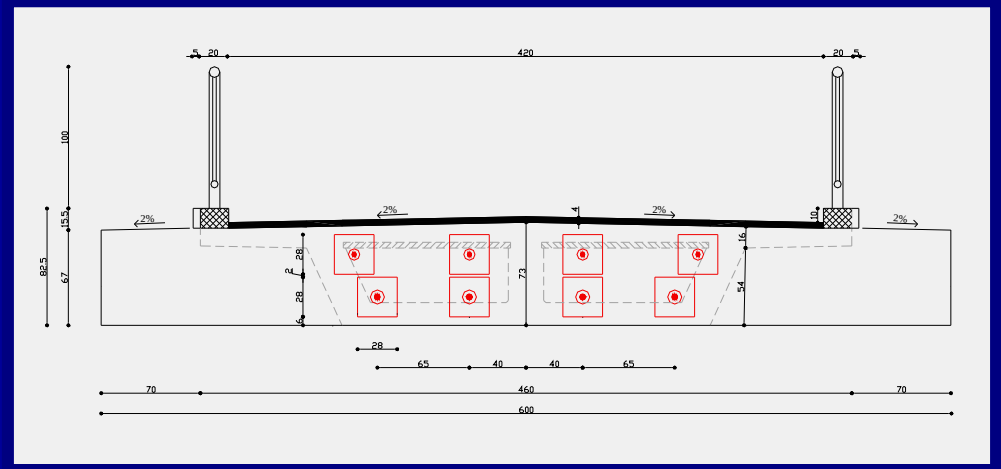




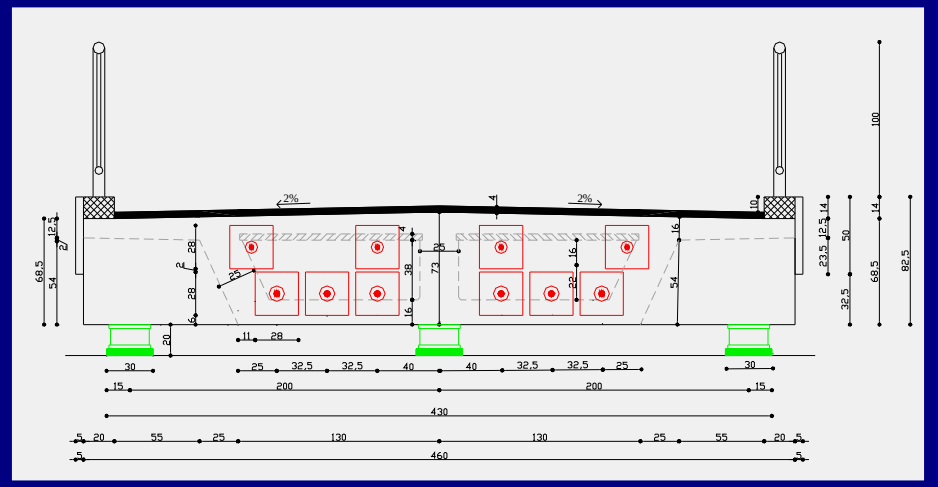
Description of bridge structures

superstructure: **girder prestressing**

- Anchorage zone at left shore pier

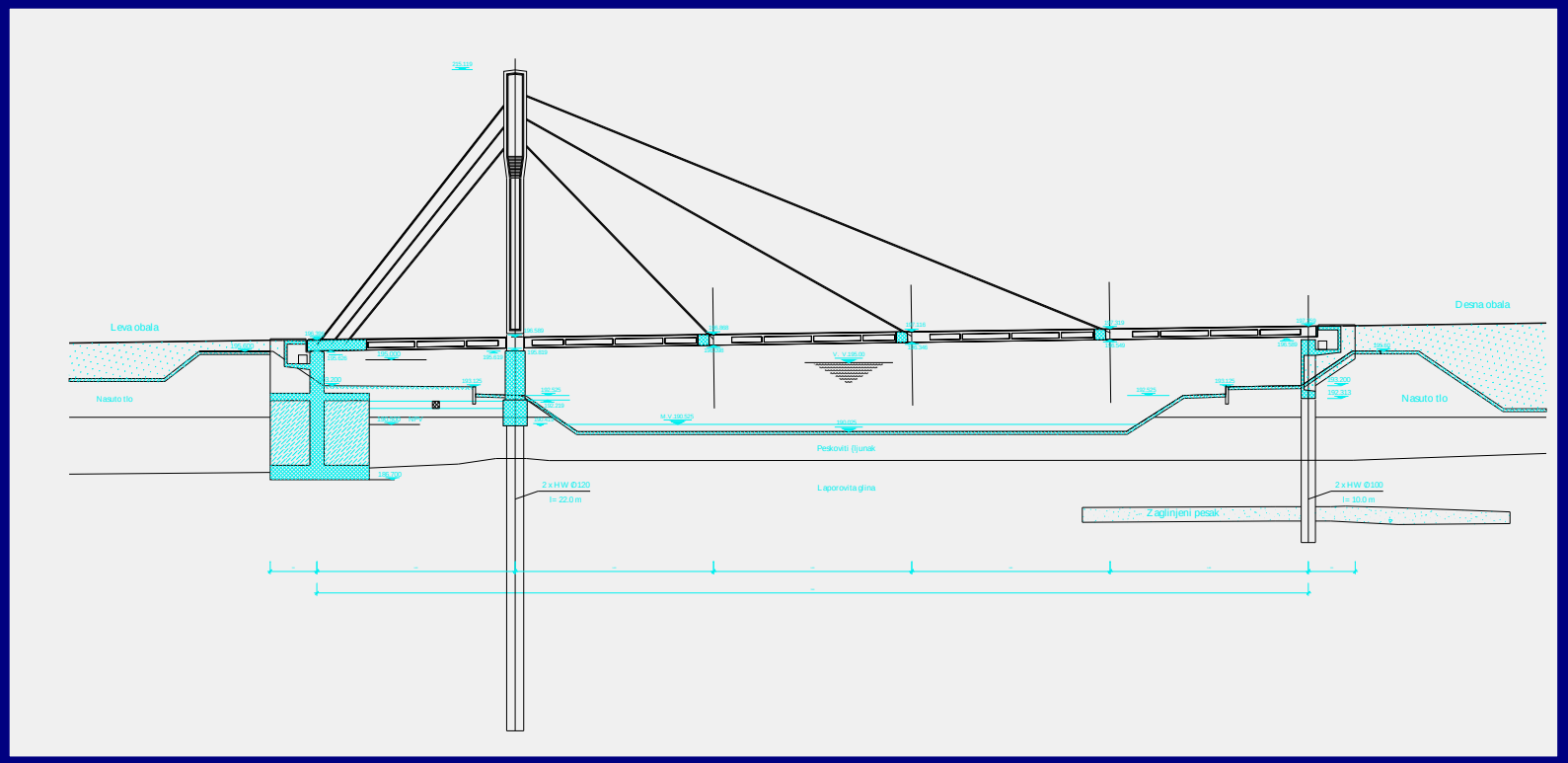


- Anchorage zone at right shore pier



Description of bridge structures

superstructure: **pylon**

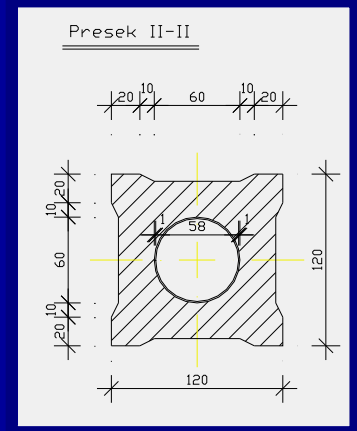


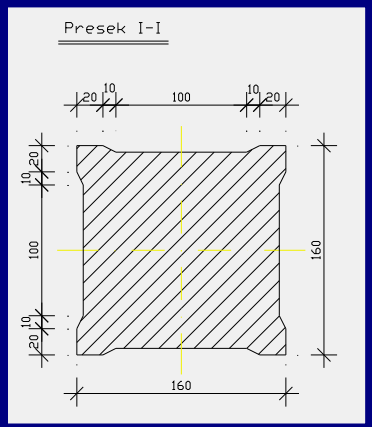
- Central concrete pier, (concrete grade 30), is placed 14 m on the left from the left abutment
- The pylon height (measured from footing to the top) is 19.5 m
- The pylon relies on the foundation pier, dimensions b/d/h = 140/ 400 /340 cm which relies on pile helmet (cushion head); piles are ϕ1200 mm in diameter, l=22.0 m (2HW drilled-in piles)

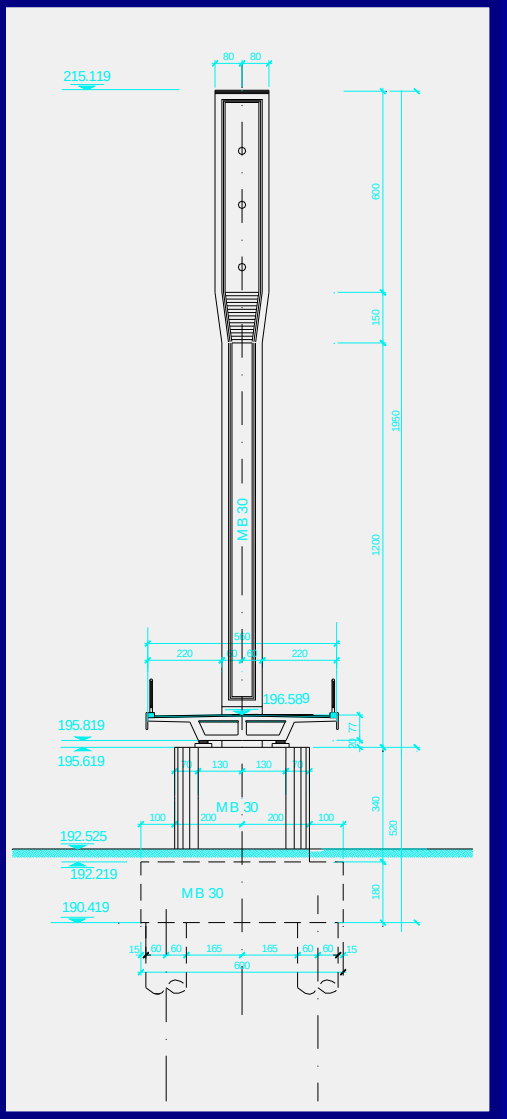
Description of bridge structures

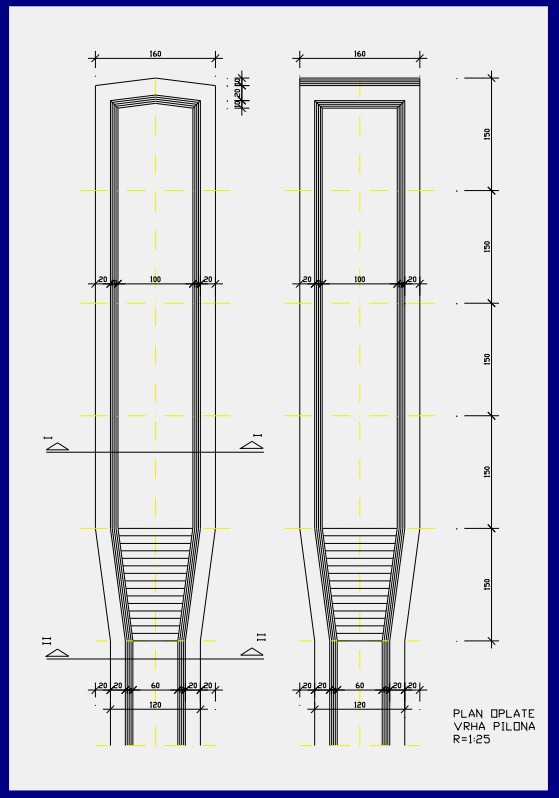
superstructure: **pylon**

- First 1.5 m of pylon height the cross section of square shape, solid concrete,
- following 10.5 m the cross section is voided and mould, 120 x 120 cm,
- next 1.5 m – the transition to the pylon head (solid mould cross section)
- head of pylon - solid mould cross section 160.0 x 160.0 cm



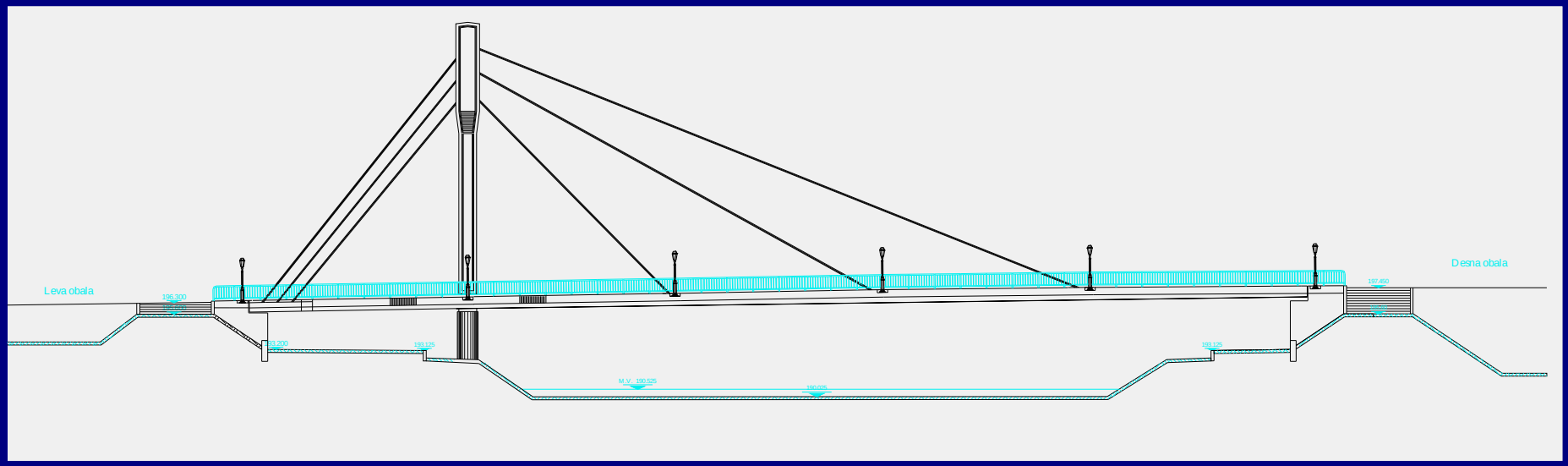






Description of bridge structures

superstructure: **stay cables**



- Three pairs of cables are placed between the left shore pier and the pylon, and they are bonded to the girder in the zone of bearing
- Between the pylon and the right shore pier three cables are placed, in the center line of the bridge. They are bonded to the girder at the main cross girders
- Stay cables are designed for the Freyssinet prestressing system

Description of bridge structures

superstructure: **stay cables**, type Freyssinet

220. THE FREYSSINET STAY CABLE

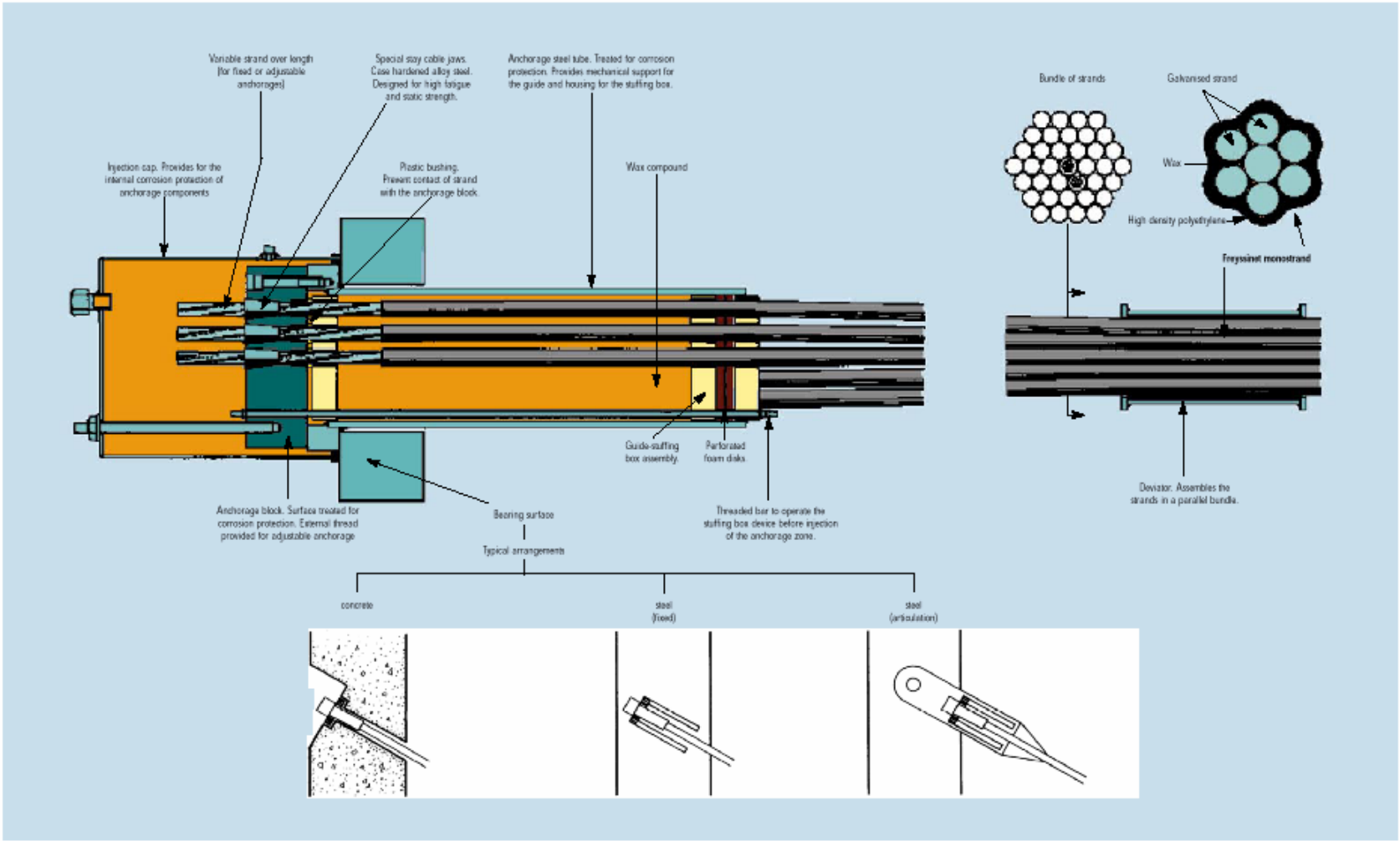
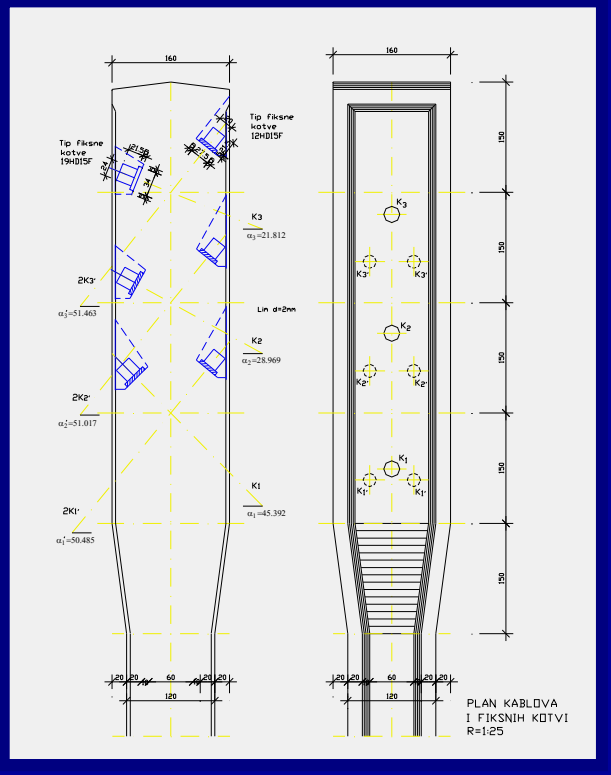


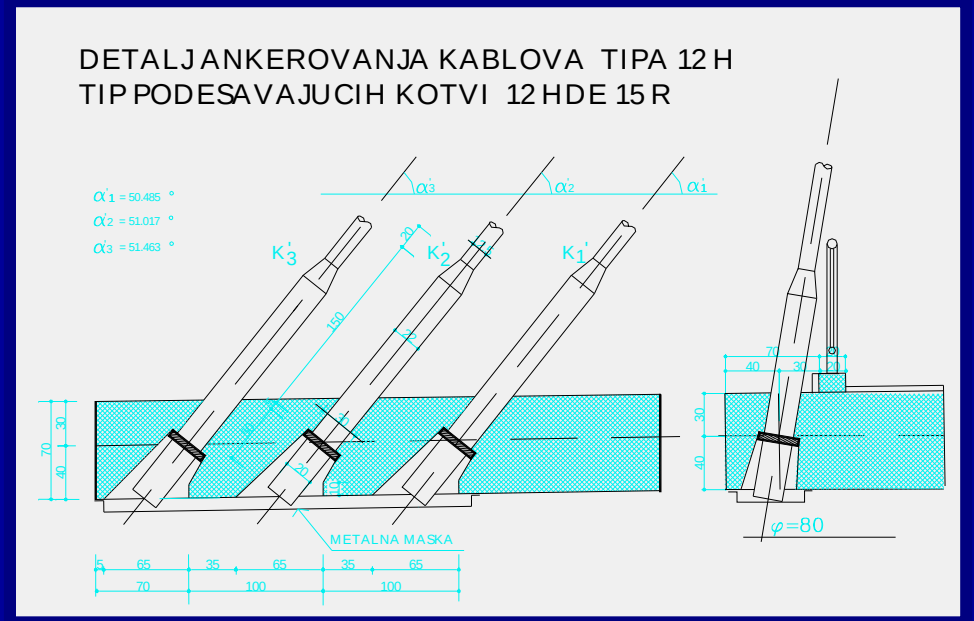
Fig. 19 - The Freyssinet anchorage

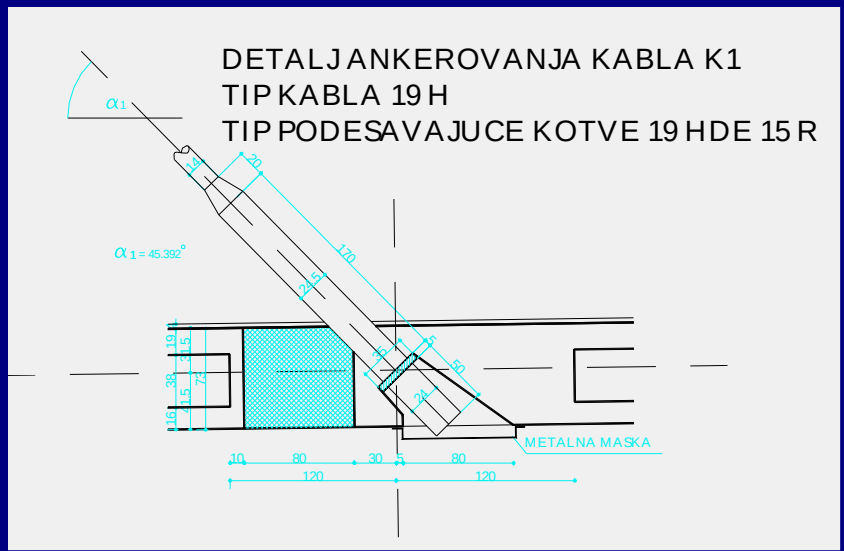
Description of bridge structures

superstructure: **stay cables**

- Anchorage types :
  - the cables are anchored in the girder at the zone of main transversal girders, transferring force by adjustable anchorage
  - anchorages at the pylon are fixed.





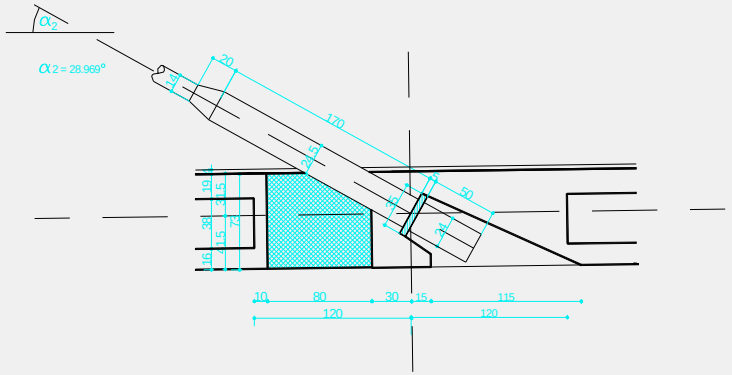


Description of bridge structures

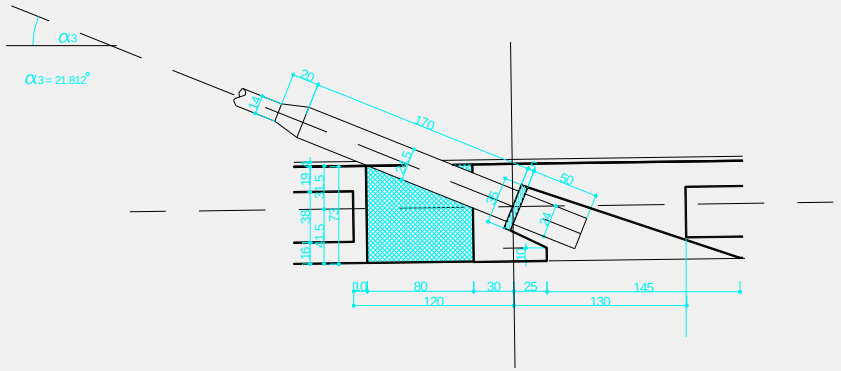
superstructure: **stay cables**

Details of adjustable anchorage

DETALJ ANKEROVANJA KABLA K2
TIP KABLA 19 H
TIP PODESAVAJUCE KOTVE 19 HDE 15 R



DETALJ ANKEROVANJA KABLA K3
TIP KABLA 19 H
TIP PODESAVAJUCE KOTVE 19 HDE 15 R



Description of bridge structures

superstructure: **stay cables design**

- The criteria considered for structural design of stay cables:
  - ULS: load bearing capacity (maximal tensile force)
  - SLS: deformation of spanning structure
  - SLS and ULS: deformation and stability of pylon
  - building and assemblage ability of structural segments
  - possibility of replacing one cable
  - the verification of the fatigue strength is not necessary done for pedestrian bridges, according to EUROCODE-2, appendix 107-cable-stayed bridges
- Ultimate limit state is defined following EUROCODE-2, with safety factor γ_s=1.50 for nominal tensioning stress for prestressing steel
- Serviceability limit state is defined following EUROCODE-2, for frequent constellations of loads, so that the tensile stress in cables does not overcome 0.45 f_{pk}

Description of bridge structures

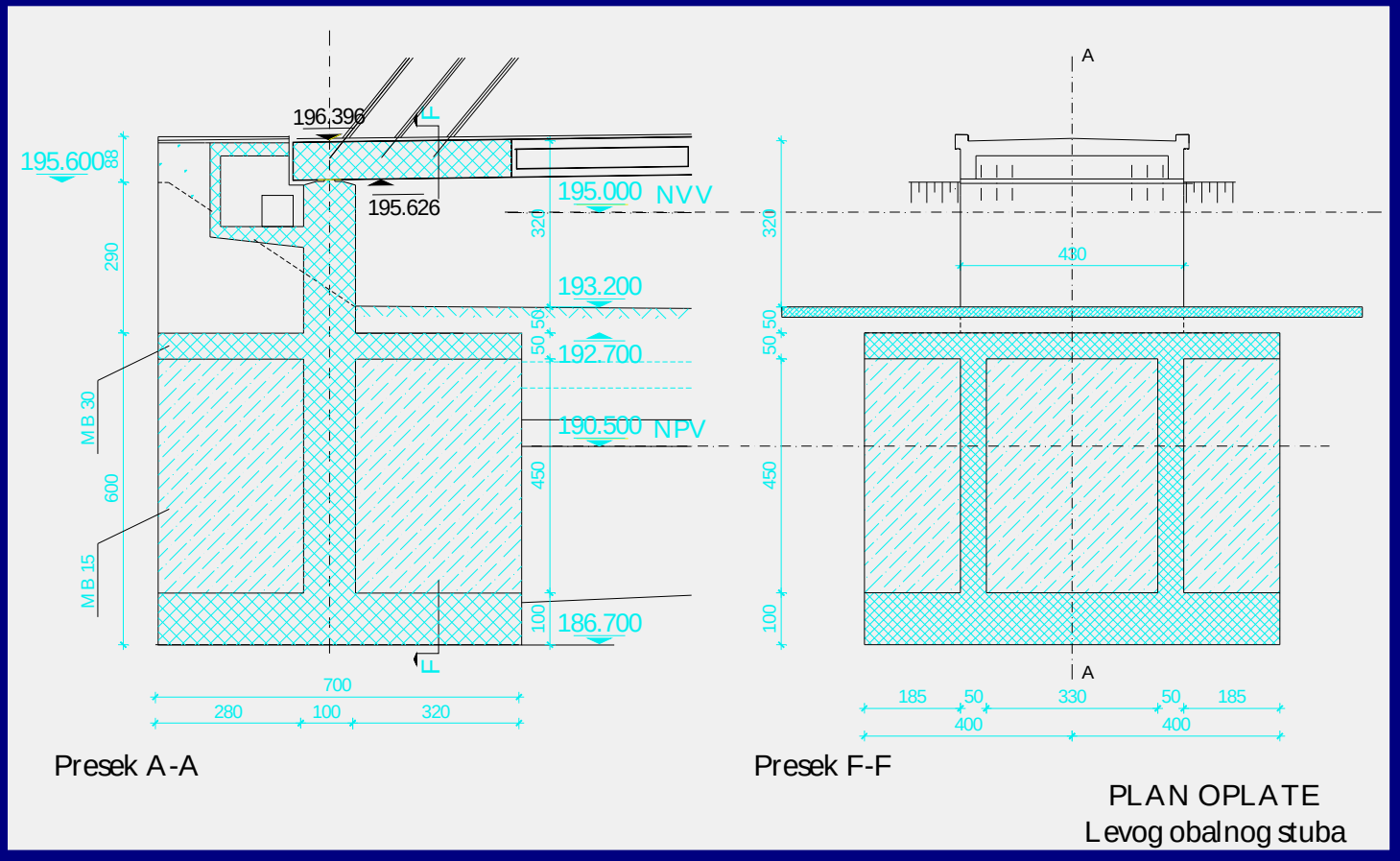
superstructure: **stay cables design**

- Prestressing forces inserted into structure by the stay cables, are designed according to the following constraints :
  - the pylon is kept vertical under action of dead load
  - admissible stress and strain range in structural elements (mainly for main spanning structure mostly)

- The prestressing of stay cables is performed following the specific prestressing program

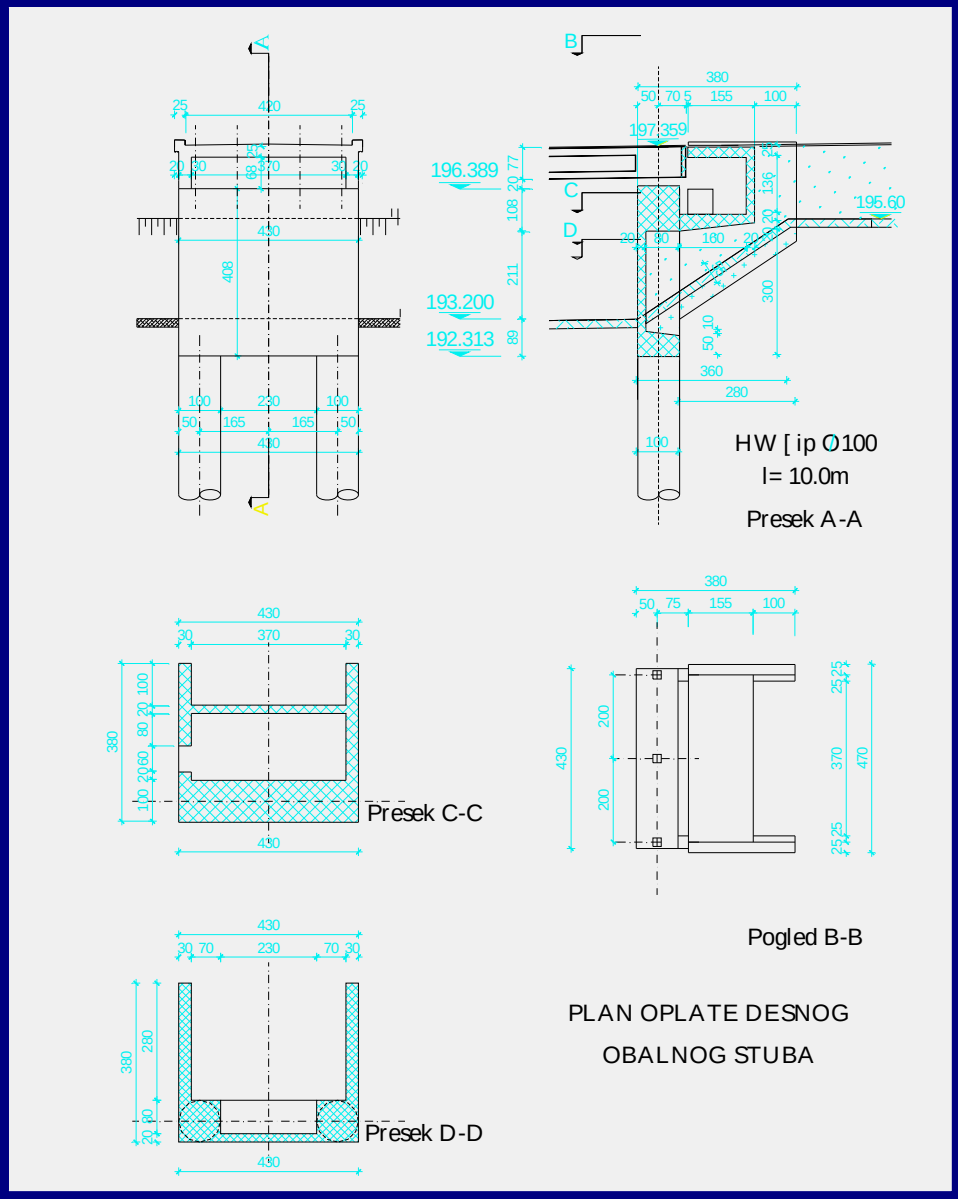
Description of bridge structures
substructure

- Substructure of the bridge consists of two shore piers (abutments), and the foundation of the pylon.



Description of bridge structures

substructure

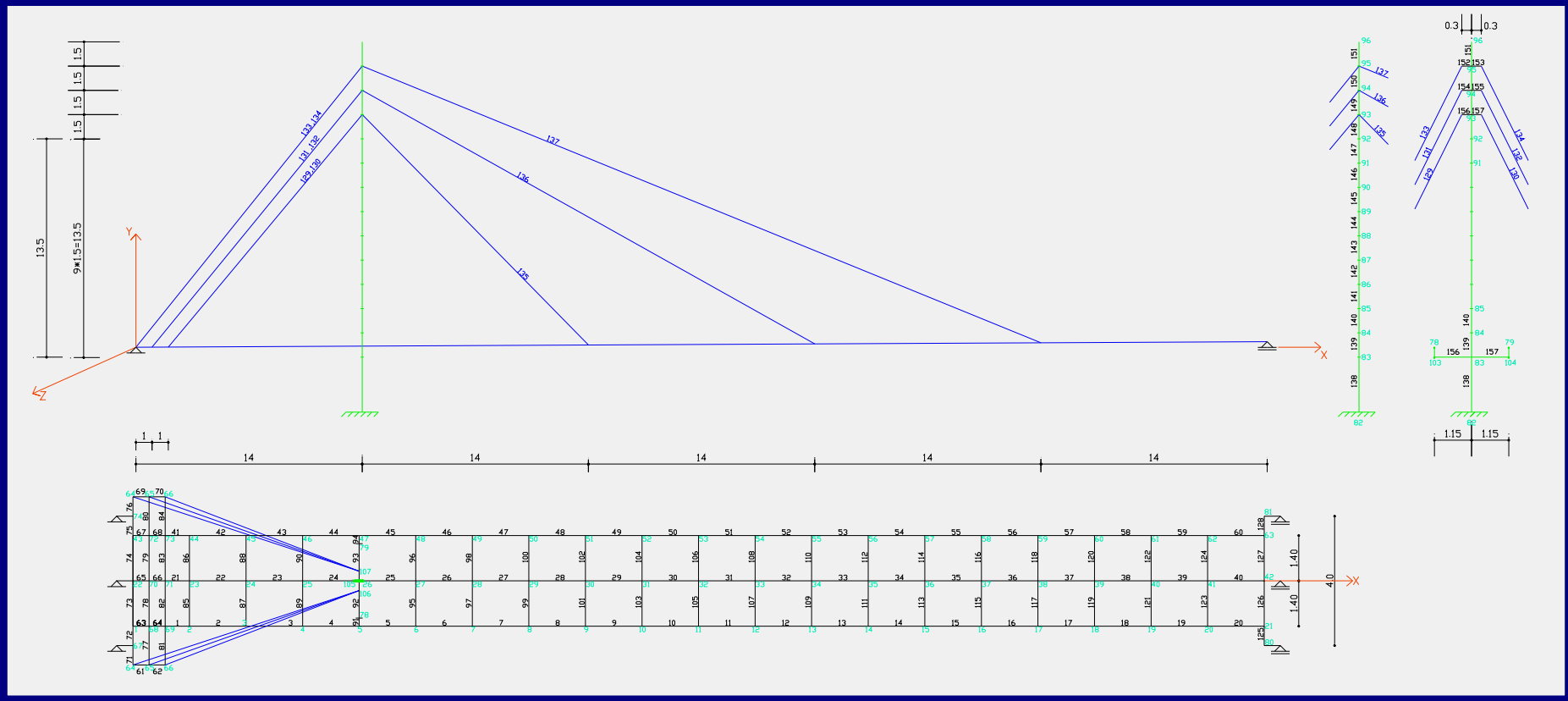


Analysis of bridge structures

static analysis

- Three calculation models have been created to serve static analysis of the bridge, with element properties according to the building phase

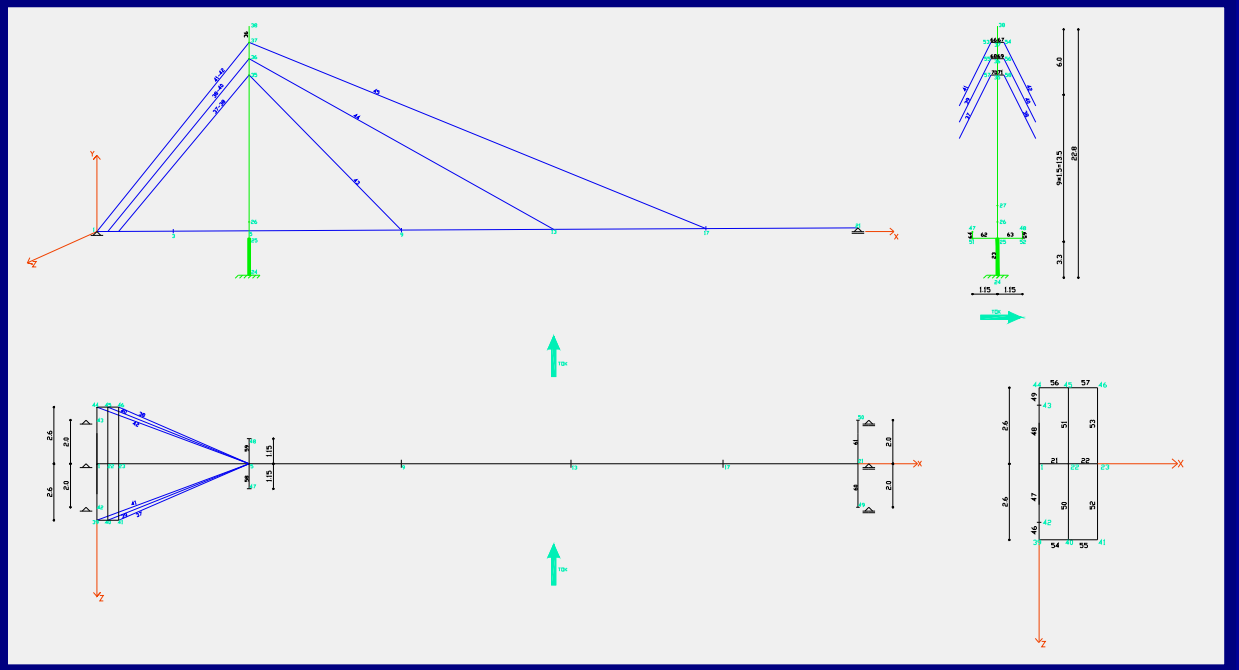
- calculation **model 1** - space frame, (with decomposition of the main girder in three girders)



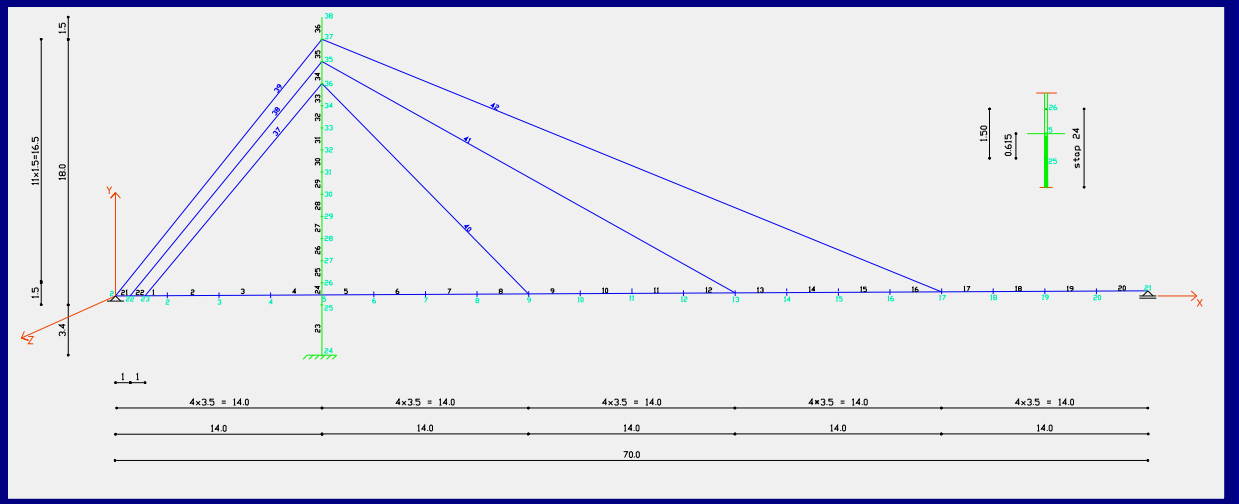
Analysis of bridge structures

static analysis

- calculation **model 2**
  - space frame, with composed main girder

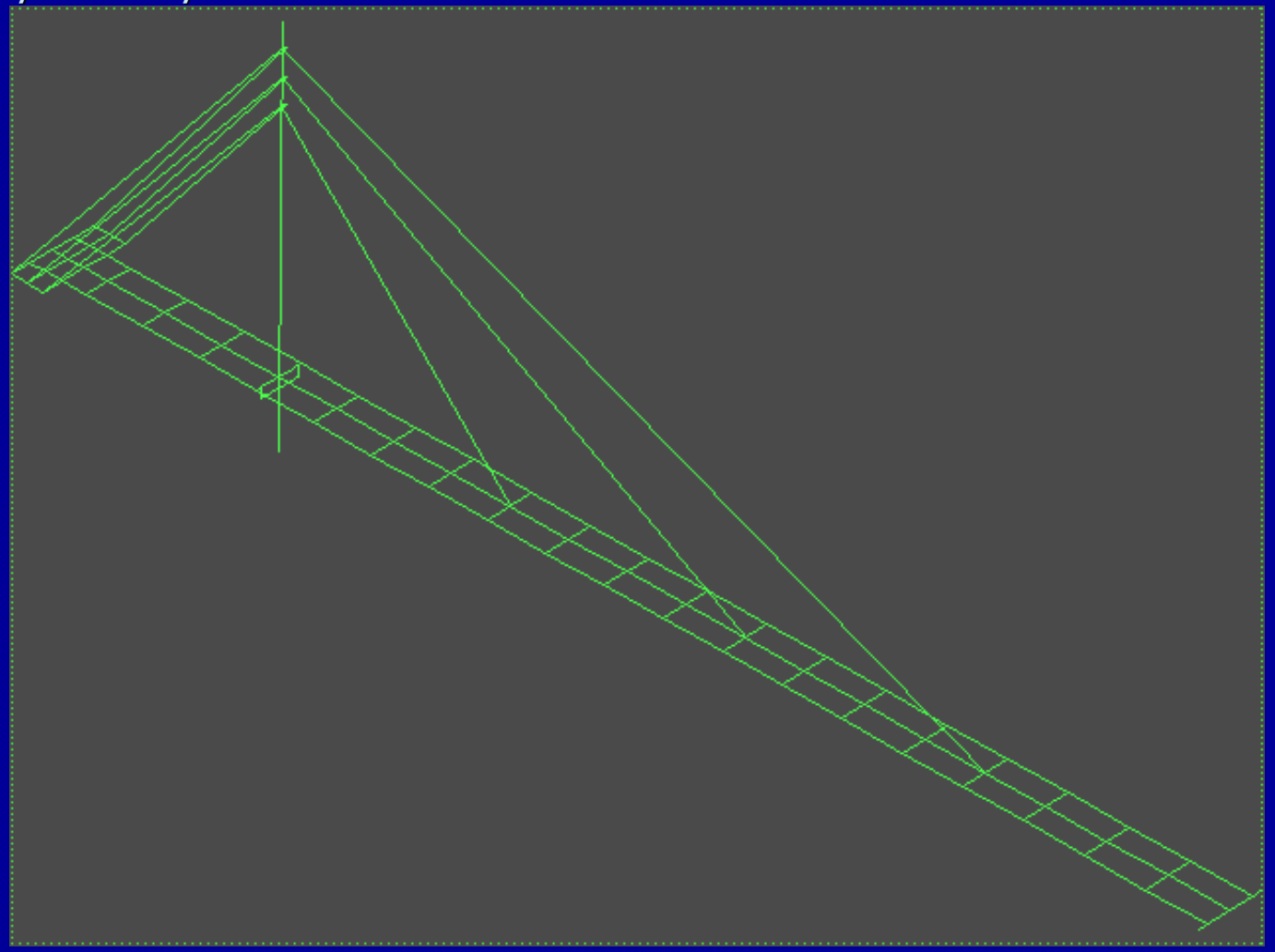


- calculation **model 3**
  - plane frame
- model 3 is used for calculation according to the Second odred theory



Analysis of bridge structures
static analysis

- calculation **model 1**
  - geometry of the system

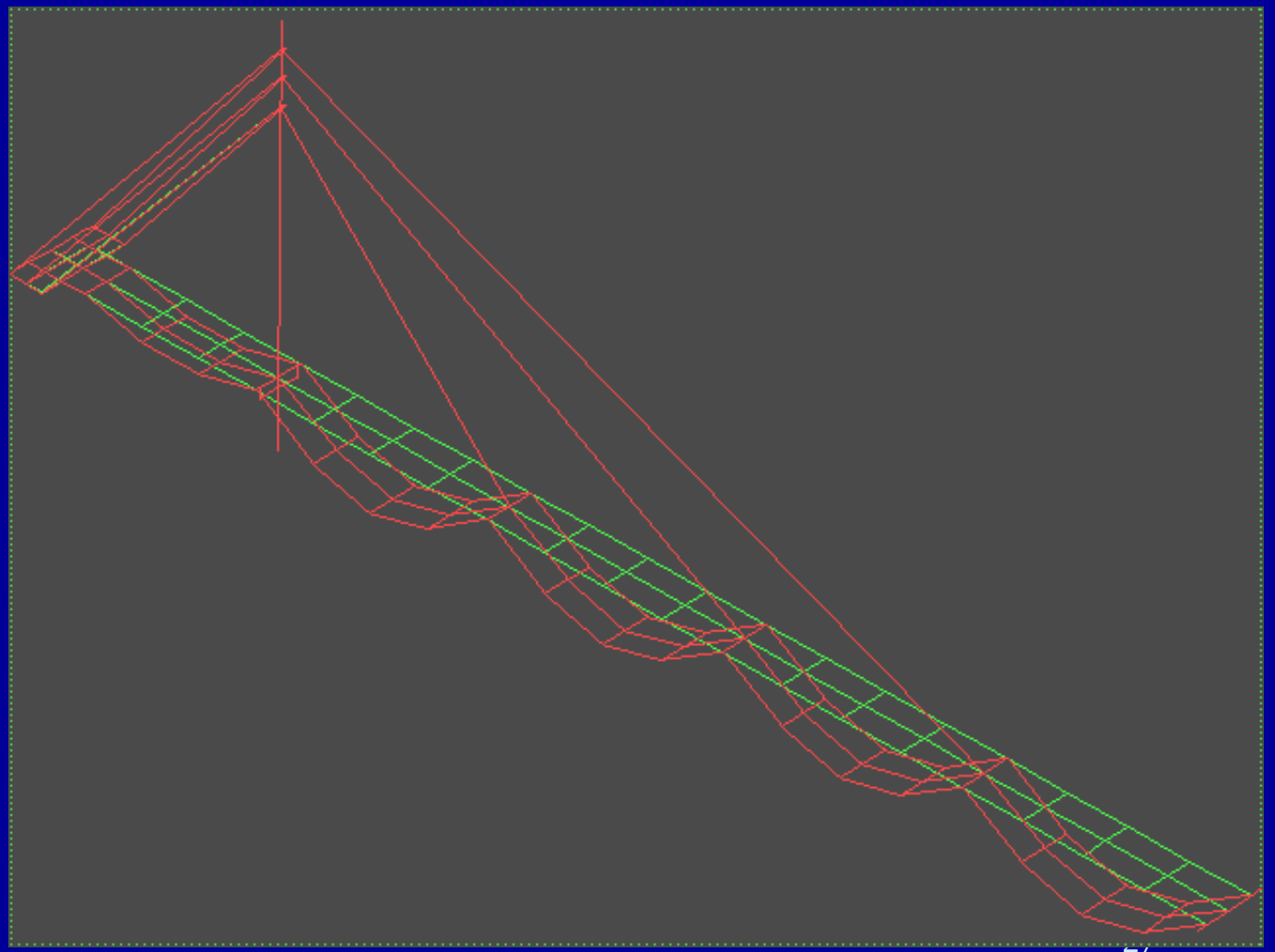


Analysis of bridge structures

static analysis

- Calculation **model 1**

  - deformation of the system in the phase of assembling (F02), before longitudinal continuity is done

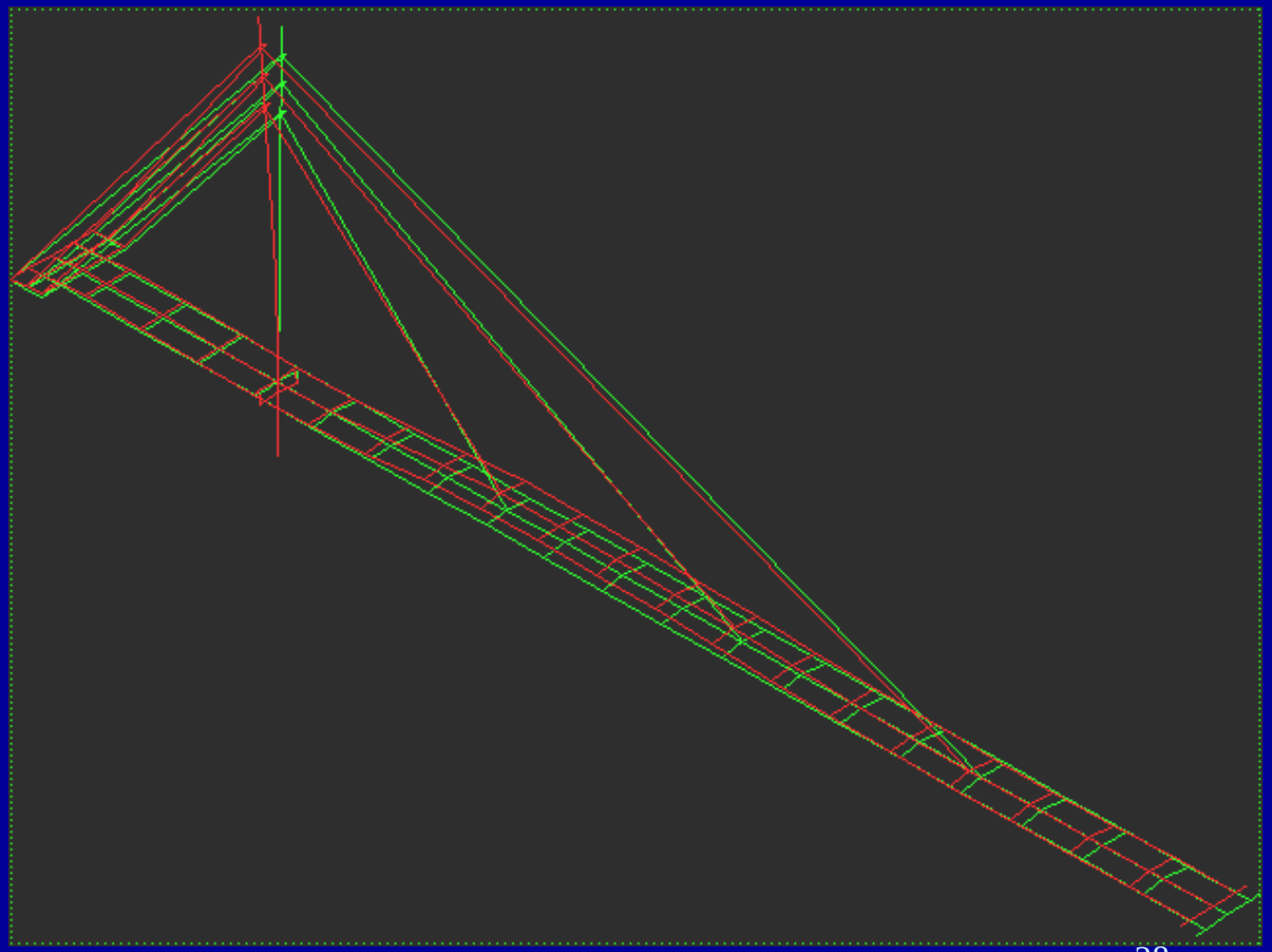


Analysis of bridge structures

static analysis

- Calculation **model 1**

  - deformation of the formed system under dead load action, in time $t=t_0$

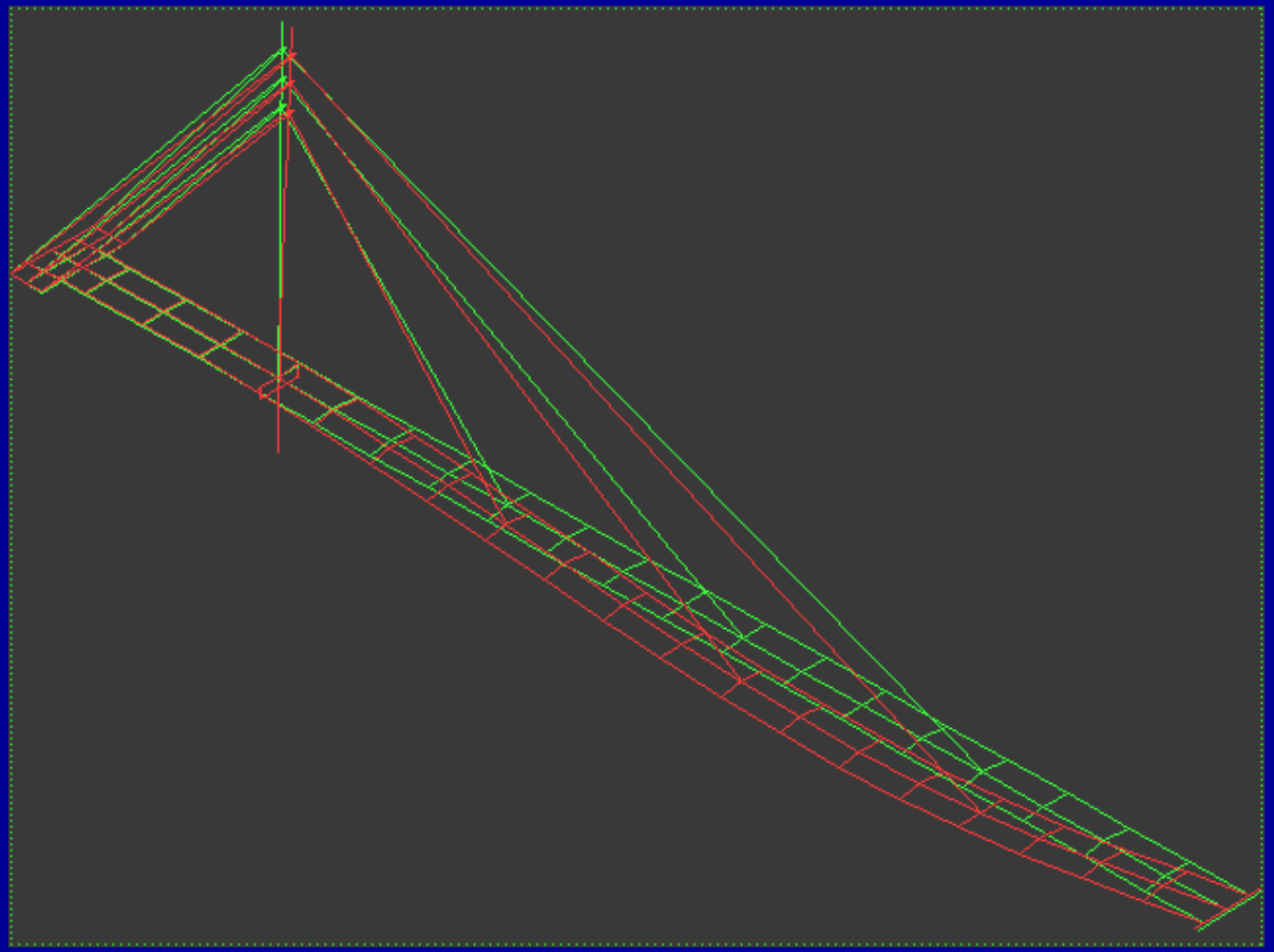


Analysis of bridge structures

static analysis

- Calculation **model 1**

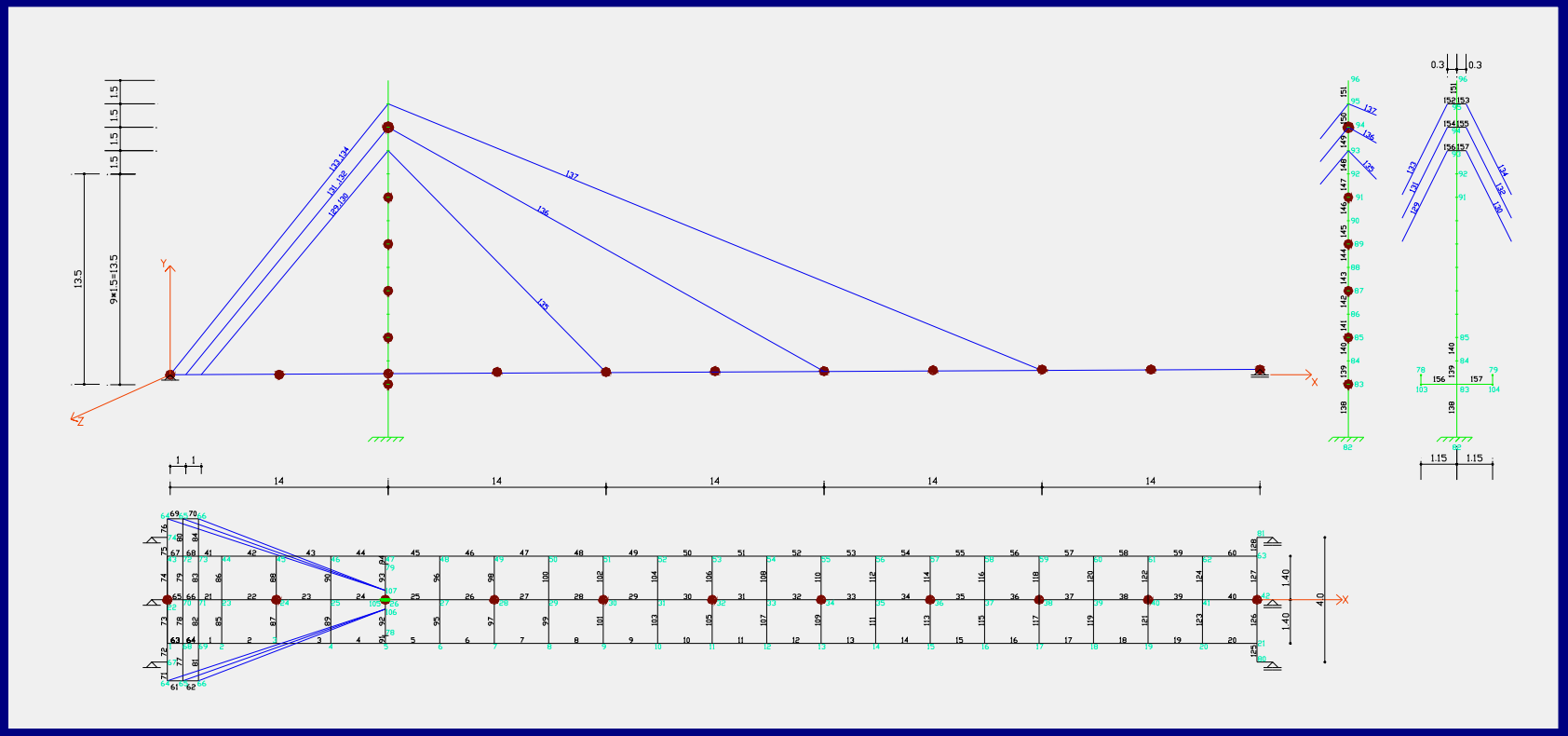
  - deformation of the formed system under dead load and service load, in time $t=t_0$



Analysis of bridge structures
dynamic analysis

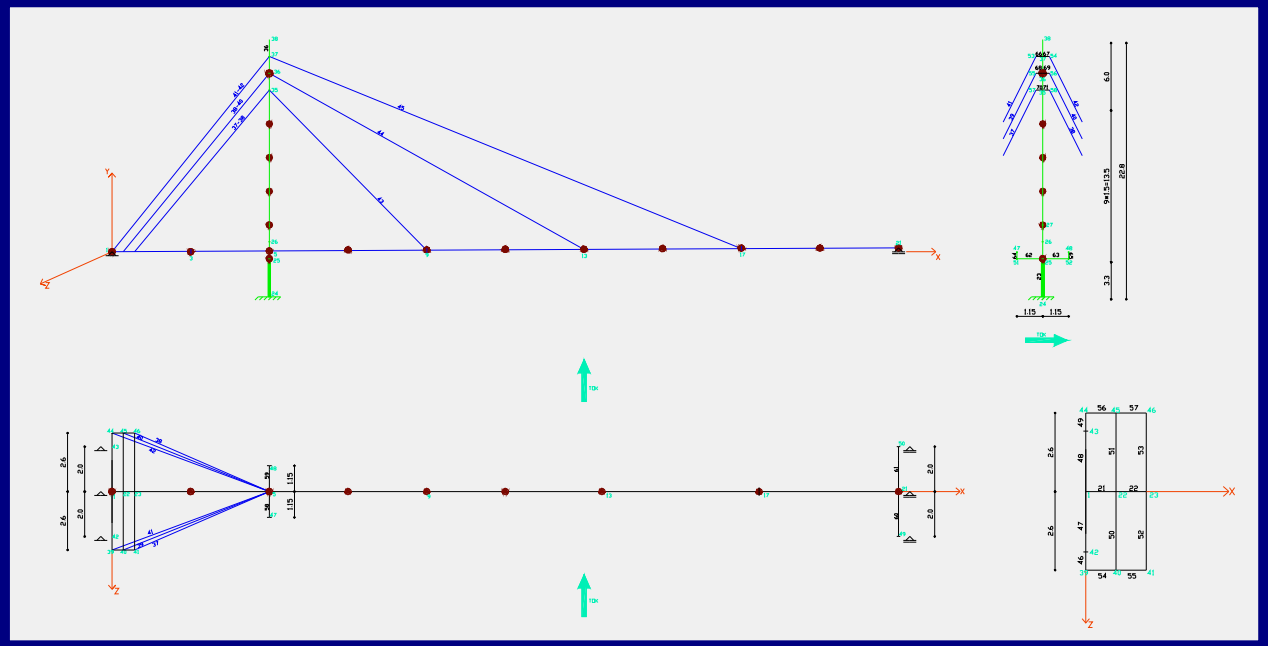
- Three calculation models have been designed to serve dynamic analysis. Continual masses have been represented by system of discrete masses:

- calculation **model D1** - space frame, with 11 + 6 oscillating masses

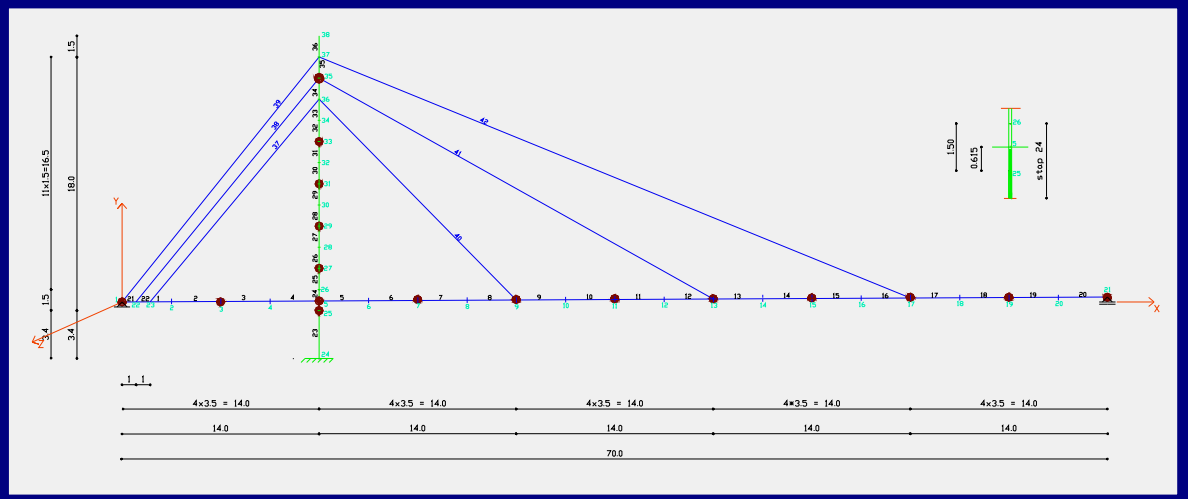


Analysis of bridge structures
dynamic analysis

- calculation **model D2**
  - space frame, composed main girder with 11 + 6 oscillating masses



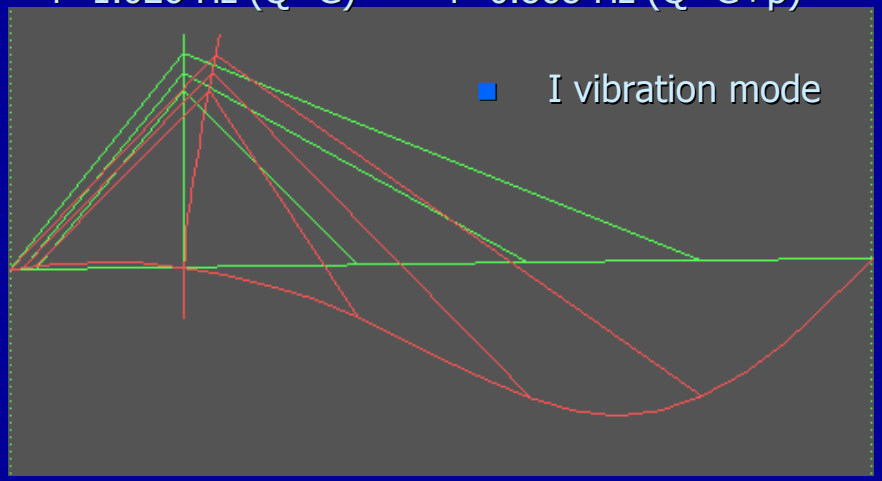
- calculation **model D3**
  - plane frame, 11 + 6 vibrating masses



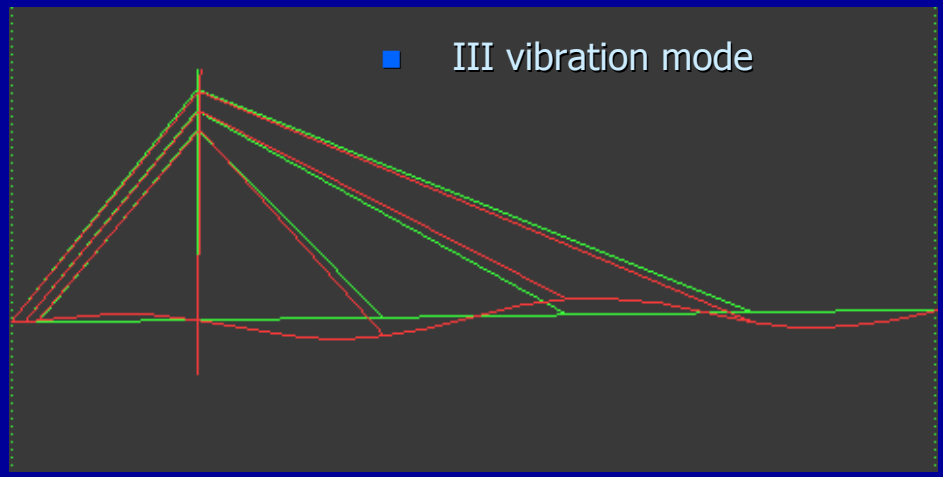
Analysis of bridge structures
dynamic analysis

- calculation **model D3**: modes of vibrations of the structure, vertical direction
- Natural frequency of principal mode
  f=1.026 Hz (Q=G) f=0.868 Hz (Q=G+p)

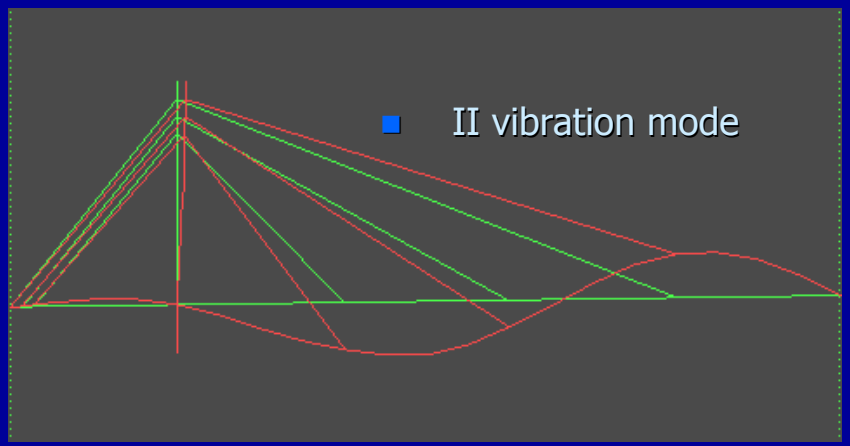
I vibration mode



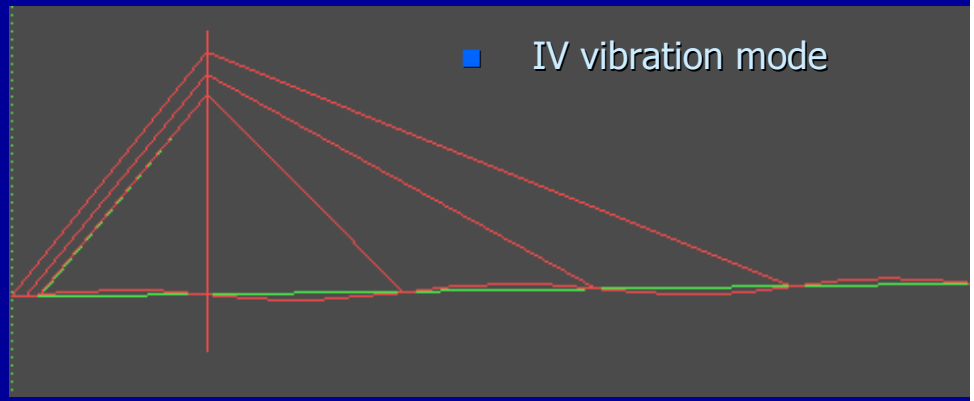
III vibration mode



II vibration mode



IV vibration mode

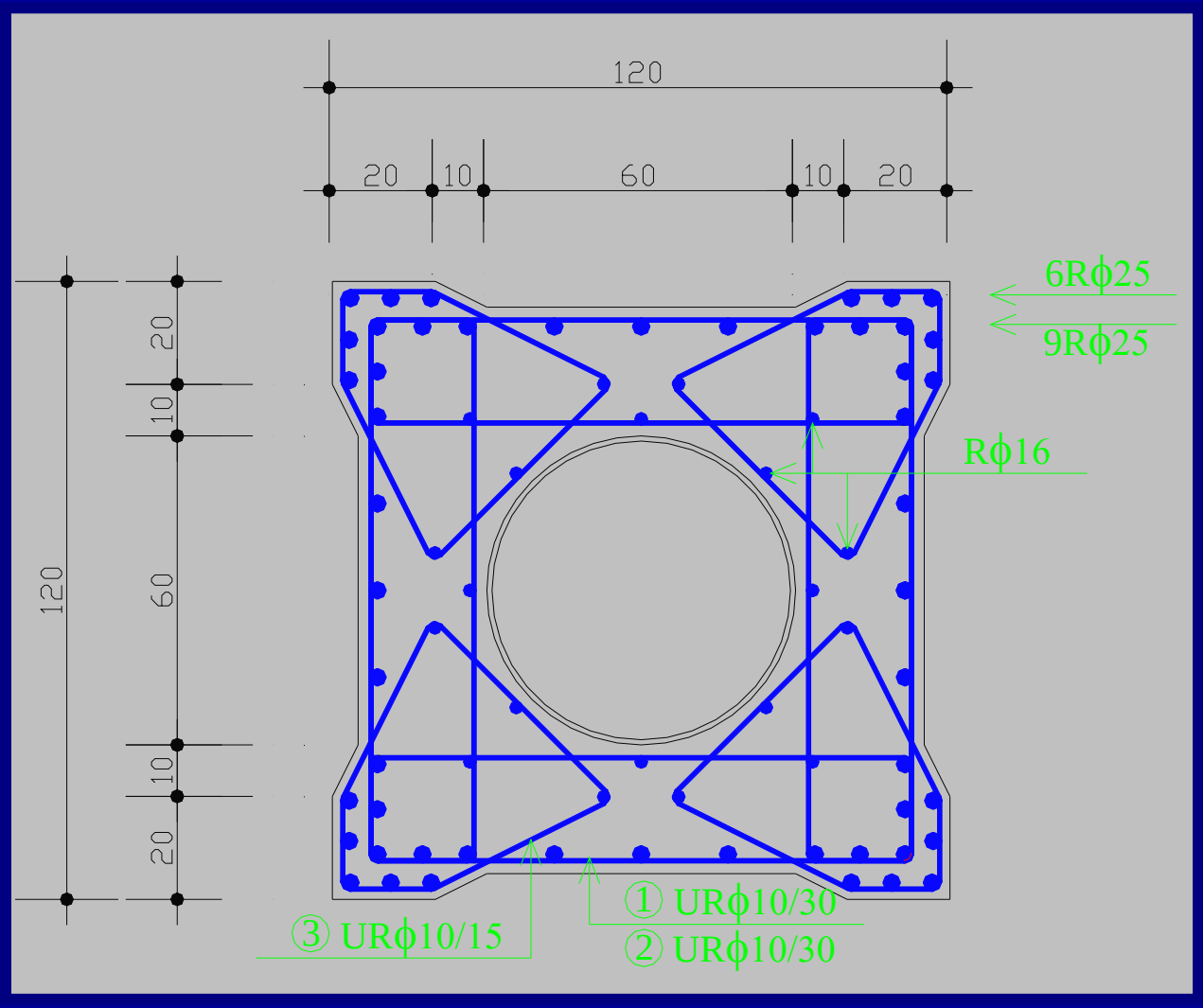


Some details...

- reinforcement plans
- assemblage of structures

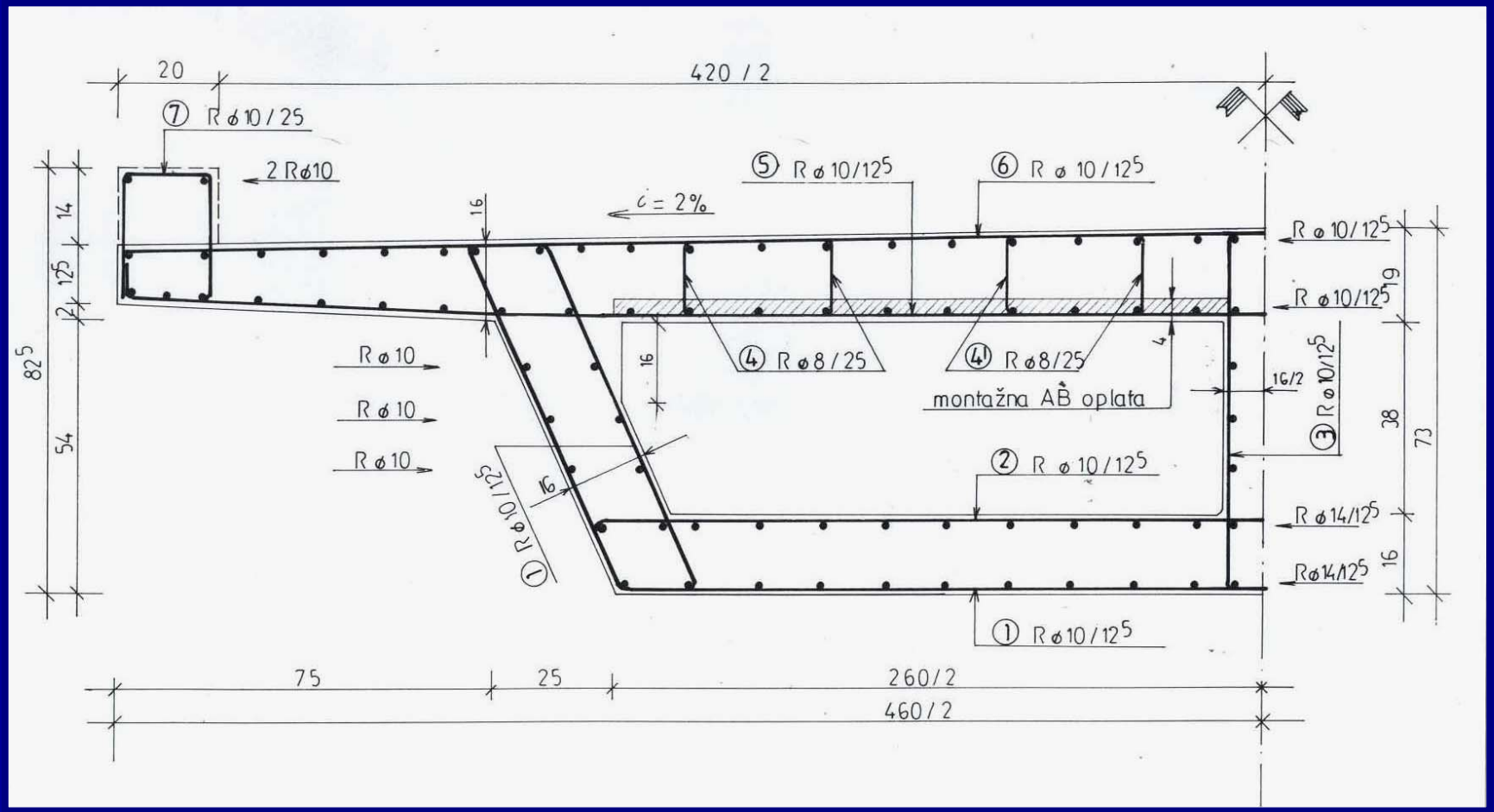
Reinforcement plans

- Reinforcement of the pylon



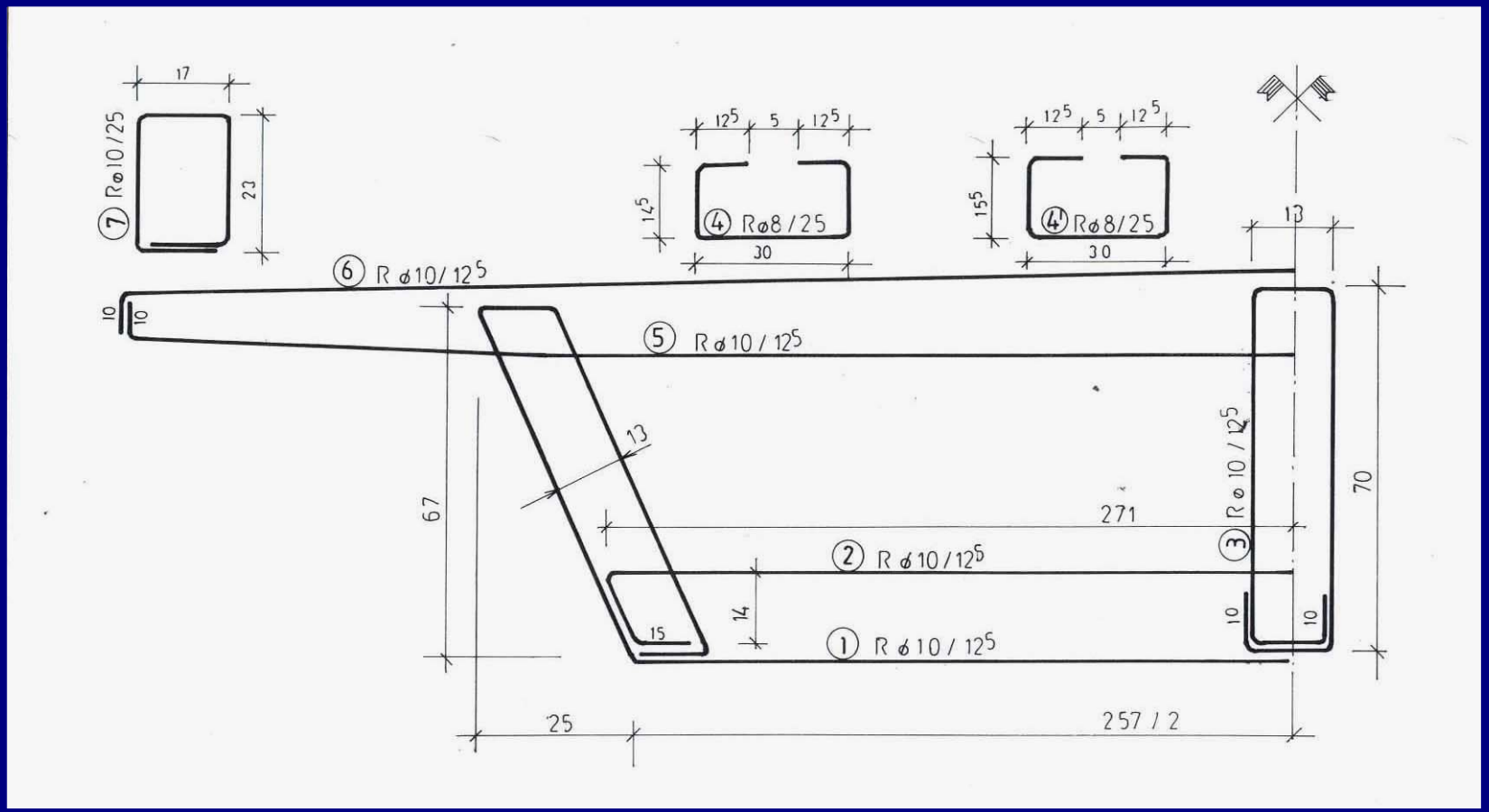
Reinforcement plans

- Reinforcement of the main girder



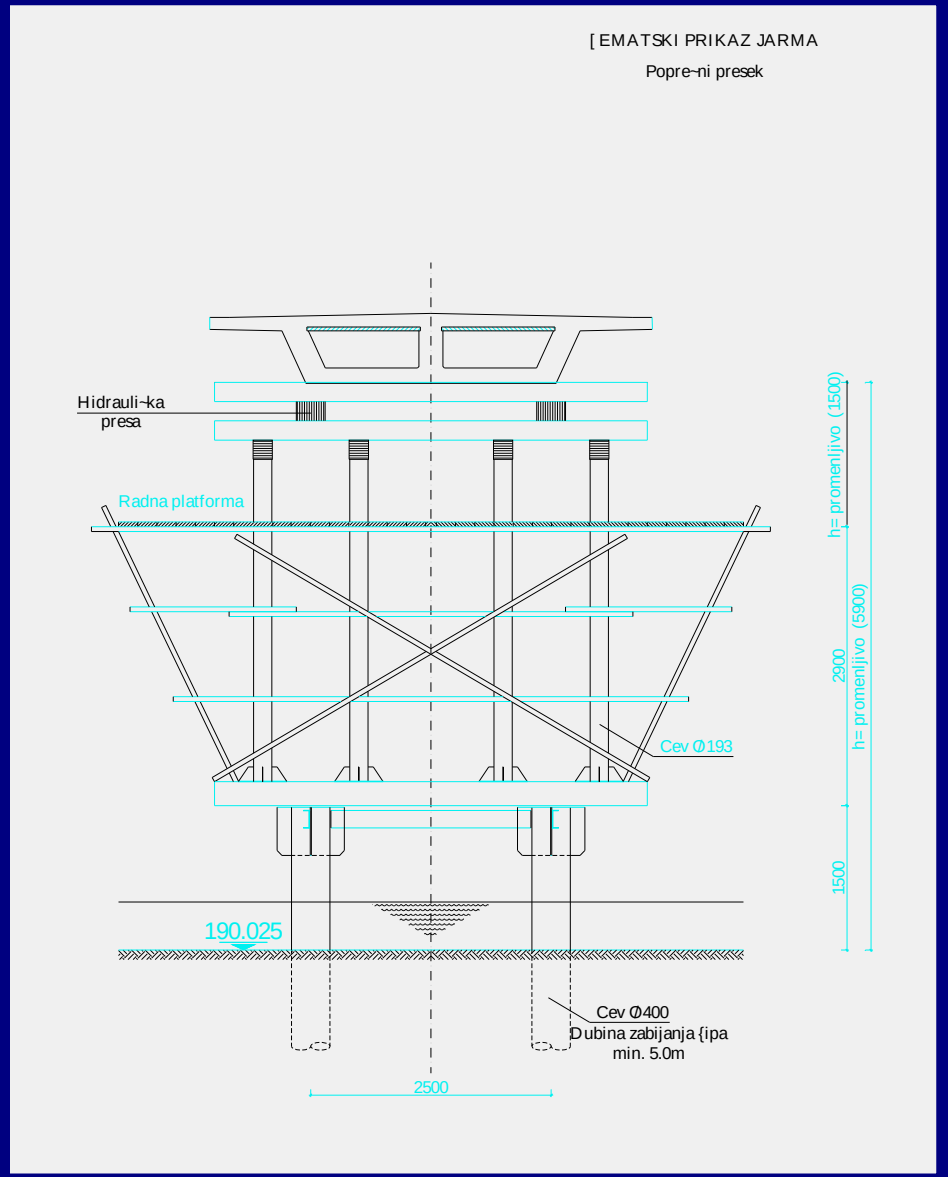
Reinforcement plans

- Reinforcement of the main girder

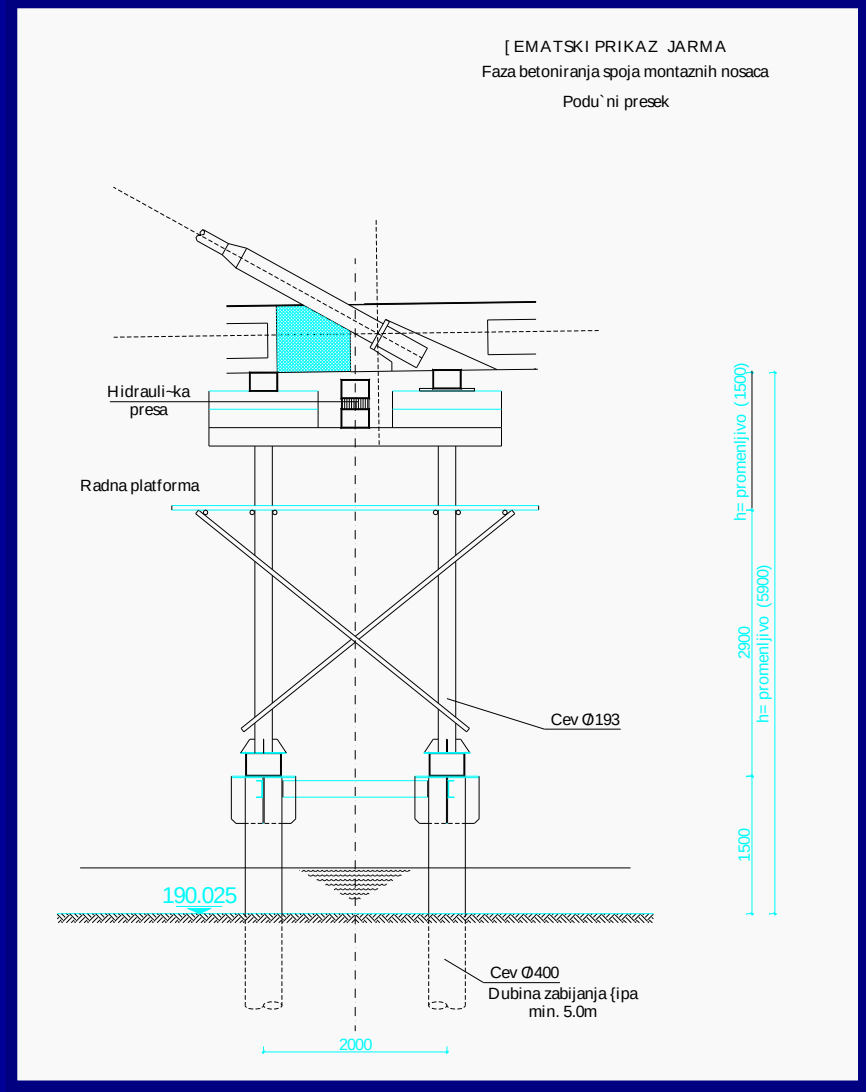


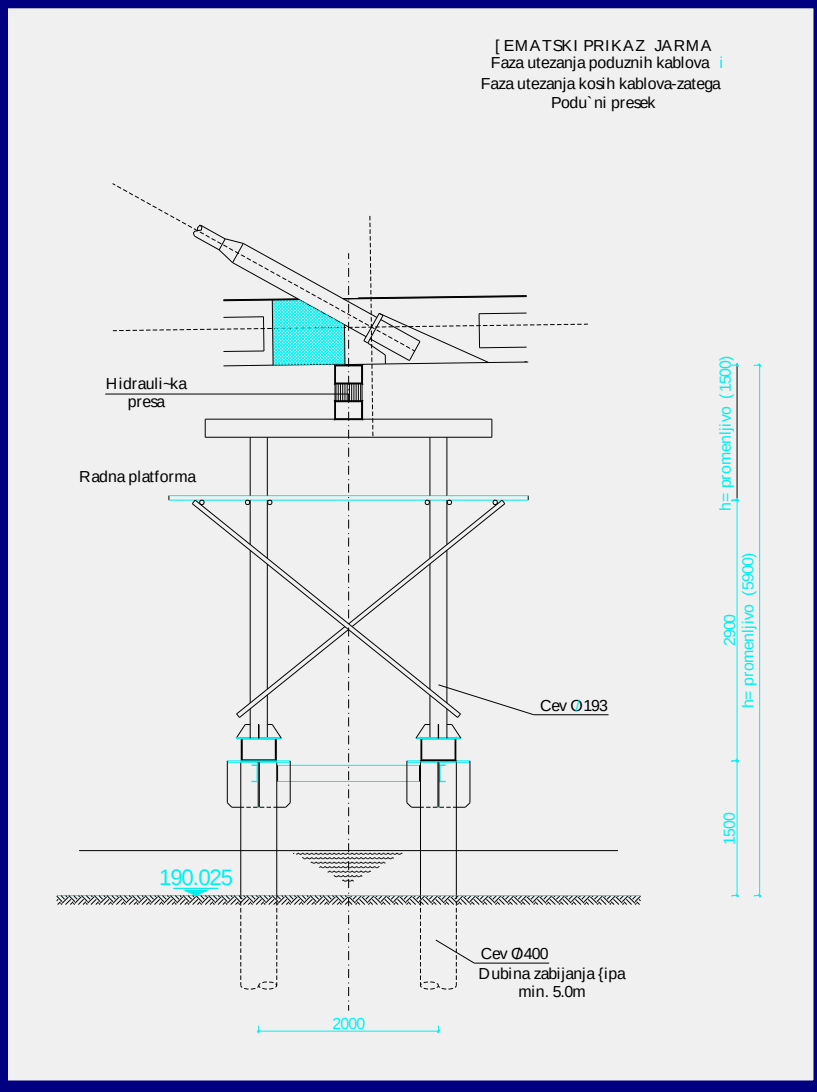
Assembling of main girder

- For the accepted concept of precast building, during the phase of assemblage the girder relies on the temporary bearings - yokes



Assembling of main girder





Pedestrian bridge over the river Nišava in Niš