PROJEKTIRANJE I ANALIZA MOSTA PELJEŠAC

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Sažetak: Pelješki most duljine 2404 m svrstava se, ne samo po kompleksnosti gradnje nego i po složenosti projekta, među najzahtjevnije mostove na svijetu. Nalazi se u području iznimno visoke seizmičke aktivnosti, s projektnim ubrzanjem tla narazini čvrste stijene PGA=0,34 g i zahtijevanim proračunskim ubrzanjem 0,54 g. Kompaktna stijena nalazi se na dubini do 80 m ispod morskog dna, što rezultira iznimno zahtjevnim temeljenjem na pilotima duljine do 124 m. Na lokaciji mosta pušu jaki vjetrovi, s referentnom brzinom koja prelazi 34 m/s. Posebna je pozornost posvećena osiguravanju stabilnosti mosta u slučaju udara vjetrova na mah i potrebi da je most otvoren u svim vremenskim uvjetima. Ispunjavanje ključnih kriterija kvalitetnog konstruiranja, kao što su stabilnost, trajnost, ekonomičnost i mirno uključenje u krajolik, rezultiralo je inventivnom koncepcijom ekstrados mosta i integralnom hibridnom strukturom s pet središnjih raspona duljine po 285 m. Tako koncipirana konstrukcija osigurava potrebnu seizmičku stabilnost mosta bez ugradbe velikih ležajeva i dodatnih seizmičkih prigušivača, što potvrđuju i brojne složene nelinearne proračunske analize, koje su detaljno predstavljene u radu. U svim nelinearnim analizama uzima se u obzir interakcija temeljnog tla i konstrukcije mosta. Most Pelješac će se nakon izgradnje svrstati među 5 najvećih i najatraktivnijih mostova u Europi izgrađenih u početku 21. stoljeća.

Ključne riječi: ekstrados most, kose zatege, duboko temeljenje, piloti, potres, vjetar, monitoring

DESIGN AND ANALYSIS OF THE PELJEŠAC BRIDGE

Abstract: The 2,404 m long Pelješac Bridge ranks among the most demanding bridges in the world, not only in terms of complexity of construction, but also in terms of complexity of design. It is located in the area of high seismic activity, with the peak design acceleration of soil at the bedrock level PGA=0.34g, and the required design acceleration of 0.54 g. The compact bedrock is located at a depth of up to 80 m below the sea bed, which requires extremely deep foundations on driven steel piles, up to 124 m long. The bridge is located in the area of strong and gusty winds with the reference wind speed exceeding 34 m/s. Particular attention was paid to ensuring that the bridge remains stable under strong wind gusts and open for traffic in all weather conditions. In order to meet the main criteria of quality design, such as stability, durability, economy and integration into the environment, the inventive design proposed the construction of an extradosed bridge with an integrated hybrid structure comprising 5 central spans, each 285 m long, and 6 low pylons. Thus, the designed structure ensures the necessary seismic stability of the bridge without installation of large bearings and additional seismic dampers, which is confirmed by numerous complex non-linear computational analyses, presented in detail in the paper. The soil-structure interaction was considered in all non-linear analyses. After completion the Pelješac Bridge will be ranked among the 5 largest and most attractive European bridges, constructed at the beginning of the 21st century.

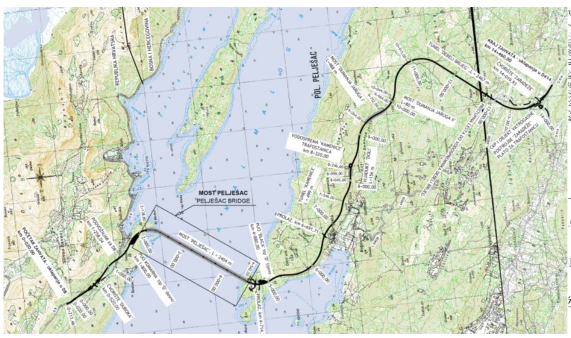
Key words: extradosed bridge, stay-cable, deep foundation, piles, earthquake, wind, monitoring

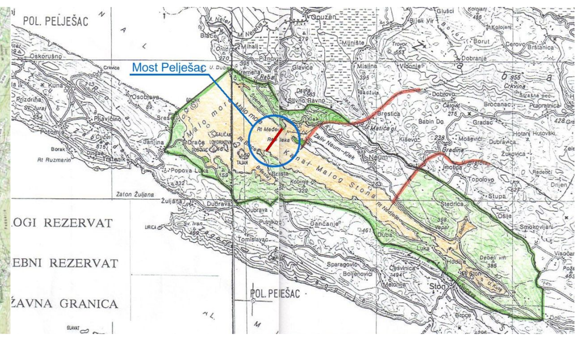
1. INTRODUCTION

The construction of the mainland-Pelješac bridge will establish a hard road connection between all parts of the Croatian territory. Dubrovnik-Neretva County will be connected with the Croatian territory, which will contribute significantly to the development of Dubrovnik, the Pelješac peninsula and the entire southernmost Croatian county. The mainland-Pelješac bridge runs over the straits. The width of the barrier at seal level is approximately 2,140 m. The length of the bridge from axis to axis of abutments is 2,404 m, while the total length of the bridge with abutments is 2,440 m. On most of the crossing, the sea depth is approximately constant and is 27.0 m.

1.1 Bridge site characteristics

The bridge is situated in a highly sensitive environmental area of Mali Ston Bay. The minimum required navigation profile under the Pelješac Bridge, agreed with Bosnia and Herzegovina, is 200 x 55 m.

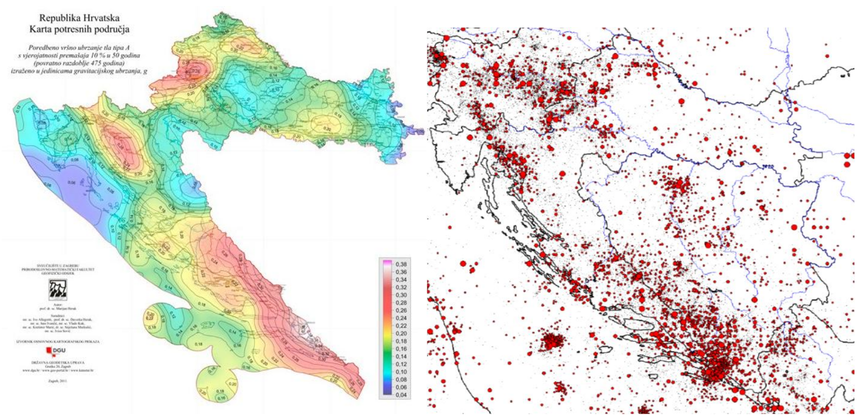




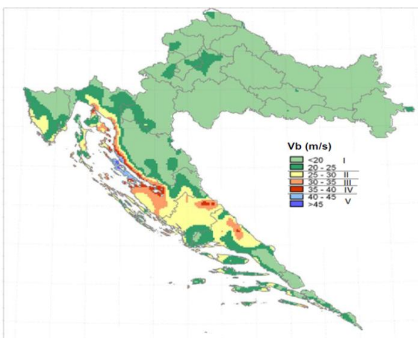
Figures 1, 2, 3. Situation view of the bridge site and strictly protected natural reserve area

The length of the bay is 21 km and has a maximum width of 2.2 km. The depth of the bay is between 7 and 28 meters. Due to the very clean sea, it was declared a marine nature reserve in 1983. The entire area is also protected by Natura 2000 - environmental network consisting of areas important for the conservation of endangered species and habitat types of the European Union. The clean sea with the appropriate characteristics was the basis for the development of mariculture in Mali Ston Bay: shellfish farming and fishing.

The bridge is situated in the high seismic activity zone with the peak design acceleration of soil at the bedrock level PGA=0.34g, and the required design acceleration of 0.54 g. The bridge site is also susceptible to strong winds with reference wind speed in excess of 34 m/s.



Figures 4, 5. The map of earthquake areas and epicenters from the Croatian Earthquake Catalog, 2011



	PLOČE					KOMARNA				
T (god)	5	10	20	50	100	5	10	20	50	100
P (%)	80	90	95	98	99	80	90	95	98	99
N	13,3	14,6	15,8	17,3	18,6	15,2	19,0	22,6	27,3	31,1
NNE	14,2	15,3	16,3	17,7	18,8	15,7	18,9	22,0	26,1	29,3
NE	11,7	13,6	15,3	17,6	19,5	16,3	20,7	24,9	30,4	34,7
ENE	8,9	10,1	11,3	12,9	14,2	13,8	16,6	19,3	22,8	25,6
E	8,5	9,3	10,1	11,1	11,9	14,0	18,0	21,9	27,0	31,0
ESE	12,2	13,7	15,2	17,2	18,8	17,0	22,3	**27,3**	**33,7**	**38,9**
SE	**14,5**	**16,0**	17,4	19,3	20,8	**17,4**	**22,4**	27,1	33,3	38,2
SSE	12,4	14,5	16,5	19,1	21,2	12,7	16,3	19,8	24,4	28,0
S	10,8	13,9	16,8	20,7	23,7	13,1	16,5	19,7	23,9	27,3
SSW	11,2	13,6	15,9	18,9	21,3	10,1	13,1	16,0	19,7	22,6
SW	9,9	12,7	15,5	19,0	21,8	11,6	14,9	18,0	22,0	25,2
WSW	10,1	13,1	16,0	19,7	22,7	11,7	14,9	18,1	22,1	25,3
W	11,2	14,7	**18,1**	**22,5**	**26,1**	13,3	16,9	20,3	24,7	28,3
WNW	9,0	11,8	14,6	18,1	21,0	15,7	19,5	23,1	27,8	31,6
NW	7,8	10,4	12,9	16,1	18,7	11,6	14,9	18,0	22,0	25,2
NNW	9,3	12,6	15,7	19,8	23,0	12,5	15,5	18,4	22,1	25,1

Figures 6, 7. Spatial distribution of basic wind speed and expected 10-minute wind speed, as well as the corresponding probability (P%) for T-year return periods obtained from the measurement data at the meteorological stations of Ploče and Komarnain the period 2005 - 2014

The geological and geotechnical structure of foundation soil in the bridge area is determined on the basis of geological and geotechnical investigations in the years 2004 through 2011. A total of 60 exploratory boreholes were drilled in lengths up to 130 m below the seabed. In 2018, the contractor drilled additional 17 exploratory boreholes based on tender documentation requirements.

The thickness of soil deposits above the limestone rock along the bridge ranges from 40 to 100 m and they predominantly consist of silty clay, in some places with higher content of sandy or gravely fractions. Clay layers down to a depth of about 60 m from the seabed belong to the group of "soft clays", soft to firm in consistency, gray to olive-drab in color. The clay layers below 60 m are of older origin, gray to yellow-brown in color, of stiff to very stiff consistency state, in some places cemented or with limestone concretions, with porosity lower than 50% and slightly overconsolidated. Their undrained strengths have significantly higher values than those of the upper layers. Coarse-grained fractions occur more frequently in these strata. Limestone bedrock is reached in most of the boreholes. On the west side, approximately 700 m from the Pelješac peninsula, the surface weathered rock zone was found at a depth of about 38 m from the seabed (reef), while in other boreholes towards the mainland, rock was found at depths of approximately 75 - 102 m.

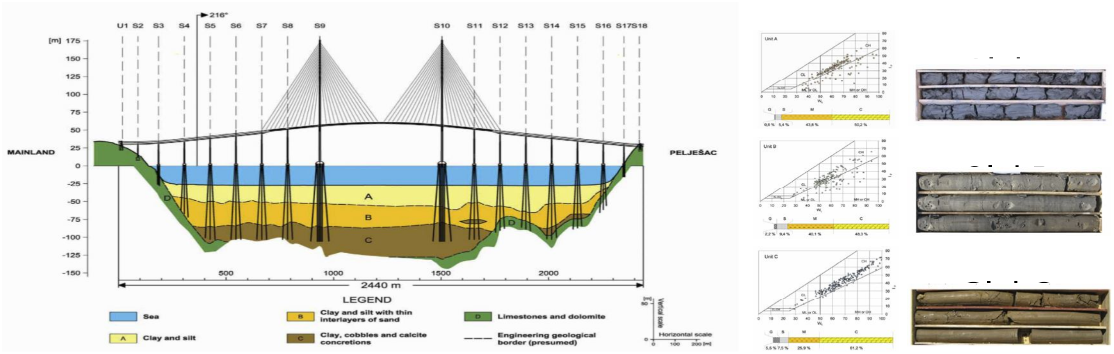


Figure 8. General view of foundation soil characteristics

1.2 Geometry of the road and traffic surface on the bridge

The traffic surface on the bridge consists of two carriageways. Each carriageway includes a driving lane 3.5 m in width and a stop lane 2.5 m in width and two marginal strips 0.50 m each. Between the carriageways there is a median strip with safety fence that provides traffic safety under strong wind conditions. The bridge design also provides wind protection that makes it possible to use the bridge in virtually all weather conditions and decreases the possibility of traffic interruptions in case of strong winds.

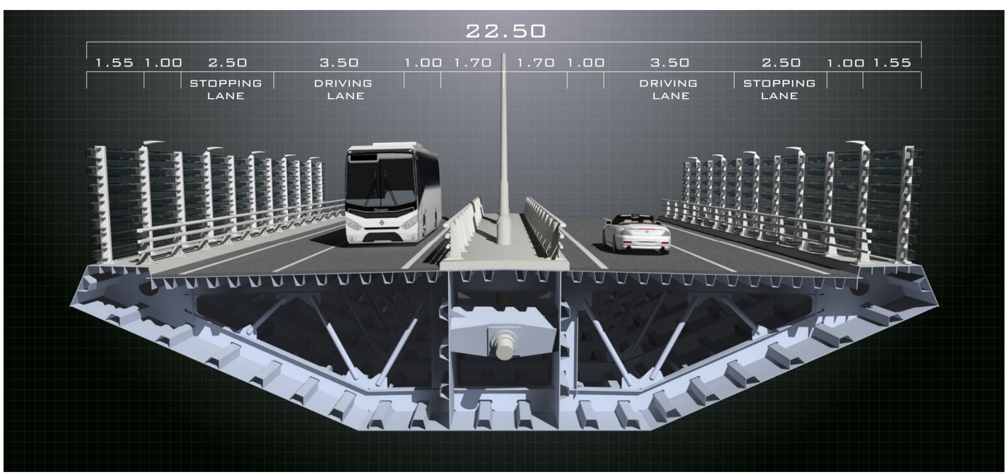


Figure 9. The bridge superstructure with traffic surfaces

The beginning of the bridge is at chainage 2+138.00 in a curve of radius R=450 m, and from chainage 2+410.45 to 2+485.45 the bridge is in a transition curve (A=184). From chainage 2+485.45 to chainage 4+500.46 the bridge is straight, while the end of the bridge from chainage 4+500.46 to 4+542.00 is in a transition curve (A=184, R=450 m). Two-sided crossfall of 2.5% is adopted on the straight part of the bridge, and on the part of the bridge in a curve the cross section is twisted according to road alignment rules, so as to achieve the maximum single-sided crossfall of 5.8% on the abutment U1 for the two carriageways. The bridge is provided with outer steel guardrail that complies with the protection class H3W3 and inner steel guardrail of protection class H2W1. 0.75 m wide inspection paths and wind protection fence are planned outside of edge guardrails. The total width of the upper surface of the bridge with inspection path and wind protection fence is 22.50 m. The bridge is provided with ambiance and road lighting.

2. ARCHITECTURAL AND STRUCTURAL CONCEPT OF THE BRIDGE

The method of integral optimization was used in the search for the structural and architectural concept of the bridge. The support structure (foundations, piers, abutments) accounts for about 40% of the total investment value, which is a relatively high percentage compared with other bridges. Therefore, it was necessary to find the optimal ratio between the number of supports, superstructure spans and selection of construction materials. Ensuring compliance with key high-quality construction criteria, such as stability, durability, economy and harmonious integration into the environment, resulted in the inventive bridge design with stay cables and integral hybrid structure. The bridge is structurally conceived inventively as a semi-integral cable-stayed hybrid structure with six low pylons and five central spans 285 m in length each. In this way, a full symmetry of the bridge in space has been achieved. The semi-integrally conceived bridge structure ensures seismic stability of the bridge without installation of large bearings and seismic dampers. Bearings are planned only on end piers and abutments.

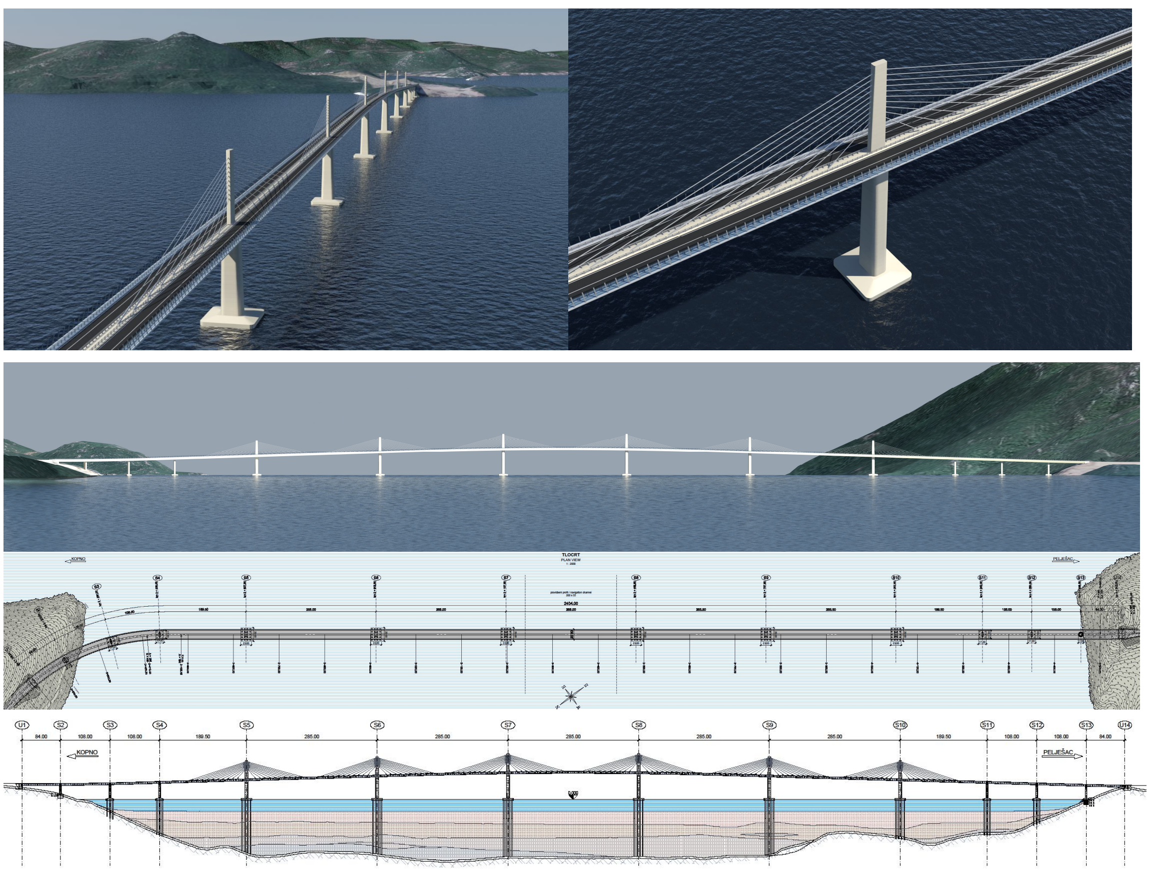


Figure 10. View of the bridge, plan view and longitudinal section

The superstructure is a continuous steel box structure 4.5 m in height and 22.5 m in width with spans 84 + 2 x 108 + 189.5 + 5 x 285 + 189.5 + 2 x 108 + 80 = 2404 m, which is stayed with cables in the central part on six centrally positioned reinforced-concrete pylons. The height of the pylons over the superstructure is 40.0 m, so that the pylon height to span ratio is 40.0/285.0 = 0.14, which classifies the bridge at the limit between cable-stayed and extradosed bridges. At pier positions S5 – S10 the superstructure is fixed to pylons.

The piers S2 - S4 and S11 - S13 have a box cross sections and measurements 4.25 m longitudinally to the bridge and variable width 8 - 10 m transversely to the bridge. The thickness of walls is constant and is 0.60 m in longitudinal and transverse direction. On tops, the piers end with bearing squares that allow installation of bearings and longitudinal guides. There is a space for placing bearing replacement jacks and opening to enter piers (inspection and maintenance of bearings). The piers S5 – S10 have a box shape with size in the bridge longitudinal direction 7.0 m and variable width transversely to the bridge 11.00 - 8.10 m. The walls are 0.80 in thickness in the transverse direction of the bridge, and 0.70 in thickness in the longitudinal direction of the bridge. For protection against ship impacts, the thickness of walls of the piers S7 and S8 is increased to 1.20 m in the lower part up to the height of 12 m. The reinforced-concrete pylons S5 - S10 are elastically fixed with the central part of the superstructure, or directly with support piers in the sea. The centrally positioned vertical pylons are concrete pylons, 40 m in height and with full cross section. The pylon measurements on top are 2.20 x 5.0 m, and 2.20 x 7.00 m at the superstructure level. The concrete of the piers is compact, impermeable of strength class C50/60, and the concrete of the pylons is of strength C70/85. The stay cables are anchored in pylons over special anchorage zones, which eliminates construction of an expensive system (housing) for anchoring stay cables. On each pylon it is planned to install 10 saddles before concreting.

Stay cables, which are the main structural and load-bearing element of the cable-stayed bridge, will be made of 55 - 109 parallel strands of rated area A=1.50 cm2 (Parallel Strand System). The steel wires are made of the material Y 1860 S7–16.0–A in all according to the standard HRN EN 10138-3, of guaranteed strength of 1860 MPa, protected by high-density polyethylene (HDPE) pipes. The protective polyethylene pipes shall be molded on external surface with spiral ribs to reduce vibrations due to the effects of wind and rain. The length of stay cables is from 32.5 m to 137 m.

The piers S3 - S12, which are in the sea, are deeply founded on driven steel piles 1800 and 2000 mm in diameter, 36 - 124 m in length. The thickness of walls of the steel piles is 40 - 60 mm. The piles of the pier positions S3, S4, S10, S11 and S12 are constructed as composite with concrete mat in compact limestone, and piles of pier positions S5 – S9 are filled with concrete only to the depth of 40 m (composite) under concrete caps. The piles are elastically fixed to massive concrete caps sized 17 x 17 x 4.5 m (piers S3, S4, S11, S12), while the sizes of pile caps under pylon piers are 23 x 29 x 5 m. Piers S3 and S12 are founded on nine piles 1800 mm in diameter, piers S4, S11 on nine piles 2000 mm in diameter, piers S5, S6, S9, S10 on 18 piles D 2000 mm, and piers S7 and S8 on 20 piles D 2000 mm (ship impact).

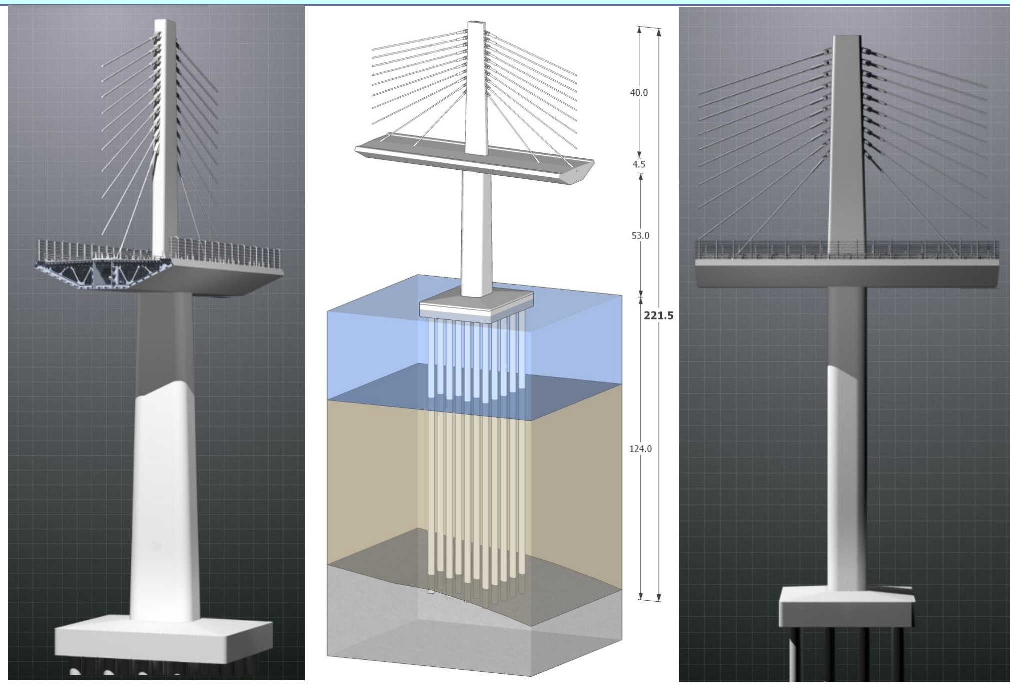


Figure 11. The concept of piers - pylons S5 – S10

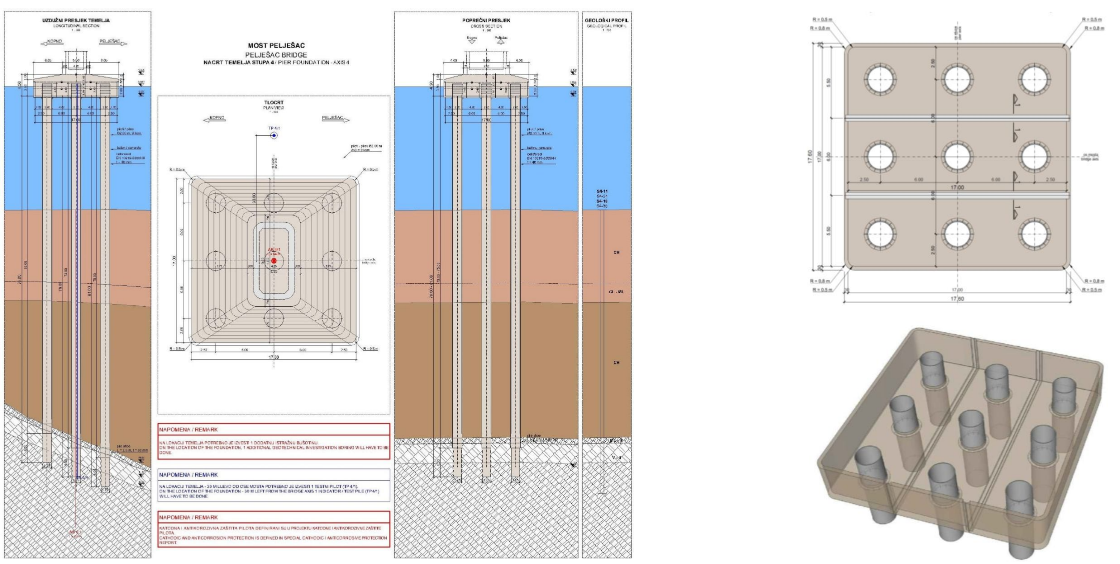


Figure 12. Foundations of piers S3, S4, S11, S12

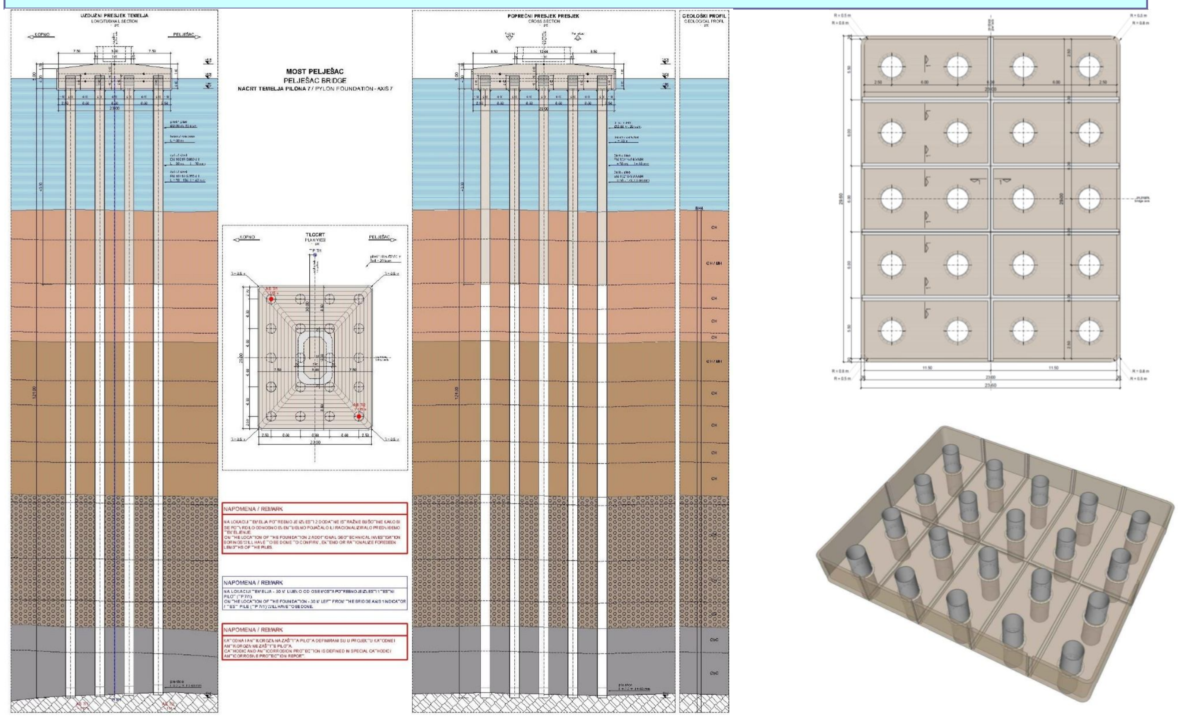


Figure 13. Foundations of piers S7 and S8

3. STATIC AND DYNAMIC ANALYSIS OF THE BRIDGE

The Pelješac Bridge ranks among the most challenging bridges in the world, not only by complexity of its construction, but also by complexity of its design. It is situated in the area of high seismic activity, with the peak design acceleration of soil at the bedrock level PGA=0.34g, and the required design acceleration of 0.54 g. The compact bedrock is found at a depth of up to 80 m below the sea bed, which results in exceptionally demanding foundations on piles over 120 m in length. Particular attention was paid to ensuring stability of the bridge under strong wind gusts and the need to keep it open in all weather conditions. Meeting the key criteria of high-quality construction, such as stability, durability, economy and harmonious integration into the environment, resulted in the inventive concept of extradosed bridge with integrated hybrid structure. The thus conceived structure ensures the necessary seismic stability of the bridge without installation of large bearings and additional seismic dampers, which is confirmed by complex non-linear computational analyses that also took the foundation soil - bridge structure interaction into account. The static and dynamic analyses of the bridge were divided into two stages. Preliminary analyses were carried out in the stage of searching for optimal structural solution of the bridge. The primary loads that significantly influenced the bridge concept were earthquake and wind. The preliminary analyses and optimization stage were followed by detailed analyses. The loads defined pursuant to HRN EN 1991 and national annexes were analyzed both for the bridge operation and construction stages:

- Dead and traffic loads
- Differential movements of foundations
- Concrete creep and shrinkage
- Temperature changes
- Earthquake, wind, ship impact (relevant for bridge stability)
- Replacement and failure of stay cables

- Fatigue

3.1 Preliminary analyses

In the stage of searching for optimum bridge concept and foundation engineering method, numerous variants were analyzed with different number of piles and with inclined piles. Significant nonlinear soil behaviors and nonelastic deformations of foundation elements are expected considering the bridge foundations on very long and slender piles passing through layers of soft soil. A 3D analysis of the interaction between foundation soil and foundation structure was made for the characteristic pier position - Pier 9 with volume finite elements (continuum model of the soil-foundation system)

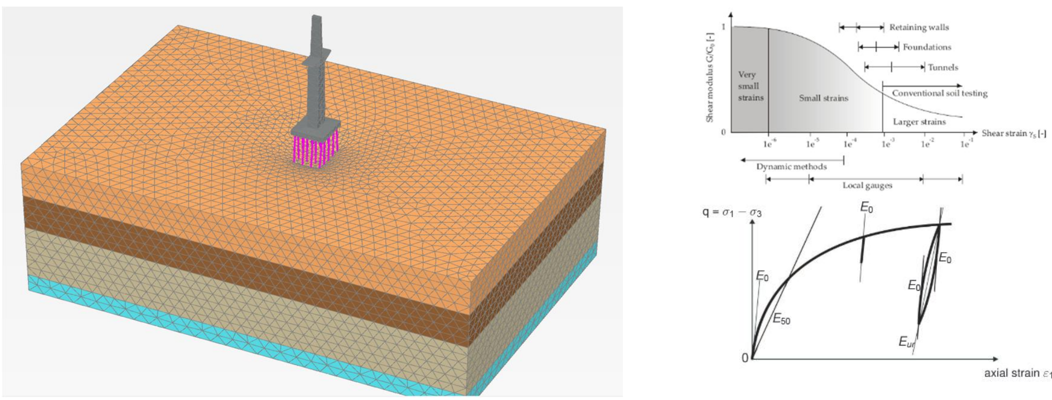


Figure 14. 3D model of the continuum of soil and foundation structure with volume FEM elements

Figure 15. In the stage of searching for optimum foundation engineering method, numerous variants were analyzed with different numbers of piles and with inclined piles.

The analysis was conducted on the geotechnical model HSS (Hardening Soil with small-strain stiffness), which allows for consideration of high variability in stiffness when increasing relative shear strains in the domain of small strains of soil, hysteretic effects and hysteritic damping in soil in case of cyclic loading or dynamic behavior of soil. The preliminary static "push over" analyses were carried out on an SSI model in order to estimate the behavior under the effects of vertical and horizontal loads of intensities from 10 to 50 MN in undrained conditions (because of the short action of horizontal load).

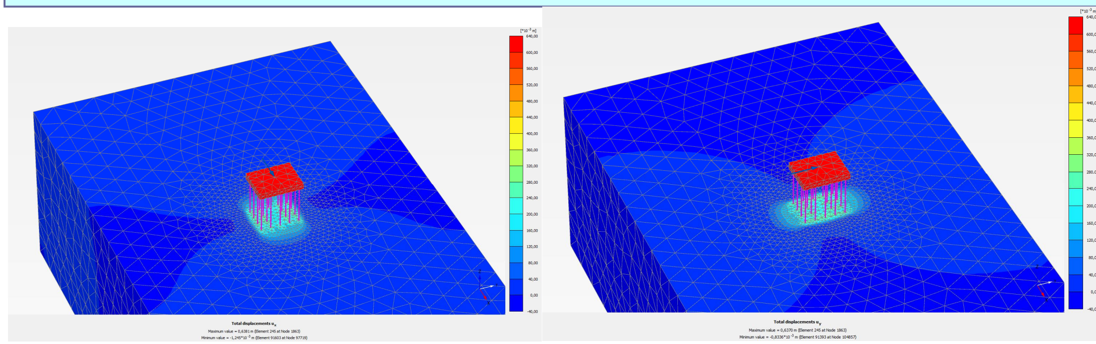


Figure 16. Structural deformations (vertical load + horizontal load 50 MN in the direction of bridge axis and transversely to bridge axis (undrained conditions))

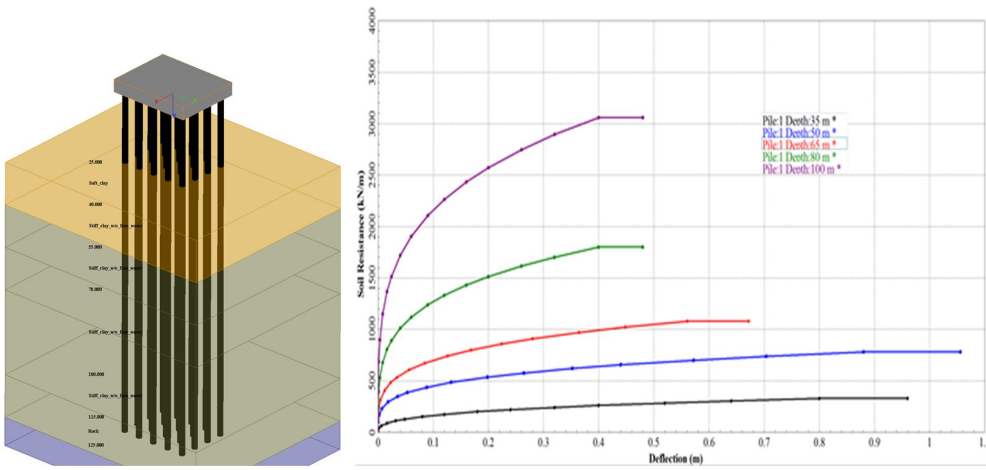
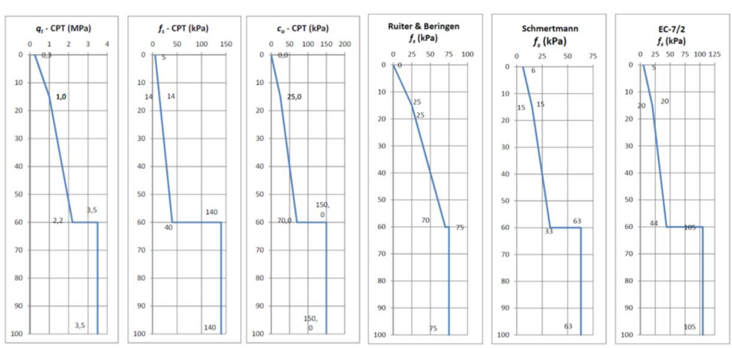


Figure 17. View of "p-y" curves / nonlinear behavior of foundation soil - clay at different depths

The bearing capacity of pile over its shaft is determined from CPT test results (the value of cone tip penetration resistance). The following figure shows the relationship of the values of cone tip penetration resistance (CPT) q_t, shaft friction f_s and undrained shear strength cu versus depth. The limit value of pile shaft friction f_s is determined according to Ruiter & Beringen (1997), Schmertmann (1978) and Eurocode 7/2, as shown in the following figure:



Figures 18, 19. The value of cone tip penetration resistance (CPT) q_t, shaft friction f_s and undrained shear strength cu vs. depth, Limit value of pile shaft friction f_s according to Ruiter & Beringen (1997), Schmertmann (1978) and EC 7/2

Considering that there are no reliable analytical expressions to determine the bearing capacity of "hollow" steel piles of large diameter, the bearing capacity of toe of such piles was obtained by nonlinear calculation of the pile toe using the finite element method. The model consists of soil and pile, and the calculation was carried out using the software package for geotechnical analyses Plaxis.

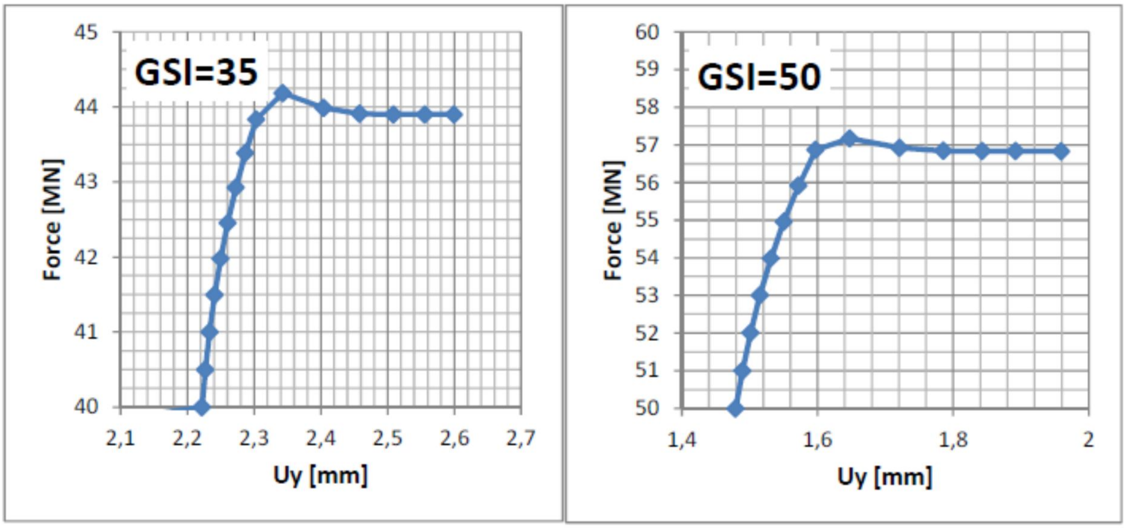


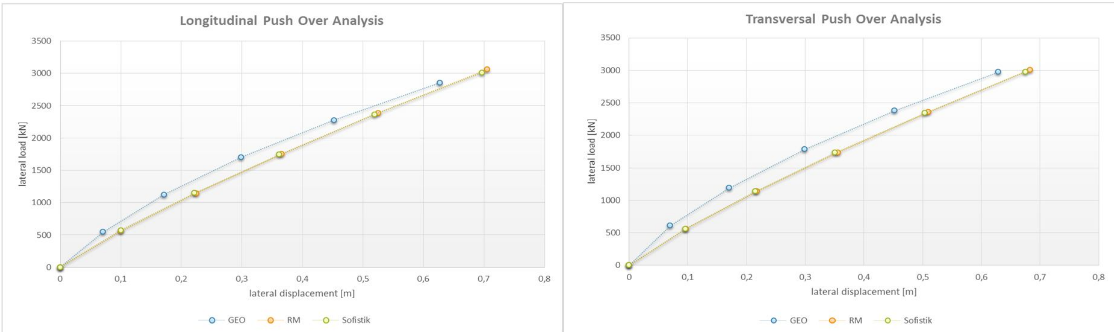
Figure 20, 21. The GSI illustration shows the displacement of the pile toe at failure (GSI=35) and force - displacement curve for the last loading step 40 MN – 50 MN (GSI=35) and 50 MN – 60 MN for GSI=50.

For the toe of the hollow steel tubular pile,the ultimate bearing capacity of 43.9 MN and 6.8 MN was obtained for GSI values of 35 and 50, respectively, ensuring that the pile is fully supported by rock. The bearing capacity of the pile toe concreted into the rock can be estimated by the expression $q_b=3q_u$. For conditions of rock with lower bearing capacity, the assumption on the safety side is that the bearing capacity at pile toe $q_b = q_u$, which was used to prove the bearing capacity of piles for the piles concreted in rock. Considering that the resistance of rock exceeds the strength of concrete, the calculation bearing capacity is limited to the bearing capacity of pile (f_{ck} = 35 MPa).

The following safety factors were taken into account when calculating the compressive bearing capacity of piles: γ_c = 1.10 (partial coefficient for compressive resistance of pile), γ_M = 1.40 (model factor for alternative bearing capacity proving methods) and γ_G = 1.35 (partial coefficient for pile weight increase). The following safety factors were taken into account when calculating the tensile bearing capacity of piles: γ_c = 1.15, γ_M = 1.40 and γ_G = 1.00.

3.2 Detailed analysis of the bridge

The global analysis of the bridge was conducted in parallel / independently with two different reputable software packages, RM-Bridge Enterprise / Bentley and Sofistik. Both computer models were made with the same accuracy, with acknowledgement of SSI (Soil - Structure Interaction). Here, it is necessary especially to emphasize - calibration and control of beam calculation models in order to properly allow for the nonlinearity of foundation soil. In order to verify the values of the "p-y" curves obtained by the soil and foundation continuum model, a control "push-over" analysis was performed for the beam model of the bridge structure with nonlinear springs of soil.



Figures 22, 23. Comparison of results of the "push-over" analysis on the geotechnical model and on the beam model with nonlinear springs

Figure 24. RM Bridge / Bentley model with beam elements and Sofistik model with beam and plate elements

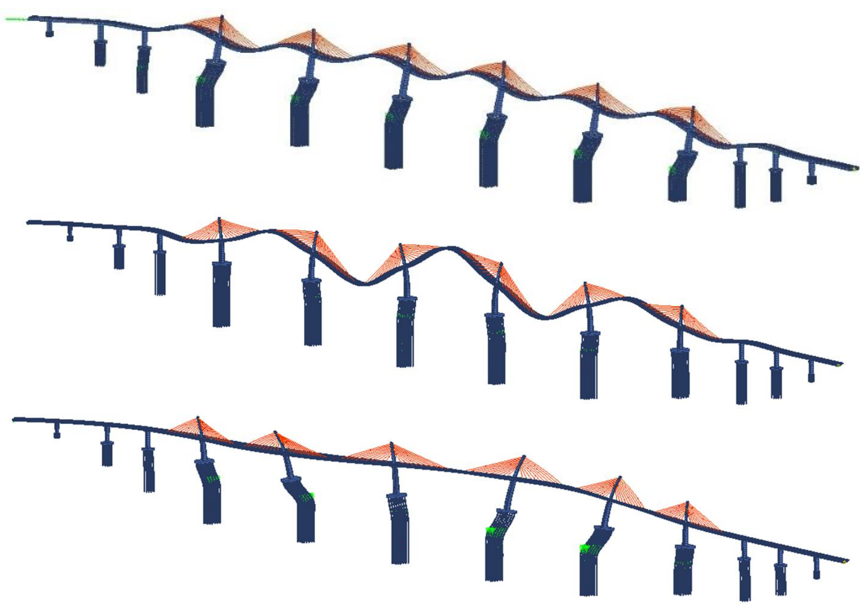
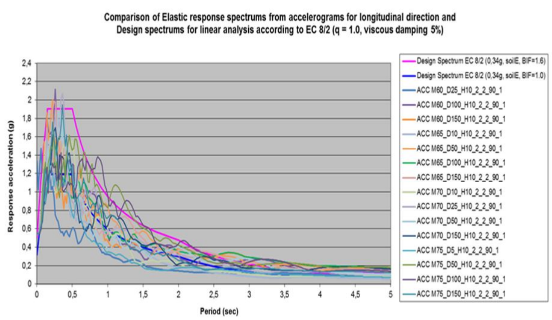


Figure 25. First three oscillation forms of the bridge structure

The bridge is designed and constructed so as to withstand the action of a destructive earthquake without damage that would affect the local or global bearing capacity and serviceability of the bridge. According to HRN EN 1998-2/NA: TNCR = 475 years, PGA = 0.34g, importance factor γI=1.60, bridge behavior factor is q = 1.0, AE= 0.34 x 1.6 = 0.54g. The analysis of soil acceleration time record (Time History Analysis) was made on the basis of the seismological study developed by the Geological Department of the Faculty of Science in Zagreb. 72 numerical synthetic accelerograms were generated for earthquakes of magnitudes M = 6.0, 6.5, 7.0 and 7.5 and for the distances from the epicenter of 5.0, 10.0, 25.0, 50.0, 100.0 and 150.0 km at a depth of 10 km, which makes a total of 24 different seismic load sets.

Each load set consists of three different records for three different directions (longitudinal, transverse, vertical). Nonlinear dynamic analysis (Nonlinear Time History Analysis) was conducted on the model with nonlinear springs (p-y). Of the 24 load sets, fifteen most critical load sets were selected and "time history" analysis was conducted for these loads. Each of these loads contains simultaneous action of three different records in three directions (along the bridge, transversely to the bridge and vertically). The analysis was carried out taking into account the maximum value of design seismic acceleration α_g = 0.54 g for all epicentral distances (accelerogram normalization at 0.54 g).



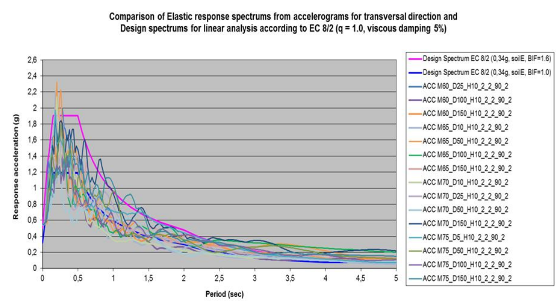


Figure 26, 27. Comparison of elastic spectra determined on the basis of the accelerogram and design spectrum determined according to HRN EN 1998-2 (q = 1.0, damping 5%)

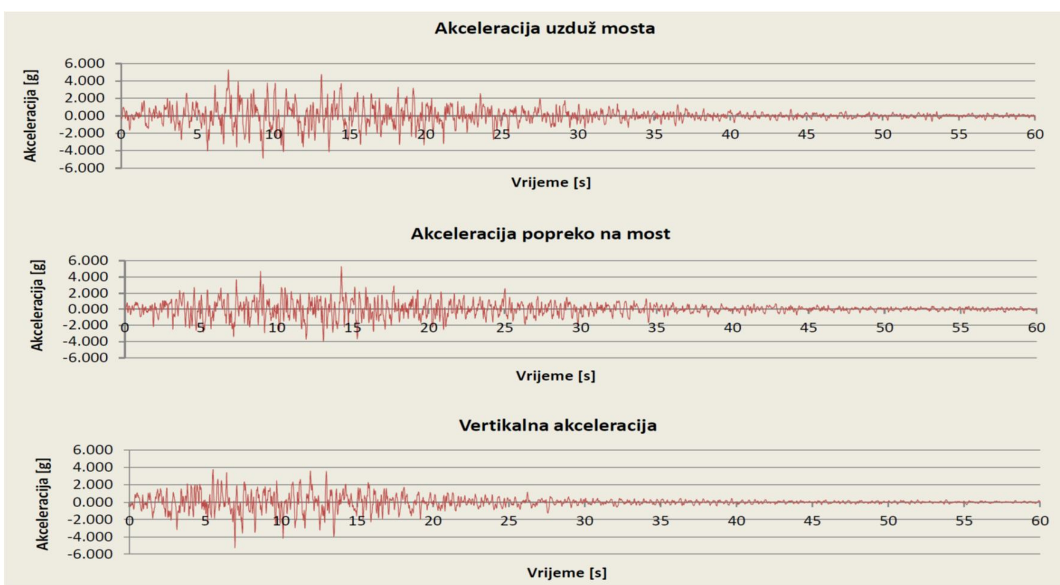


Figure 28. An example of earthquake load - synthetic accelerograms, simultaneously acting longitudinally, transversely and vertically to the bridge (M = 7.5, epicenter distance 100 km)

Rayleigh damping is defined by the damping matrix C = α K + β M. The material-based damping values given in EN 1998/2, 4.1.3 are: welded steel ξ = 2% and reinforced concrete ξ = 5%. Structural damping taken into account in the analysis is 2.5%.

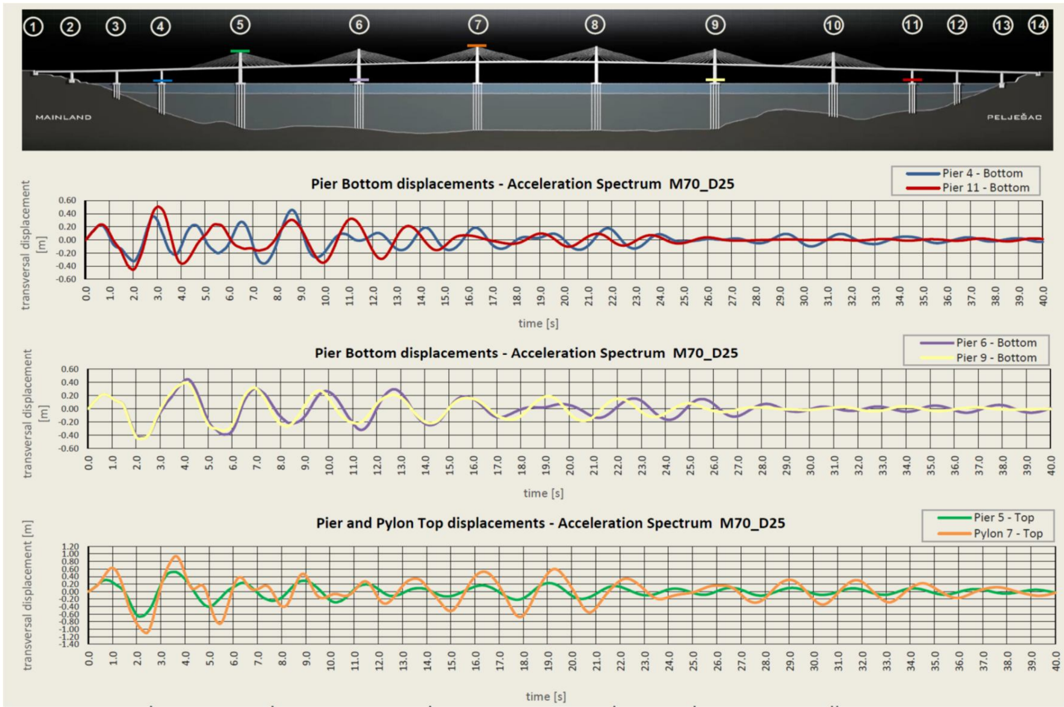


Figure 29. TH analysis results - time dependent displacements of the structure in the transverse direction

In the search for the optimal shape of superstructure and wind protection, several different forms of cross sections with and without wind protection fence were analyzed by CFD (Computational Fluid Dynamic) analysis.

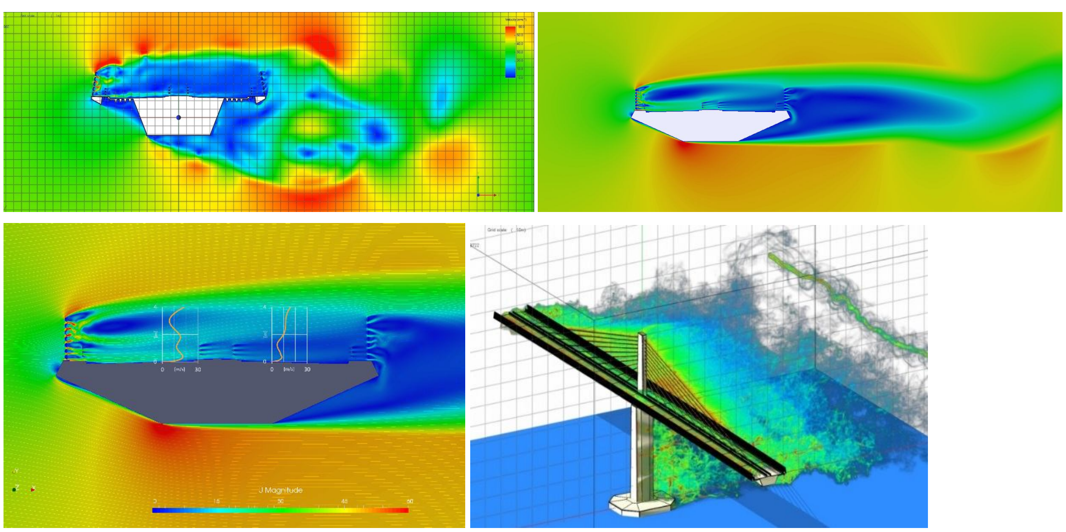
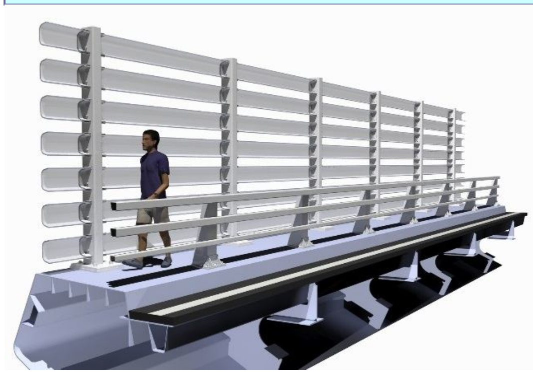
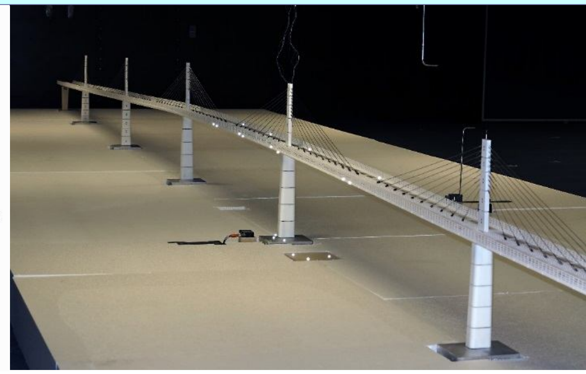


Figure 30. Results of “in-house” CFD analyses of cross section and bridge in the construction stage





Figures 31, 32. Wind protection fence and bridge model testing (Full Bridge Model Test, 1:150) in the wind tunnel of Force Technology / Copenhagen - Denmark

The aerodynamic characteristics of the cross section and the bridge as a whole were confirmed by testing the bridge in the air tunnel. Testing of a bridge segment model was carried out in the first stage. Since the results obtained in the air tunnel for 2D model cannot be directly compared with the actual behavior of the entire bridge structure, model of the entire bridge was tested in the next stage of design. Full bridge model testing was conducted in the air tunnel of the company Force Technology. The testing program included the testing of aerodynamic stability of the model of full bridge in the operation stage and of a part of the structure in the construction stage - pylon with cantilever.

Based on the aerodynamic response tests of the entire bridge model, it can be concluded that the aerodynamic stability of the bridge is ensured for all wind speeds and different directions of action, both in laminar and turbulent flow, at least up to a wind speed of 250 km/h (70 m/s). The steel superstructure was analyzed for global and local effects. Internal forces for all reference actions and maximum/minimum normal and shear stresses in individual steel elements were calculated both for construction and operation stages. The global analysis was followed by testing of buckling resistance of superstructure plate elements and sizing of welds. The thicknesses of superstructure sheet metals do not exceed 40 mm, higher quality steel (S460) is planned in zones where stresses are exceeded.

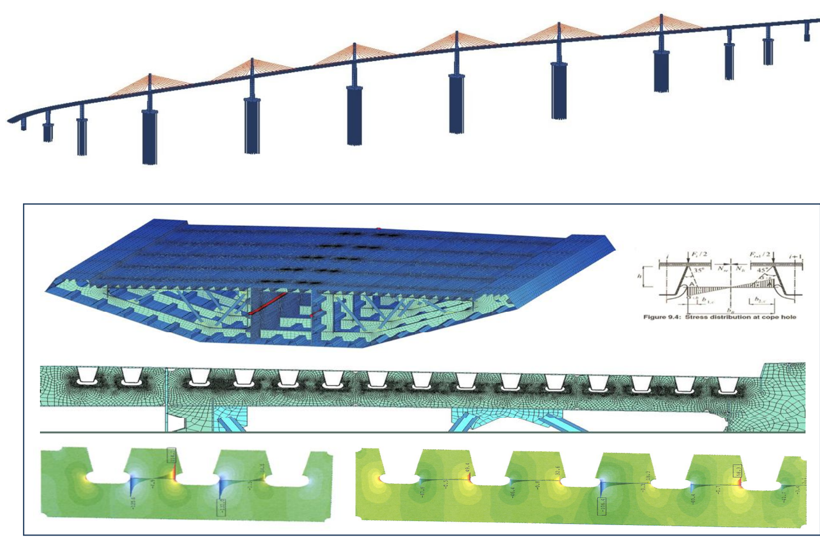


Figure 33. Model of the entire bridge and illustration of fatigue control in superstructure sheet metals

A combination of local and global load effects was analyzed. Transverse stiffenings and diaphragms above piers were analyzed in the transverse direction. Control of stay cable anchorages was made, and the contact / connection between concrete and steel structure was especially analyzed in detail.

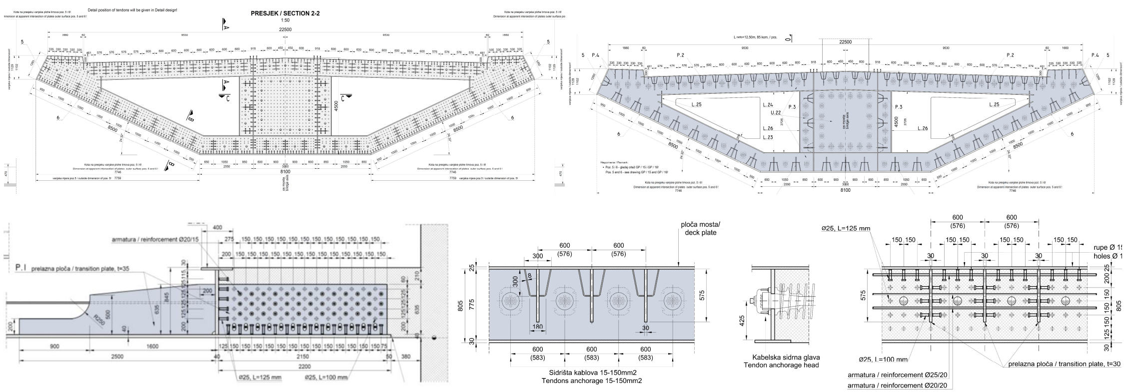


Figure 34. Illustration of the contact / connection between concrete and steel structure

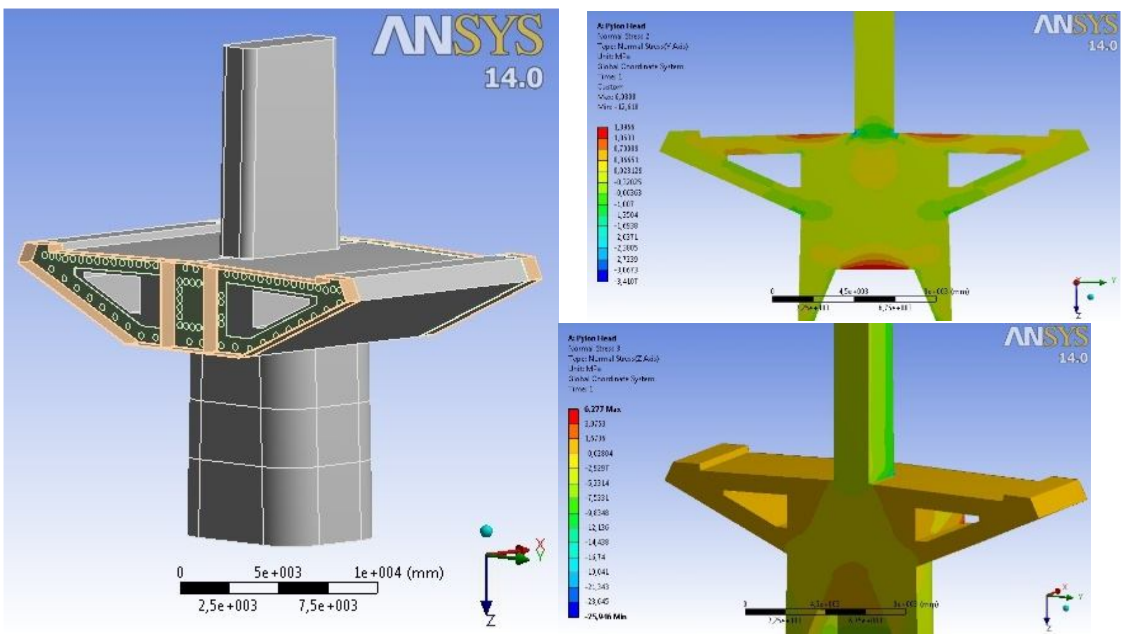


Figure 35. A view of the detailed analysis of the connection of pier, pylon and steel structure with solid elements

4. MONITORING IN THE CONSTRUCTION STAGE AND IN THE OPERATION STAGE

For the Pelješac Bridge it is planned to use the model of constant monitoring of the state of structure from a single central point where the following will be monitored in time in the construction stage and in the stage of operation of the structure:

- structural behavior parameters (temperature of steel structure, stay cables and concrete structure, stresses, deformations, vibrations, ...)
- weather parameters using the weather station with installed ultrasonic anemometer (air temperature and humidity, wind direction and speed)
- seismic activity (measurement of seismic activity in the inner bridge area)
- durability of the structure

5. CONCLUSION

It should be noted that great effort has been made to build a bridge that is modern in structural terms, unique and cost-effective in terms of design, one that is clearly indicative of the time when it was created. However, such a great and impressive bridge cannot be just a modern and superbly designed engineering structure without a soul and character. In the history of construction, great and important bridges have always played a special role also as monuments of technical culture of a nation. Bridges express the most beautiful architectural messages about the used construction technology, strength, technical and cultural enlightenment of the investor, as well as the designer's sense of structural harmony and inventiveness.

After construction, the Pelješac Bridge will be ranked among the five largest and most attractive bridges in Europe. There is no doubt that the bridge will also represent one of the new symbols of modern Croatia.