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Železničko-drumski most u Novom Sadu.

Projekat i izgradnja

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Železničko-drumski most u Novom Sadu

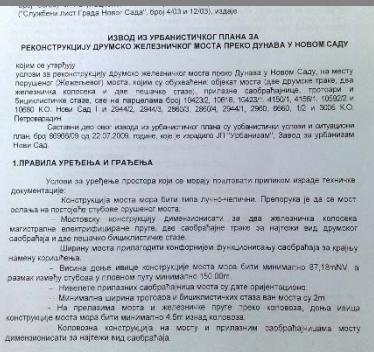
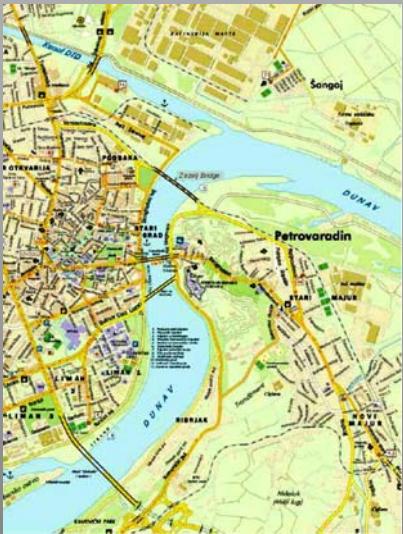


Sadržaj prezentacije

- 1 Projektni zadatak
- 2 Konstruktivno rešenje
- 3 Opterećenja
- 4 Proračun konstrukcije
- 5 Izrada i montaža
- 6 3D-animacije
- 7 Poređenja sa sličnim mostovima u svetu
- 8 Projektantski tim



Urbanistički uslovi i Projektni zadatak



ИЗВОД ИЗ УРБАНИСТИЧКОГ ПЛАНА ЗА РЕКОНСТРУКЦИЈУ ДРУМСКО ЖЕЛЕЗНИЧКОГ МОСТА ПРЕКО ДУНАВА У НОВОМ САДУ

1. ПРАВИЛА УРЕЂЕЊА И ГРАЂЕЊА

Услови за уређење простора који се морају поштовати приликом израде техничке документације:

- Конструкција моста мора бити типа лучно-челични. Препорука је да се мост ослања на постојеће стубове срушеног моста.
- Мостовску конструкцију димензионисати за два железничка колосека магистралне електрифициране пруге и две саобраћајне траке за најтежи вид друмског саобраћаја и две пешачко бициклестичке стазе.
- Ширина моста припогодити конформирајући дундуковитом сводбарија за крајњу намену коришћења.
- Висине днице конструкције моста морају бити минимално 87,19mN, а размак између стубова у главном путу минимално 150,00m.
- Гравитациони преградни саобраћајни вожњи су дате оријентације.
- Максимални радиус кривине близинском стази јан моста су 2m.
- На премазима моста и железничке пруге преко чупара, днице днице конструкције моста морају бити минимално 4,5m изнад колосека.
- Коловона конструкција на мосту и припадни саобраћајници мосту димензионисати за најтежи вид саобраћаја.

Projektni zadatak

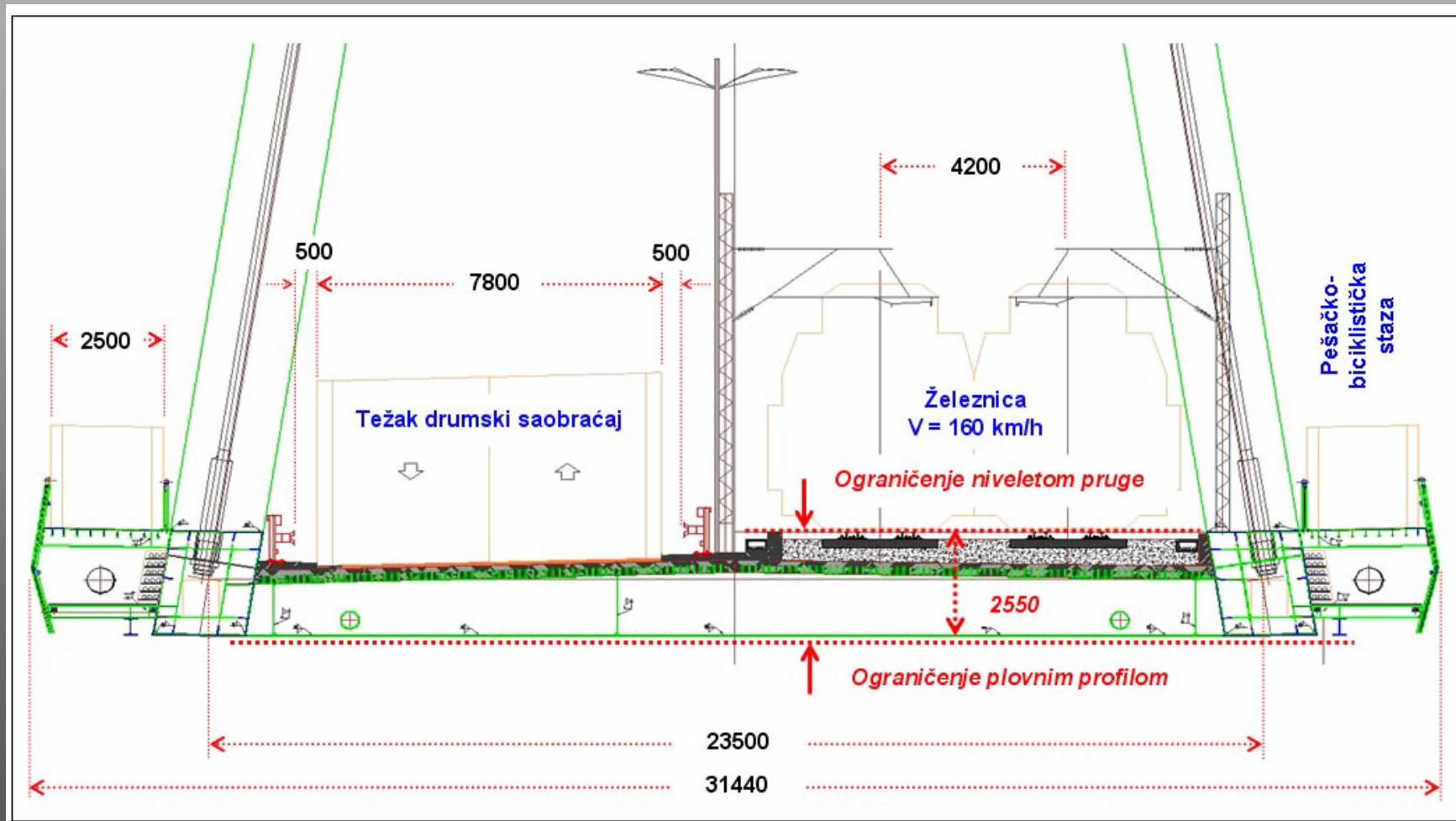
Niveleta pruge:

- podignuta oko 1,5 m zbog gabarita plovног profila;
 - што kraća dužina za povezivanje sa postojećim kolosekom.
- (Rešeno u Idejnom projektu)



Lokacija	Lokacija starog mosta.
Saobraćaj na mostu	2 koloseka (e = 4,20m) + 2 drumske trake (2 x(3,50+0,35)m) + 2 pešačko-biciklističke staze (2 x 2,50m).
Brzine vozova	160 i 120 km/h (putn. i teretni)
Vertikalno ubrzanje konstr.	max 1,3 m/s²
Vozovi za dinamički proračun	Tipa 2 i tipa 5. (DIN-Fb 101:2009, EN 1991-2:2005)
Instalacije i oprema na mostu	Po posebnim zahtevima korisnika: železnička oprema, vodovod, PTT, odvodnjavanje, signalizacija, reviziona kolica, javno i dekorativno osvetljenje.
Norme za projektovanje	Nemačke Smernice za železničke mostove Ril 804:2003 + + prateće norme DIN-Fb 101do104 (= EN 1991do1994).

Projektni zadatak



Železničko-drumski most u
Novom Sadu

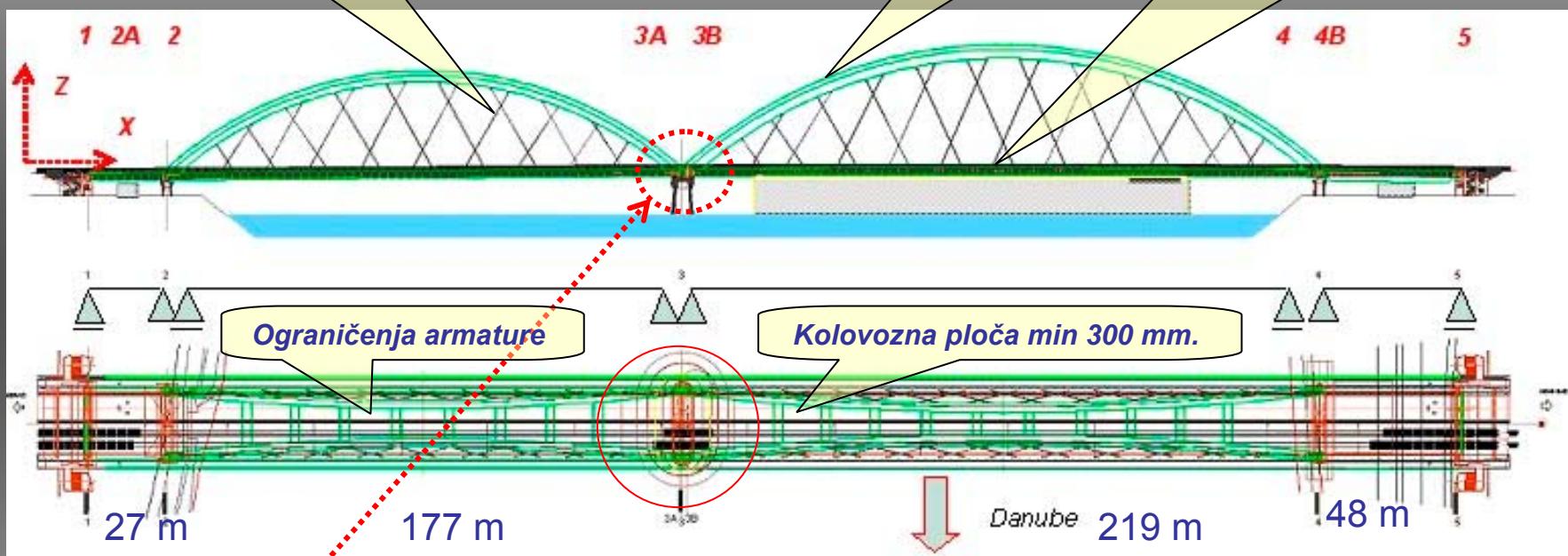
Dispozicija mosta i najvažnija ograničenja pri projektovanju

Broj vešaljki minimalan.
Sve moraju biti zategnute u
svim stanjima ULS i SLS.

Čelik konstrukcije S355.
Izbeći podklase M, M/L.
Čelik S460 minimalno.

Visina preseka lukova max 5,0 m.

Visina preseka zatege max 2,5 m.

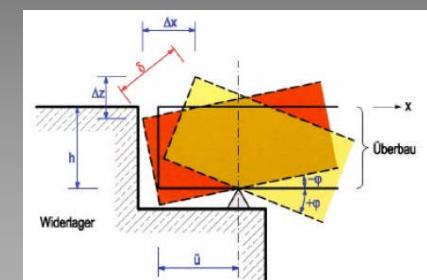
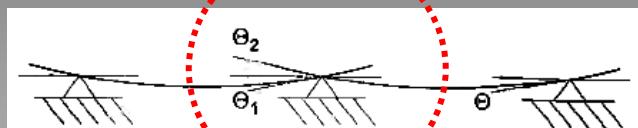


Najkritičniji uslovi projektovanja:

$$\theta + \theta_2 \text{ (LM71/1 track} + \Delta T_M) \leq 5 \text{ mrad}$$

takođe i

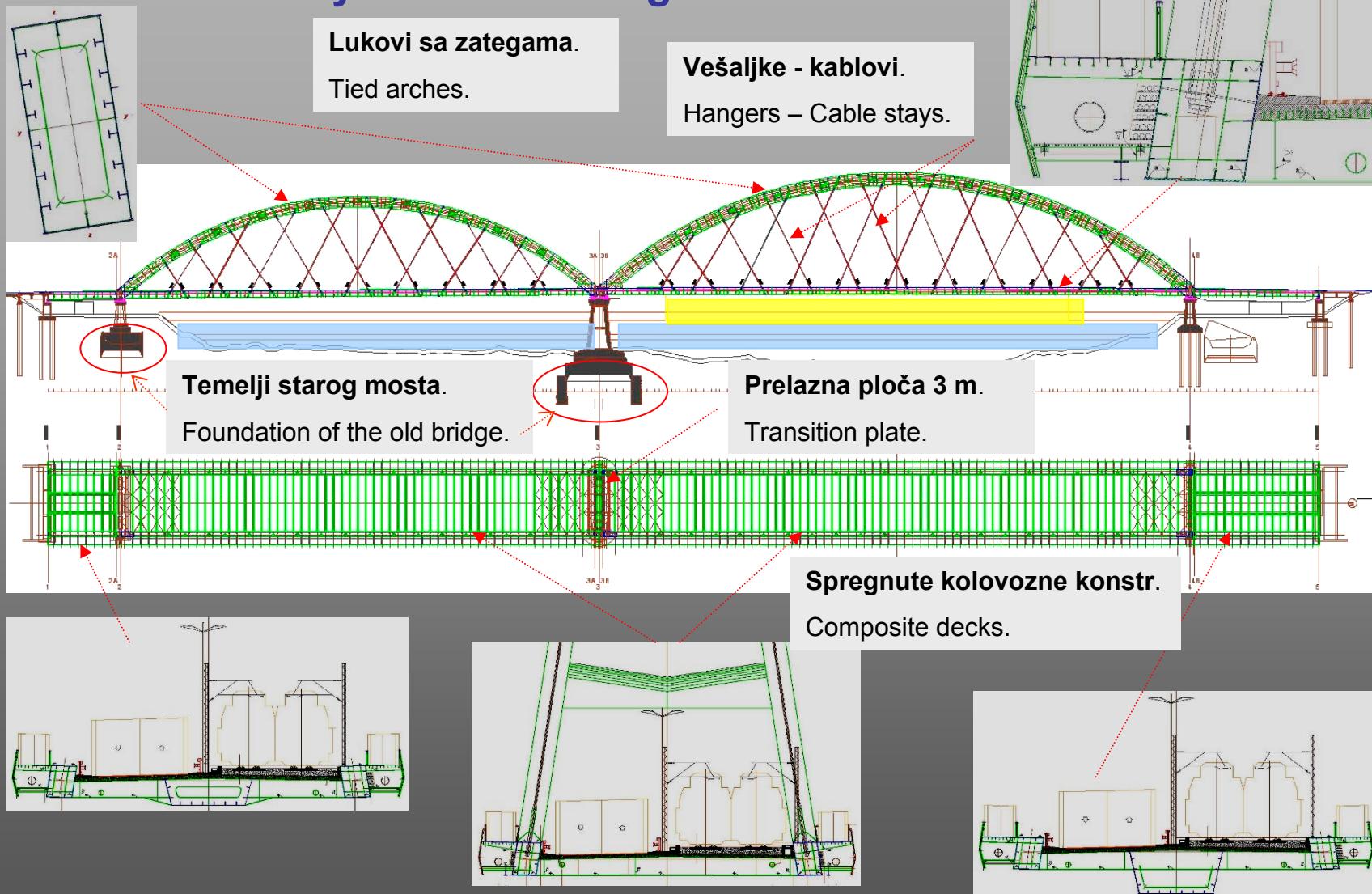
$$\delta \leq 9 \text{ mm}$$



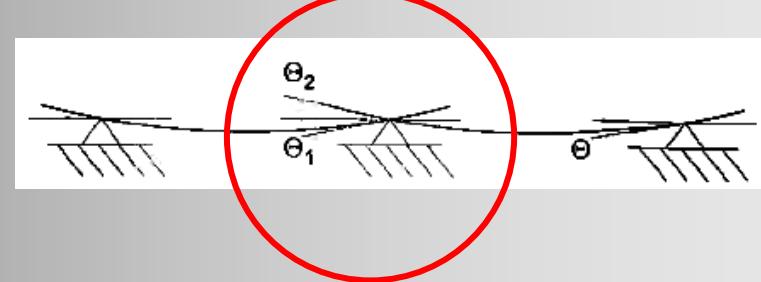
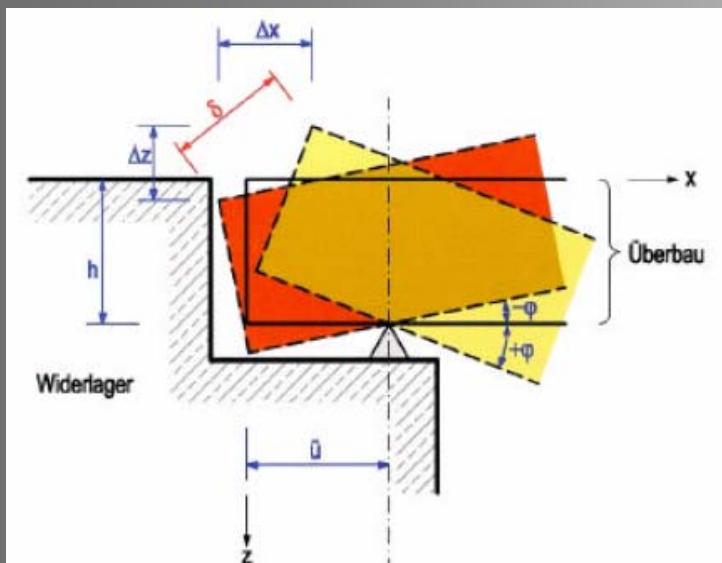
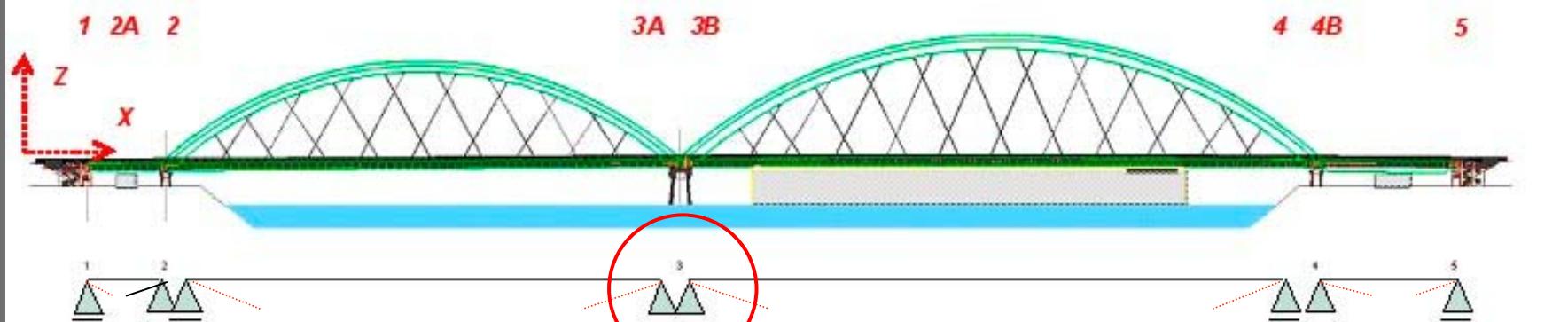
Železničko-drumski most u
Novom Sadu

Dispozicija konstrukcije mosta

Layout of the bridge structure



Železničko-drumski most u
Novom Sadu



Najkritičniji uslovi projektovanja:

The most critical requirement:

$$\theta_1 + \theta_2 \text{ (LM71/1 track} + \Delta T_M) \leq 5 \text{ mrad}$$

takođe i / and also

$$\delta \leq 9 \text{ mm}$$

Ril 804:2003

DIN-Fb 101:2009

Change of relevant norm requirement: Vertical hangers → Diagonal hangers

Izmena merodavne norme: Vertikalne vešaljke → Diagonalne vešaljke

DIN-Fachbericht 101:2009-03

Einwirkungen auf Brücken (2009) Verkehrslasten auf Brücken Anhang G IV

Abb. G.2: Endtangentendrehwinkel

G.3.1.2.3 Vertikalverformungen des Überbaus (Gleise mit Schotterbett)

(1) P Der in der Gleismitte gemessene Endtangentenwinkel des Überbaus darf unter dem mit ϕ und α multiplizierten charakteristischen Wert des Lastmodells 71 und ggf. SW/0 bei gleichzeitig wirkendem Temperaturunterschied die folgenden Werte nicht überschreiten:

- a) Eingleisige Brücken

$\theta = 6,5 \cdot 10^{-3}$ rad	am Übergang zwischen Überbau und Bahndamm	(G.2)
$\theta_1 + \theta_2 = 10 \cdot 10^{-3}$ rad	zwischen zwei aufeinander folgenden Überbauten	
- b) Mehrgleisige Brücken

$\theta = 3,5 \cdot 10^{-3}$ rad	am Übergang zwischen Überbau und Bahndamm	(G.3)
$\theta_1 + \theta_2 = 5 \cdot 10^{-3}$ rad	zwischen zwei aufeinander folgenden Überbauten	

G.3.1.2.3 Endtangentenwinkel des Überbaus (Gleise mit Schotterbett)

(1) P Der in der Gleismitte gemessene Endtangentenwinkel des Überbaus darf unter dem mit ϕ und α multiplizierten charakteristischen Wert des Lastmodells 71 und ggf. SW/0 sowie bei Temperaturunterschied die folgenden Werte nicht überschreiten:

- a) Eingleisige Brücken

$\theta = 6,5 \cdot 10^{-3}$ rad	am Übergang zwischen Überbau und Bahndamm	(G.2)
$\theta_1 + \theta_2 = 10 \cdot 10^{-3}$ rad	zwischen zwei aufeinander folgenden Überbauten	
- b) Zweigleisige Brücke

$\theta = 3,5 \cdot 10^{-3}$ rad	am Übergang zwischen Überbau und Bahndamm	(G.3)
$\theta_1 + \theta_2 = 5 \cdot 10^{-3}$ rad	zwischen zwei aufeinander folgenden Überbauten	

Fascimile / Faksimil DIN-Fb 101:2009

DIN-Fb 101:2009:

The measured tangential rotation of structure in railway axis, calculated according to characteristic values of load model LM71 (or in case SW/0) and multiplied by factors ϕ and α with **simultaneous** acting of temperature loads, must not exceed following limit:

DIN-Fb 101:2003:

The measured tangential rotation of structure in railway axis, calculated according to characteristic values of load model LM71 (or in case SW/0) and multiplied by factors ϕ and α **as well** linear temperature difference component according to temperature loads, must not exceed following limits:

DIN-Fb 101:2009:

Mereni ugao tangente noseće konstrukcije u osi koloseka, proračunat na osnovu karakterističnih vrednosti modela opterećenja LM71 (već prema slučaju i SW/0) i pomnoženih sa ϕ i α pri **istovremenom** delovanju razlike temperature, nesme da prekorači sledeće vrednosti:

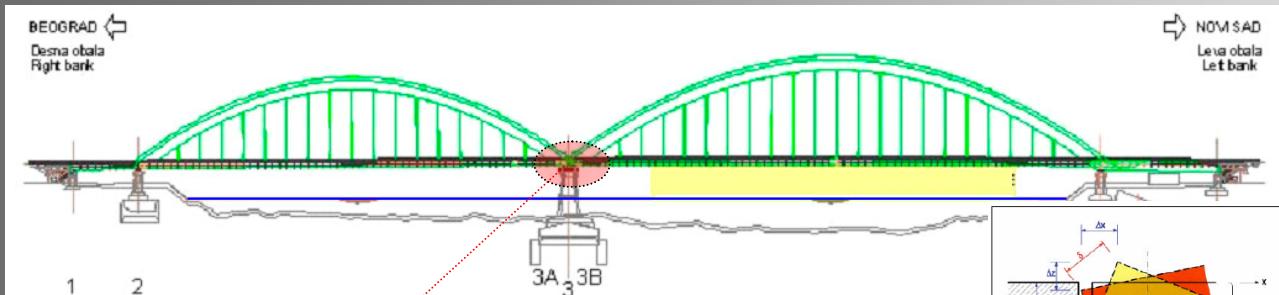
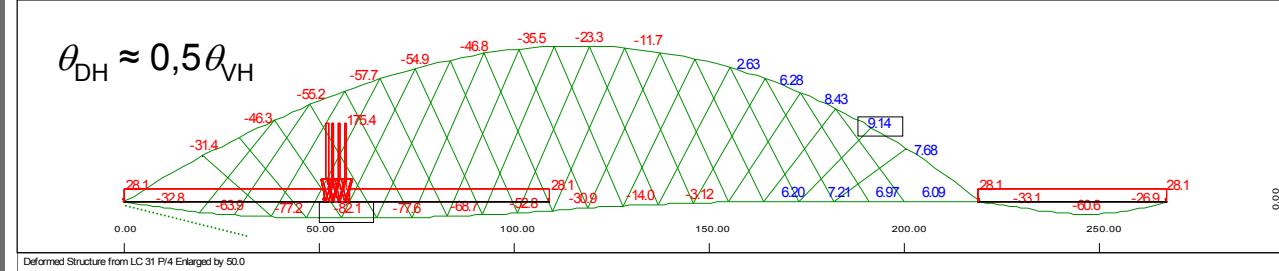
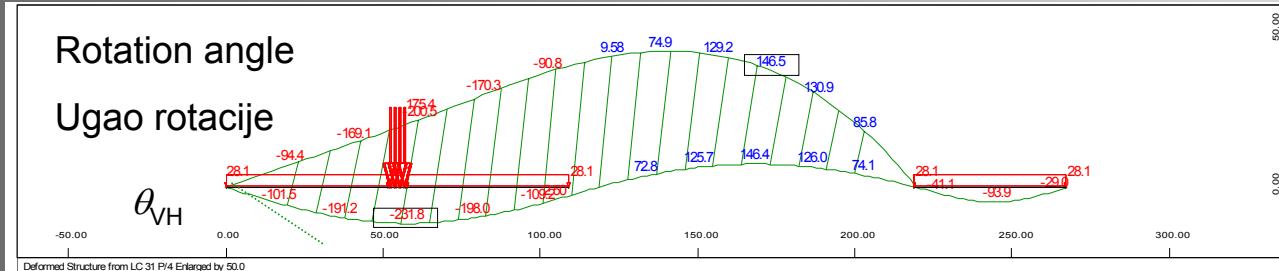
DIN-Fb 101:2003:

Mereni ugao tangente noseće konstrukcije u osi koloseka, proračunat na osnovu karakterističnih vrednosti modela opterećenja LM71 (već prema slučaju i SW/0) i pomnoženih sa ϕ i α , **kao i** pri delovanju razlike temperature, nesme da prekorači sledeće vrednosti: ...

Fascimile / Faksimil DIN-Fb 101:2003

Vertical hangers → Diagonal hangers

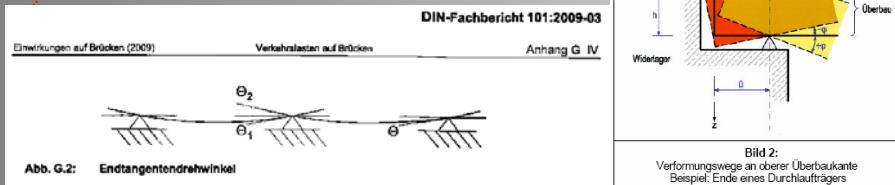
Vertikalne vešaljke → Diagonalne vešaljke



Critical condition

Kritični uslov:

$$\theta_1 + \theta_2 \leq \theta_{lim}$$



Change of relevant norm:

Promena merodavne norme:

DIN-Fb 101:2003 →

DIN-Fb 101:2009

Preliminary Design Idejni projekt	Detailed Design Glavni projekt
DIN-Fb 101:2003:	DIN-Fb 101:2009: $\theta(LM71) \leq \theta_{lim}$ and / i $\theta(T_{M, pos, neg}) \leq \theta_{lim}$ $\theta(T_{M, pos, neg}) \leq \theta_{lim}$

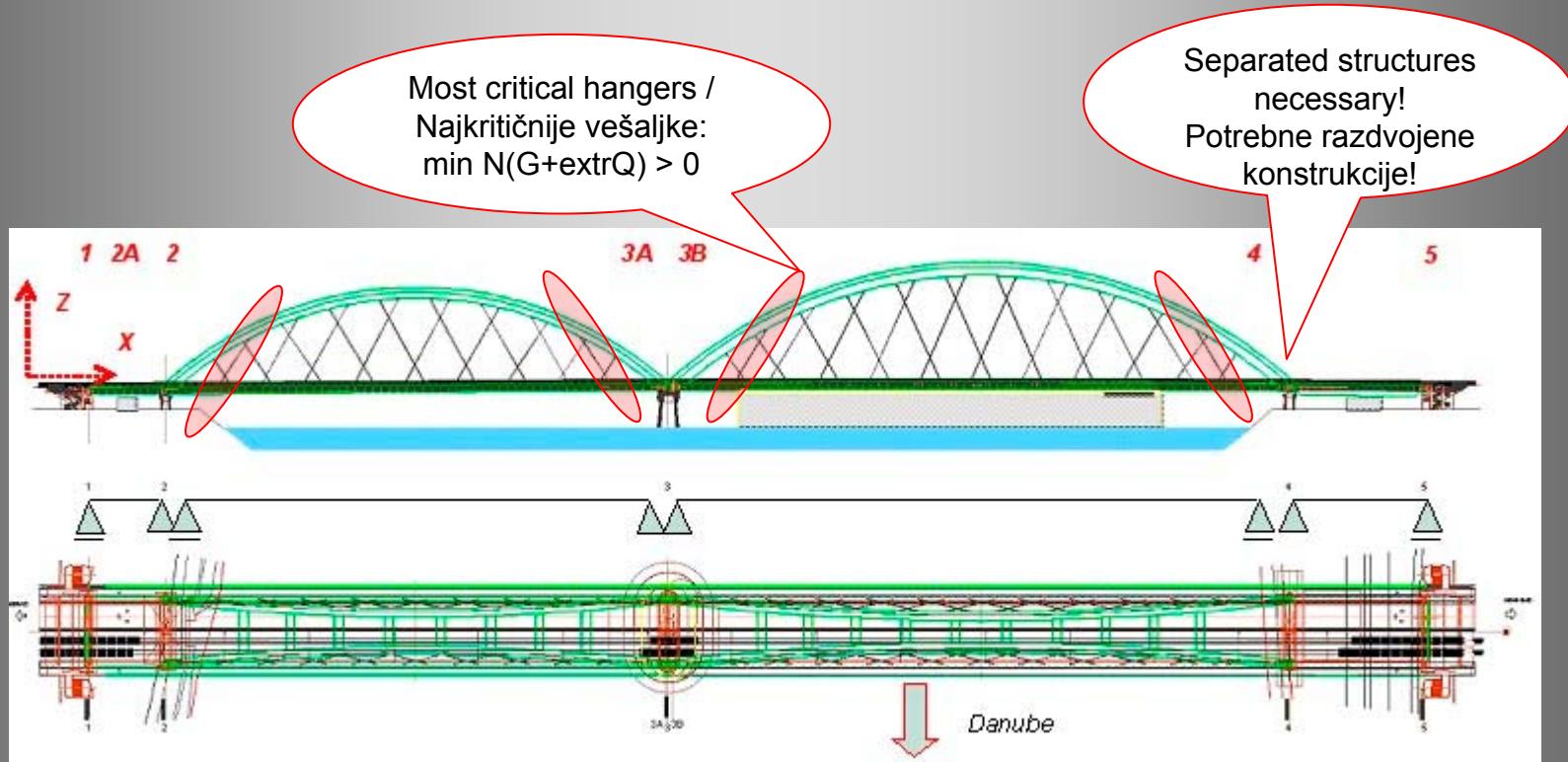
Only solution / Jedino rešenje:

Far more rigid / mnogo krući



Separated bridge structures - Consequence of diagonal hangers

Razdvojene mostovske konstrukcije - posledica diagonalnih vešaljki



(Positive) consequences of separation:

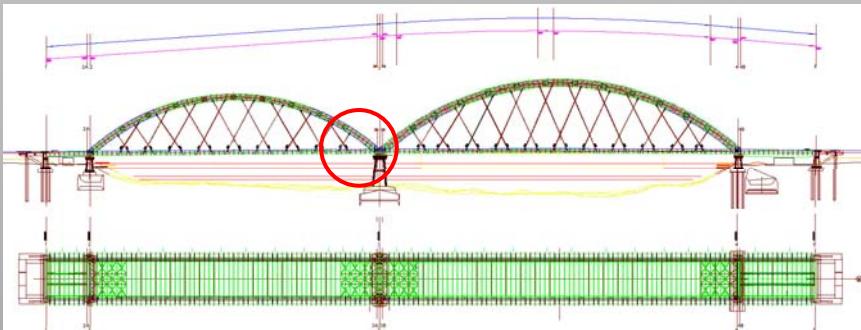
- Longitudinally symmetric structures;
- More suitable for erection;
- No negative consequences for rails;
- Not visible for the public.

Solution:
Separated struct.
Rešenje:
Razdvojene konstrukcije.

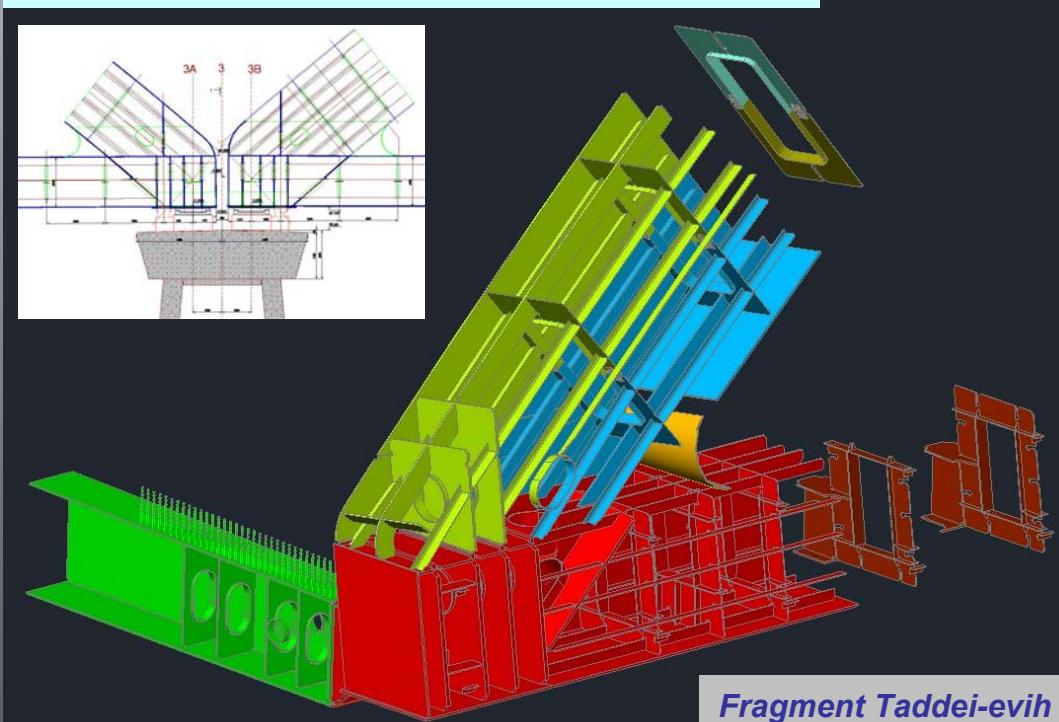
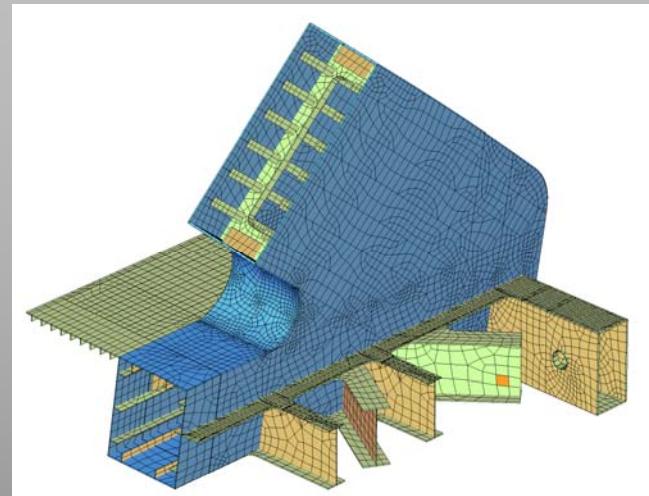
(Pozitivne) posledice razdvajanja:

- podužno simetrične konstrukcije;
- pogodnije za montažu;
- nema negativnih posledica za šine;
- nevidljivo za posmatrače.

Čelična konstrukcija mosta

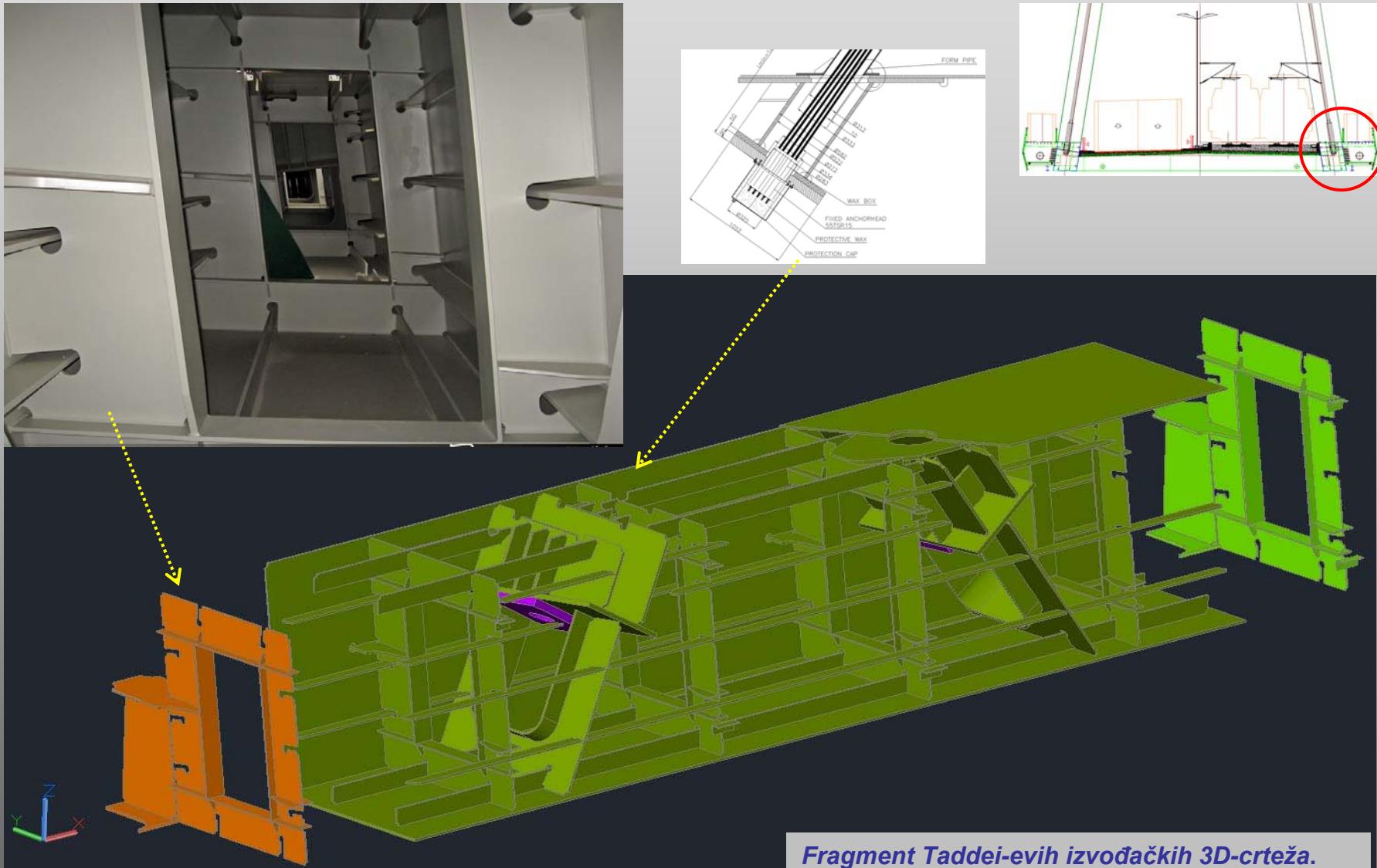


Spoj luk/greda/krajnji poprečni nosač.



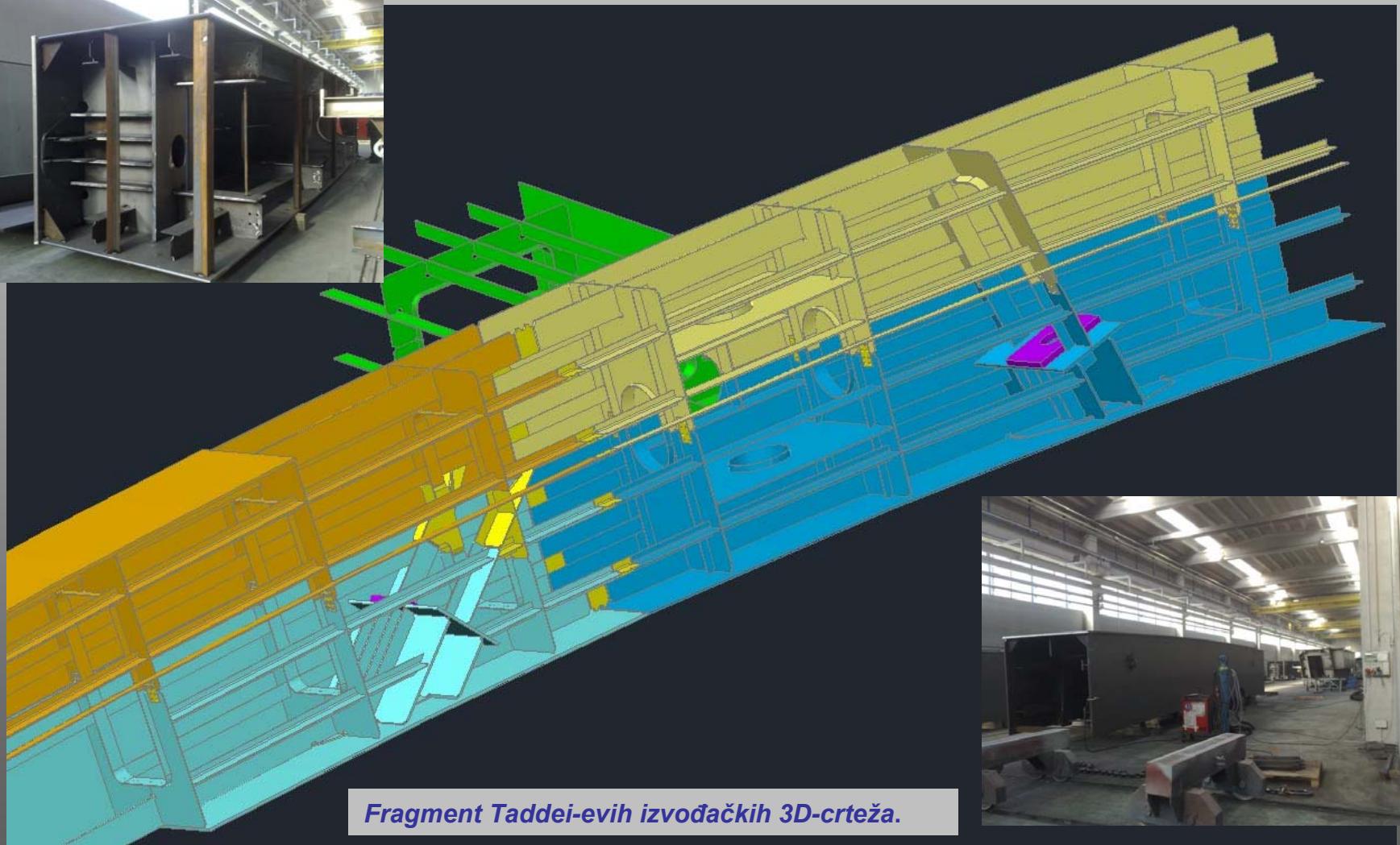
Fragment Taddei-evih izvođačkih 3D-crteža.

Čelična konstrukcija mosta: Greda sa ankernim konstrukcijama kablova.



Fragment Taddei-evih izvođačkih 3D-crteža.

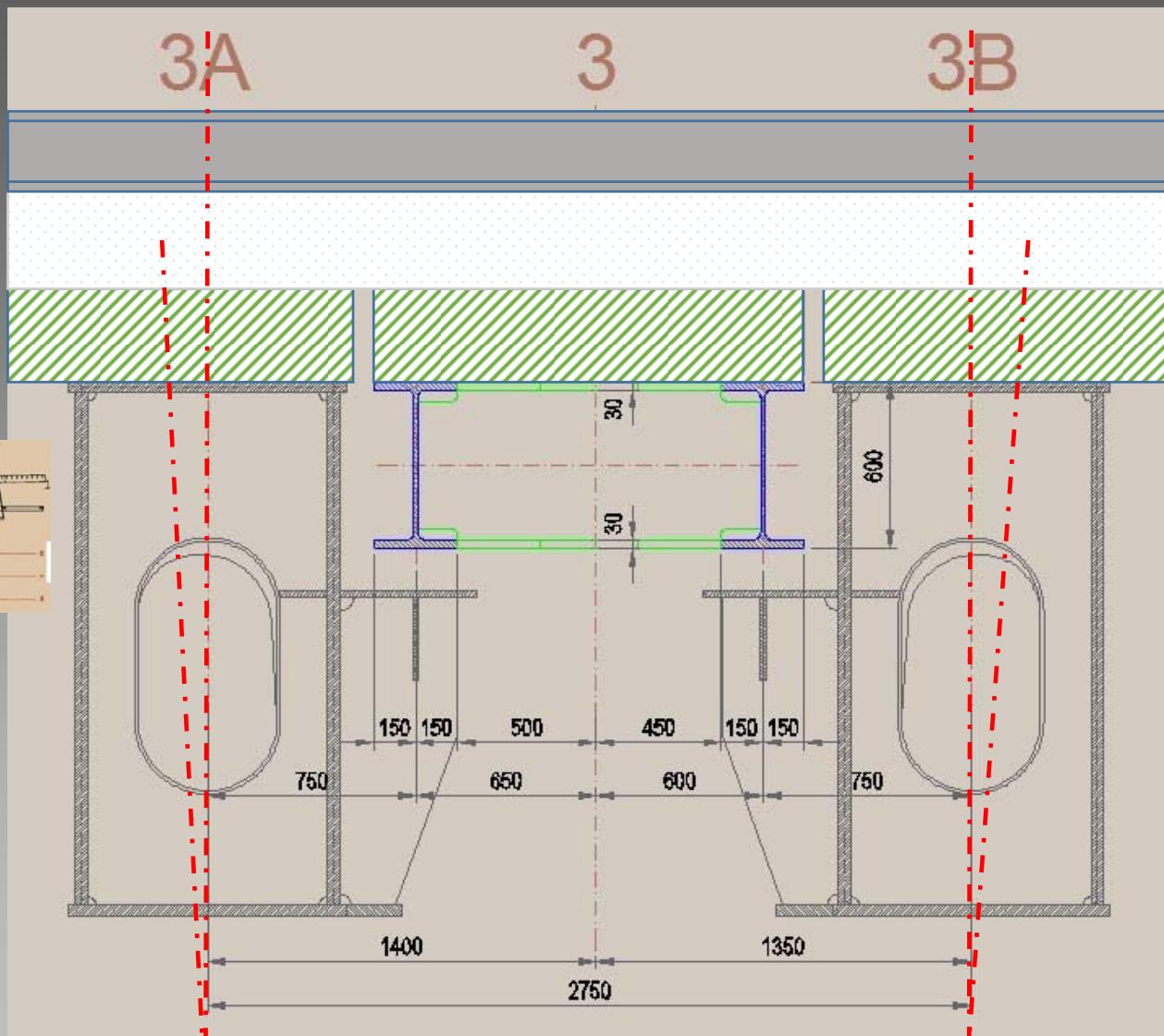
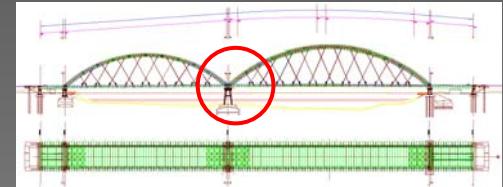
Čelična konstrukcija mosta: Luk sa ankernim konstrukcijama kablova.



Fragment Taddei-evih izvođačkih 3D-crteža.

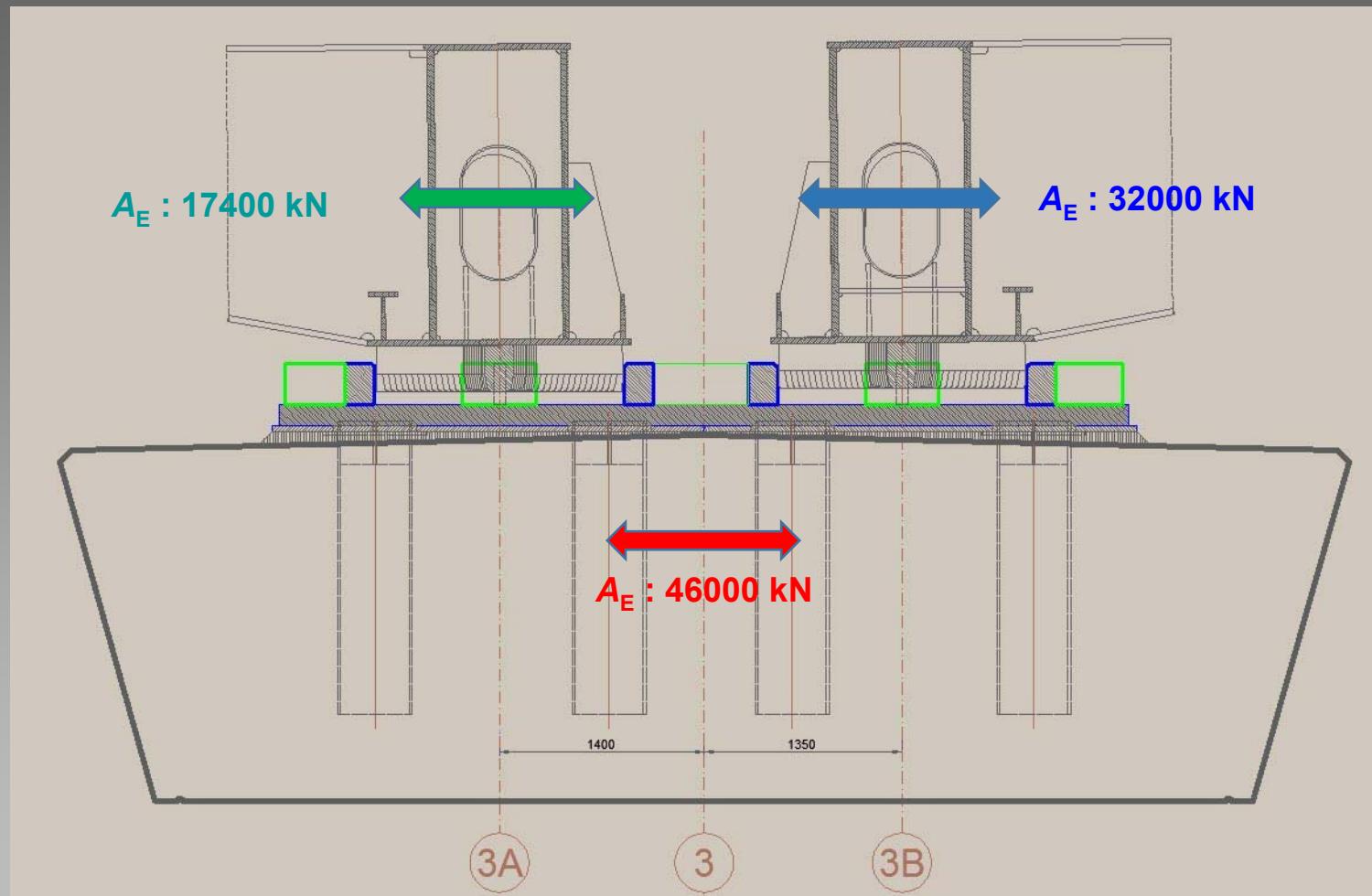
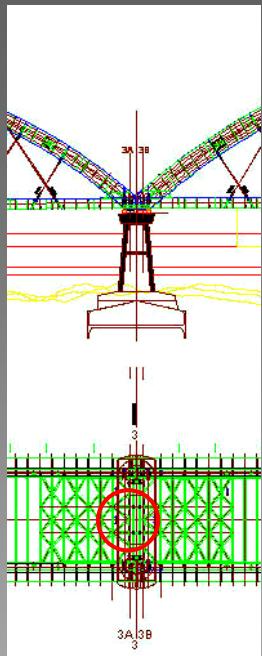


Čelična konstrukcija mosta: Prelazna ploča 3A-3B.

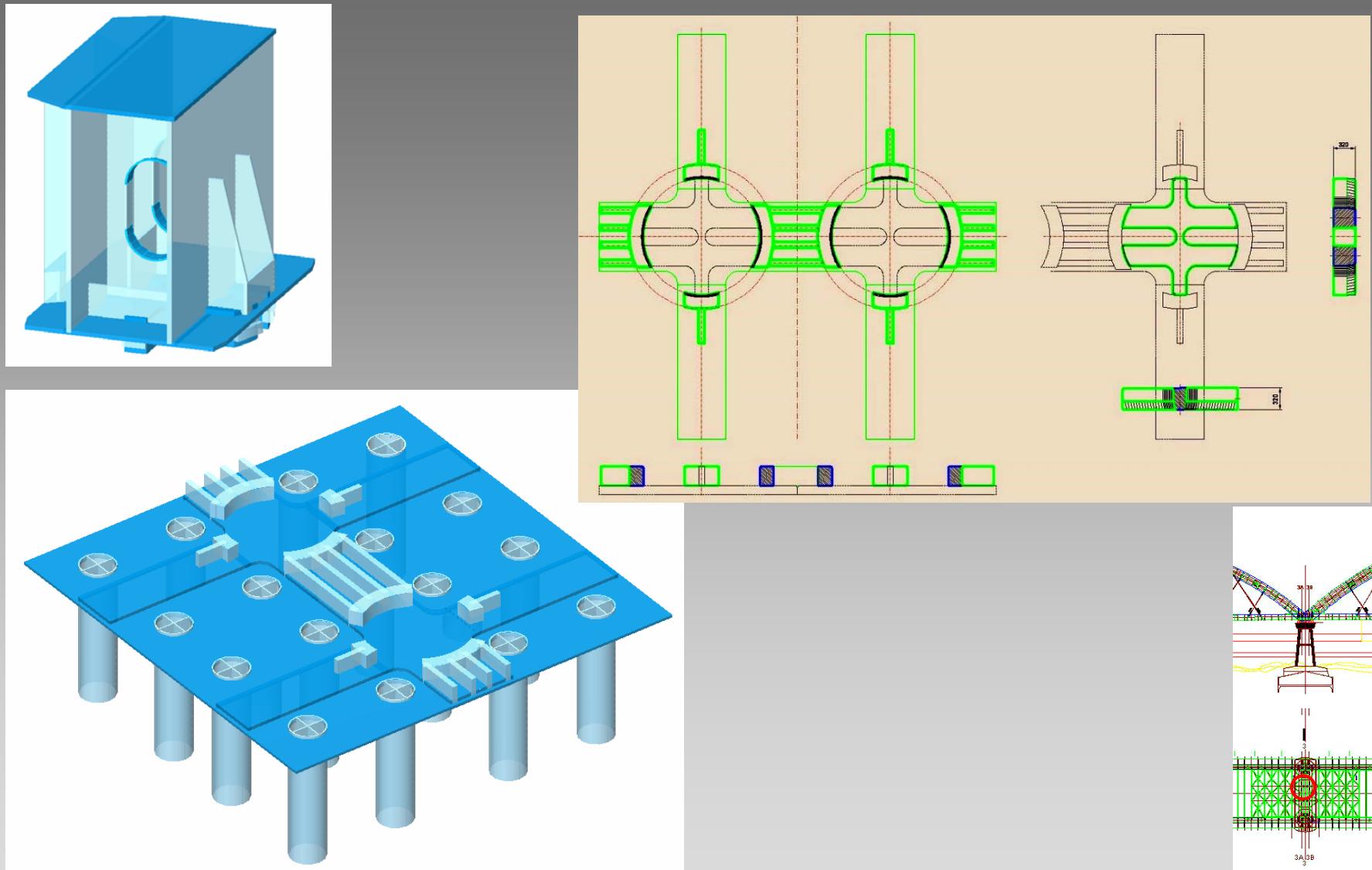


Železničko-drumski most u
Novom Sadu

Čelična konstrukcija mosta: Fiksna horizontalna ležišta u 3A-3B.

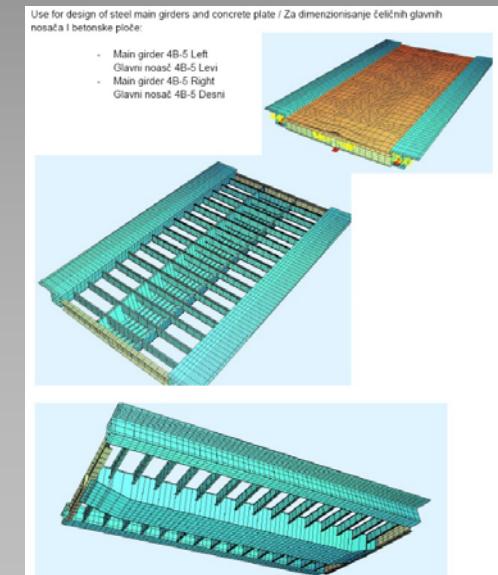
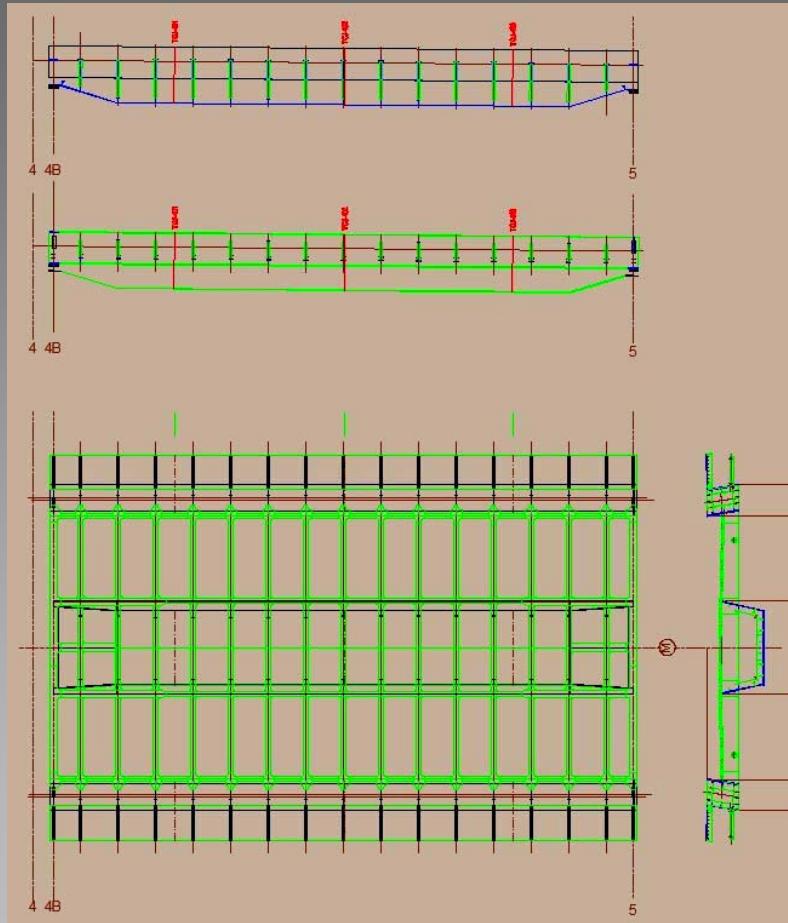


Čelična konstrukcija mosta: Fiksna horizontalna ležišta u 3A-3B.



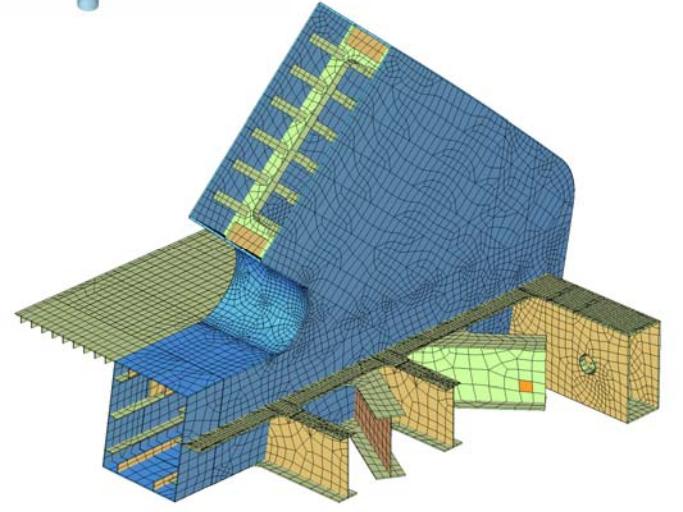
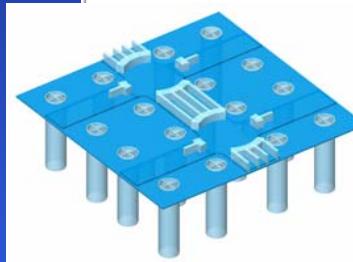
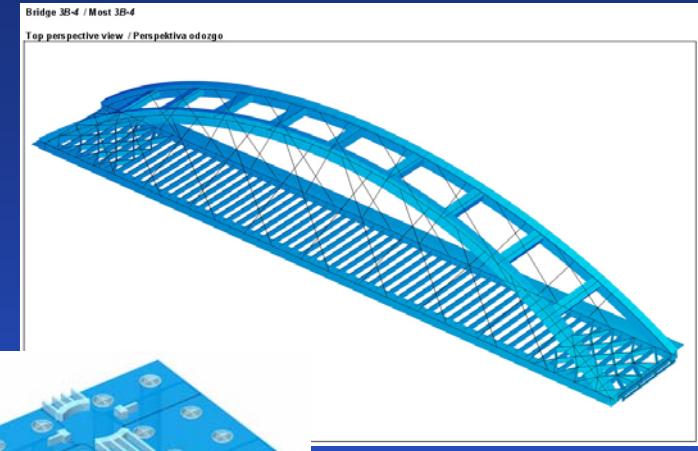
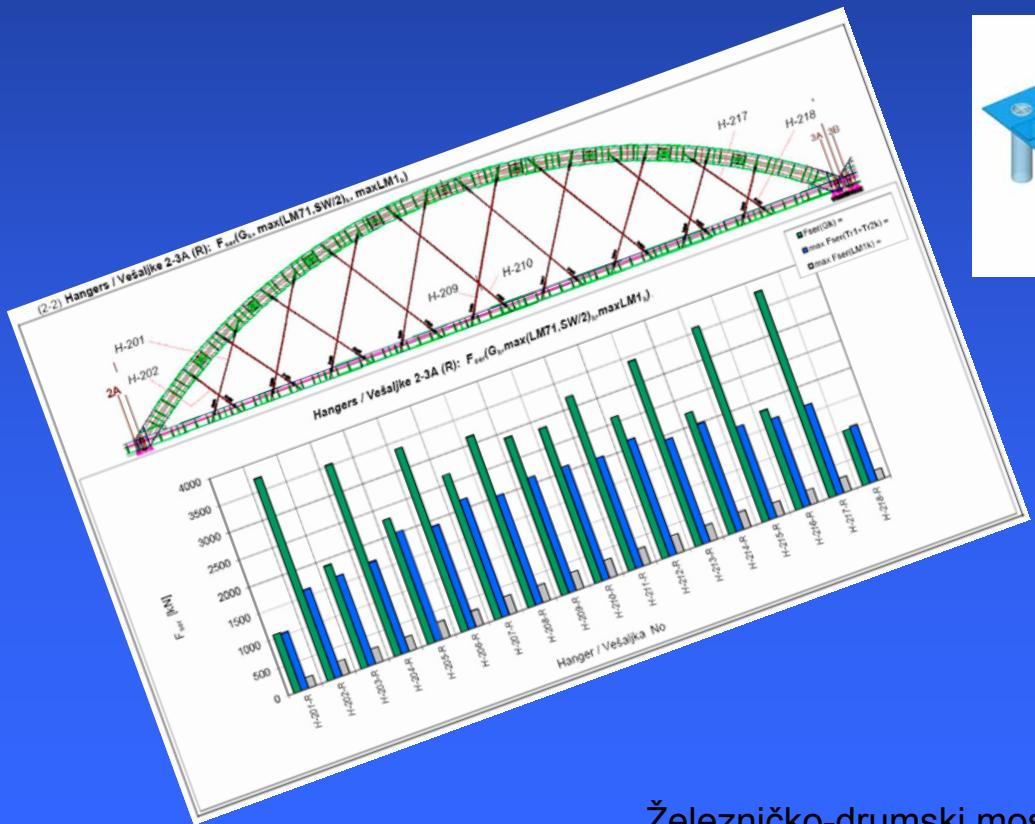
Železničko-drumski most u
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Čelična konstrukcija mosta: Most 4-5 – spregnuta prosta greda (48 m).



Železničko-drumski most u
Novom Sadu

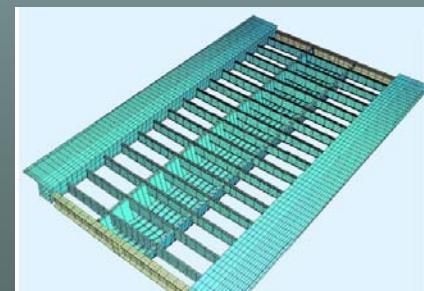
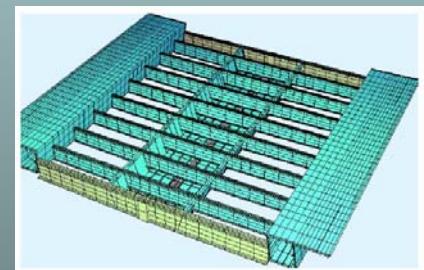
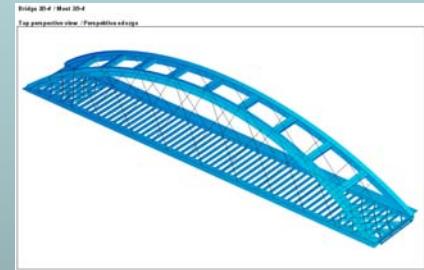
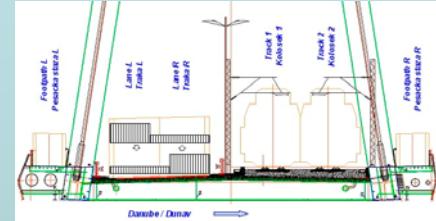
Proračun konstrukcije



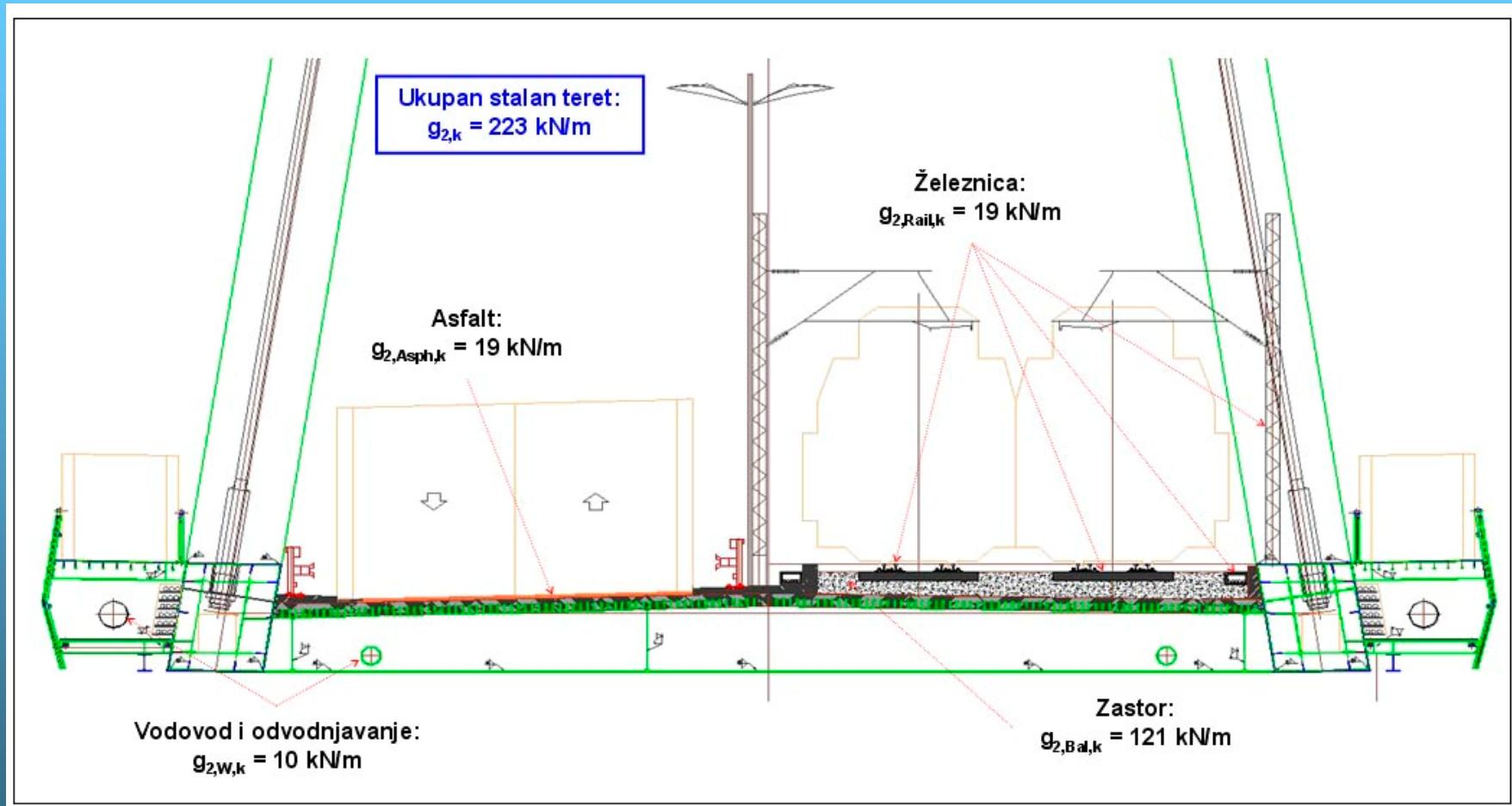
Železničko-drumski most u
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Proračun konstrukcije

<i>Modeli / Programi</i>	Globalni: Sofistik , uporedno i SAP. Detalji: Sofistik, Tower, SAP.
<i>Opterećenja</i>	<p>Težine:</p> <p>$G_{1,a,k}$ = Čelična konstrukcija</p> <p>$G_{1,c,k}$ = Betonska ploča = 181 i 232 kN/m</p> <p>$G_{2,k}$ = Stalni teret = 223 kN/m</p>
EN 1991-2:2003	<p>Saobraćajna opterećenja:</p> <p>Železnica: LM71, SW/2; Tip 2, Tip 5 .</p> <p>Drum: LM1, LM3 .</p>
EN 1991-1-4:2005 +AC1:2010	<p>Vetar: $v_{b,0} = 20,8 \text{ m/s.}$</p> <p>Toplotna delovanja:</p> <p>$\Delta T_{N,\text{pos,neg}}$, $\Delta T_{M,\text{pos,neg}}$, i kombinacije (10).</p>
EN 1991-1-5:2003	
EN 1991-2:2003	<p>Pokretanje i kočenje vozila: Q_{lbk} i Q_{lk}.</p>
EN 1998-2:2005 +AC1:2009	<p>Seizmičke sile:</p> <p>Prema lokalnim karakteristikama tla;</p> <p>Sa karakteristikama opruga tla (u X,Y,Z) i krutostima 0,5K i 2,0K;</p> <p>Proračun – metodom multimodalne analize i metodom time history.</p>



Opterećenja. Stalni teret (G_2)

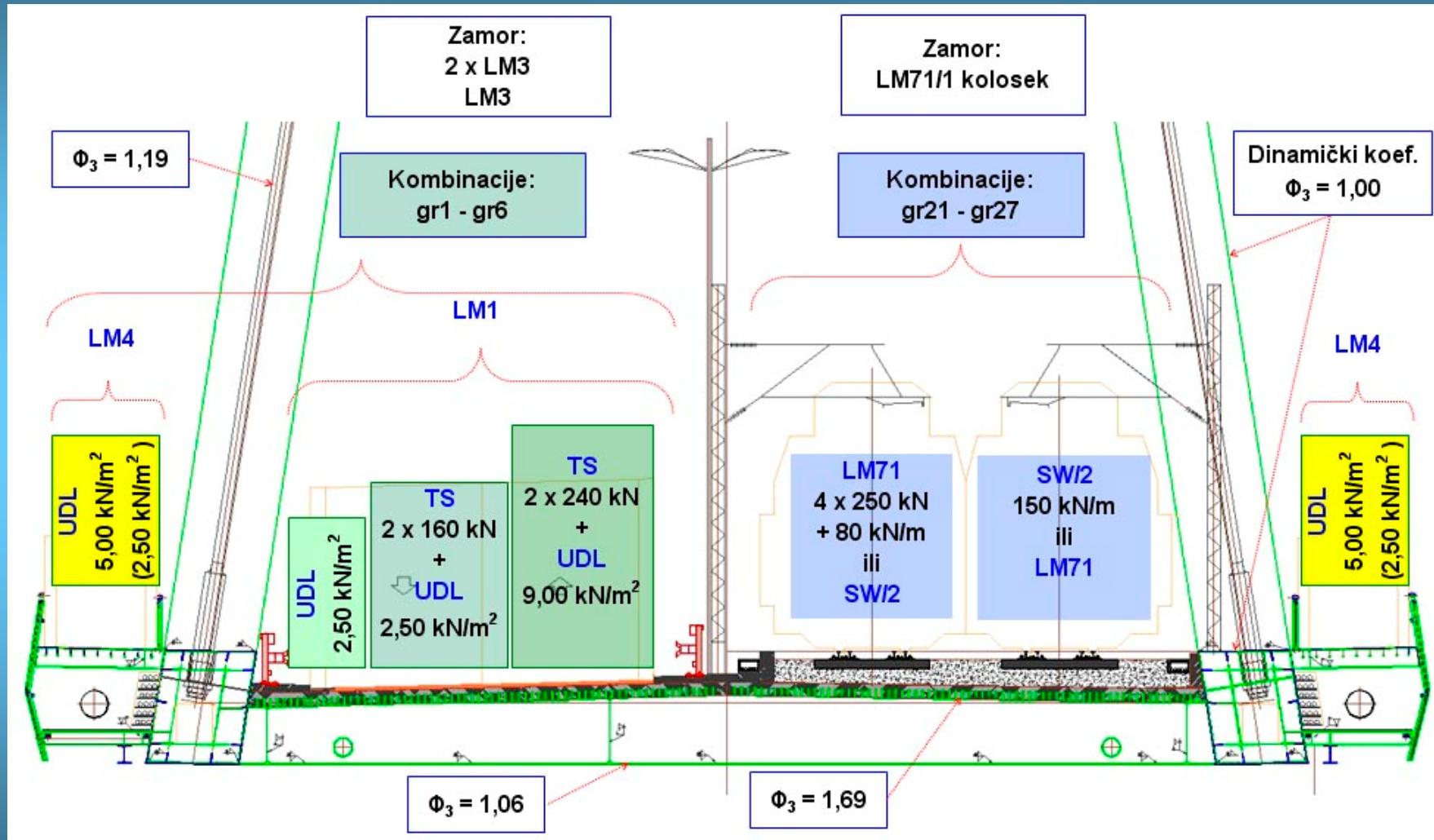


Most sa najvećim stalnim teretom u Srbiji!

Primer Gazele: $G_{2,k} = 100 \text{ kN/m}$, $G_{1,k} + G_{2,k} = 200 \text{ kN/m} < 223 \text{ kN/m} !$

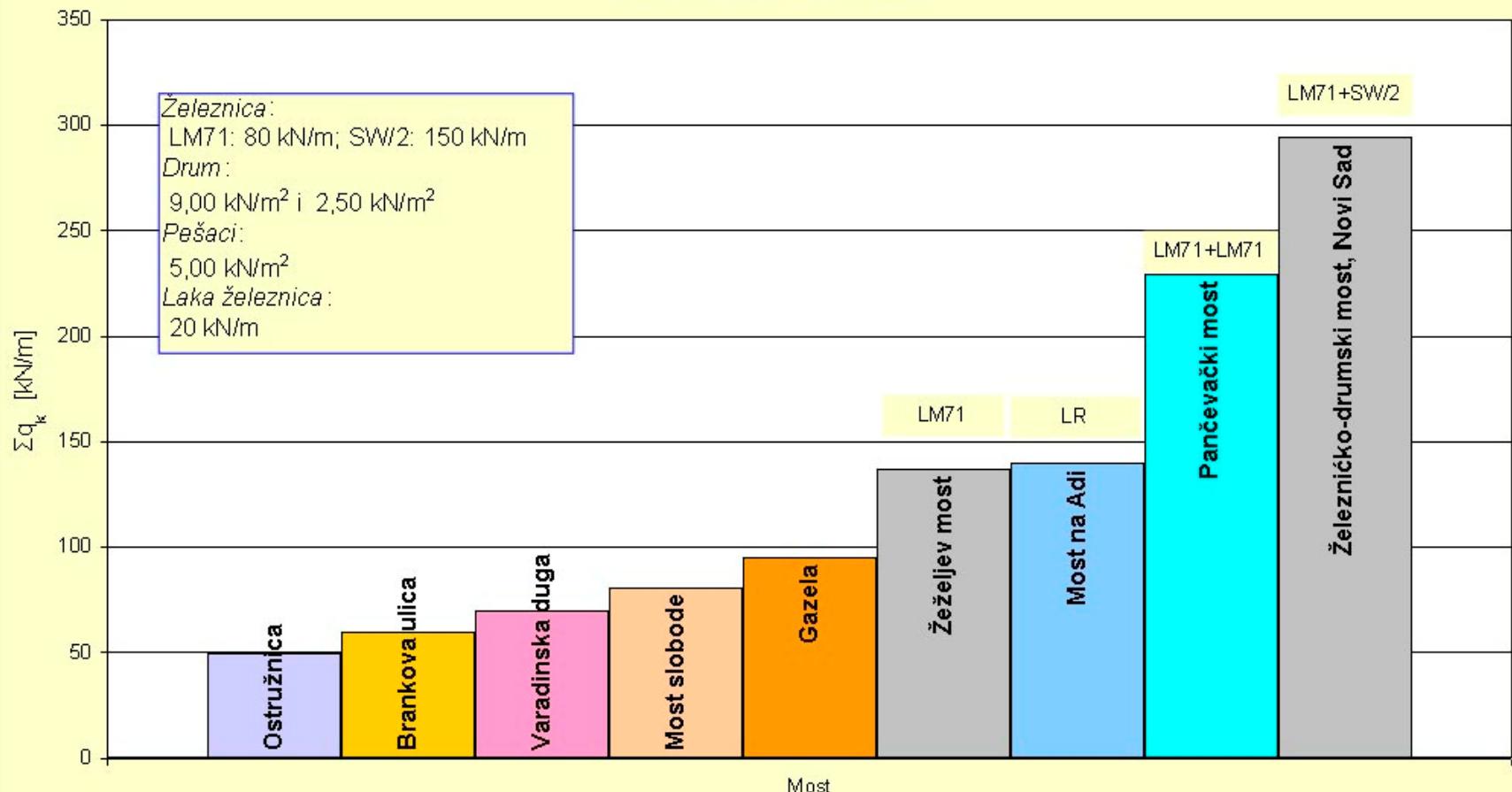
Težina tucaničkog zastora je $0,55 G_{2,k}$.

Opterećenja. Saobraćajna opterećenja (q , Q)



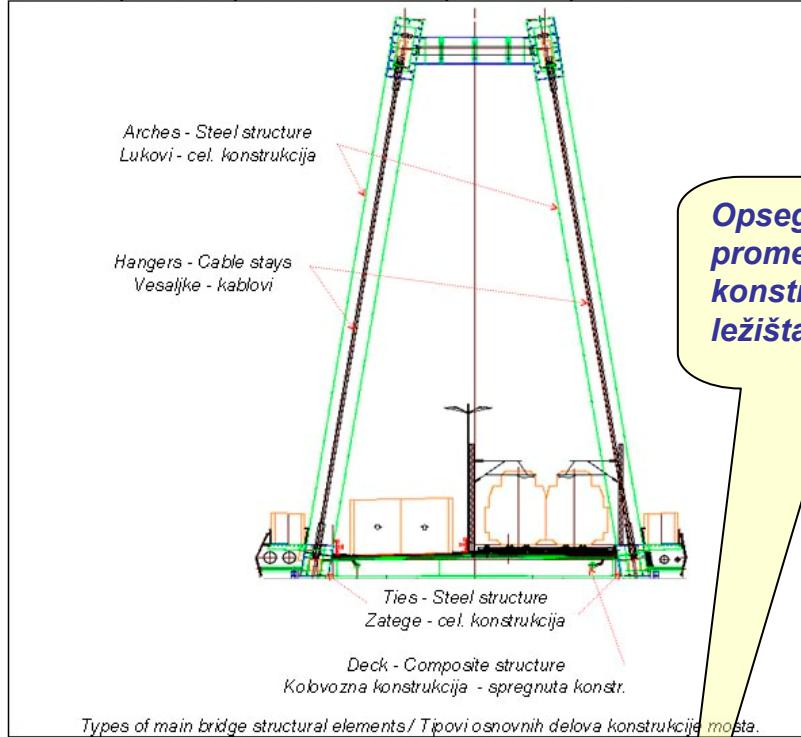
Opterećenja. Saobraćajna opterećenja (q , Q)

Zbir karakterističnih podeljenih saobraćajnih opterećenja po EN 1991-2 nekim mostova u Srbiji.
Železnica + Drum + Pešaci



Opterećenja. Toplotna delovanja (ΔT_N , ΔT_M i kombinacije)

Uniform temperature component / Konstantna temperaturna komponenta



Bridge element Deo konstruk. mosta	Type of the structure Tip konstrukcije <u>DIN-Fb 101:2009, V.6.3.3.1. EN 1991-1-5:2003, Ch.6.11.</u>	Group Grupa	$T_{e\min}$ K	$T_{e\max}$ K	Bridge struct. Konstr. mosta		Bearings, EJs Ležista,dilat. 1)	
					$\Delta T_{N\text{neg}}$ K	$\Delta T_{N\text{pos}}$ K	$\Delta T_{M\text{neg}}$ K	$\Delta T_{M\text{pos}}$ K
Arches Lukovi	Steel structure Celicna konstrukcija	1	-26	51	-36	41	-46	51
Zatege Ties	Steel structure Celicna konstrukcija	1	-26	51	-36	41	-46	51
Deck Kolovozna kon.	Composite structure S pregnuta konstrukcija	2	-20	41	-30	31	-40	41

Temperature load combinations for analysis

Kombinacije temperaturnih delovanja za proračun

Max air temperarure /Max temp. vazduha

Min air temperature / Min temp. vazduha

$T_{A\min} = -24 \text{ K}$

$T_{A\max} = 37 \text{ K}$

Bridge structure / Konstrukcija mosta

Arches/Lukovi Ties/Zatege	$\Delta T_{N\text{pos}} = 41 \text{ K}$	$\Delta T_{N\text{reg}} = -36 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \Delta T_{N,15K}$	$\Delta T_{N\text{reg}} + \Delta T_{N,15K}$
	$\Delta T_{N\text{pos}} = 31 \text{ K}$	$\Delta T_{N\text{reg}} = -30 \text{ K}$	$\Delta T_{M\text{pos}} = 12 \text{ K}$	$\Delta T_{M\text{reg}} = -22 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
	$\Delta T_{N\text{pos}} = 41 \text{ K}$	$\Delta T_{N\text{reg}} = -36 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
	$\Delta T_{N\text{pos}} = 41 \text{ K}$	$\Delta T_{N\text{reg}} = -36 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
Deck Kolovoznakon.	$\Delta T_{N\text{pos}} = 41 \text{ K}$	$\Delta T_{N\text{reg}} = -36 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
	$\Delta T_{N\text{pos}} = 31 \text{ K}$	$\Delta T_{N\text{reg}} = -30 \text{ K}$	$\Delta T_{M\text{pos}} = 12 \text{ K}$	$\Delta T_{M\text{reg}} = -21,6 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
	$\Delta T_{N\text{pos}} = 41 \text{ K}$	$\Delta T_{N\text{reg}} = -40 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
	$\Delta T_{N\text{pos}} = 41 \text{ K}$	$\Delta T_{N\text{reg}} = -40 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$

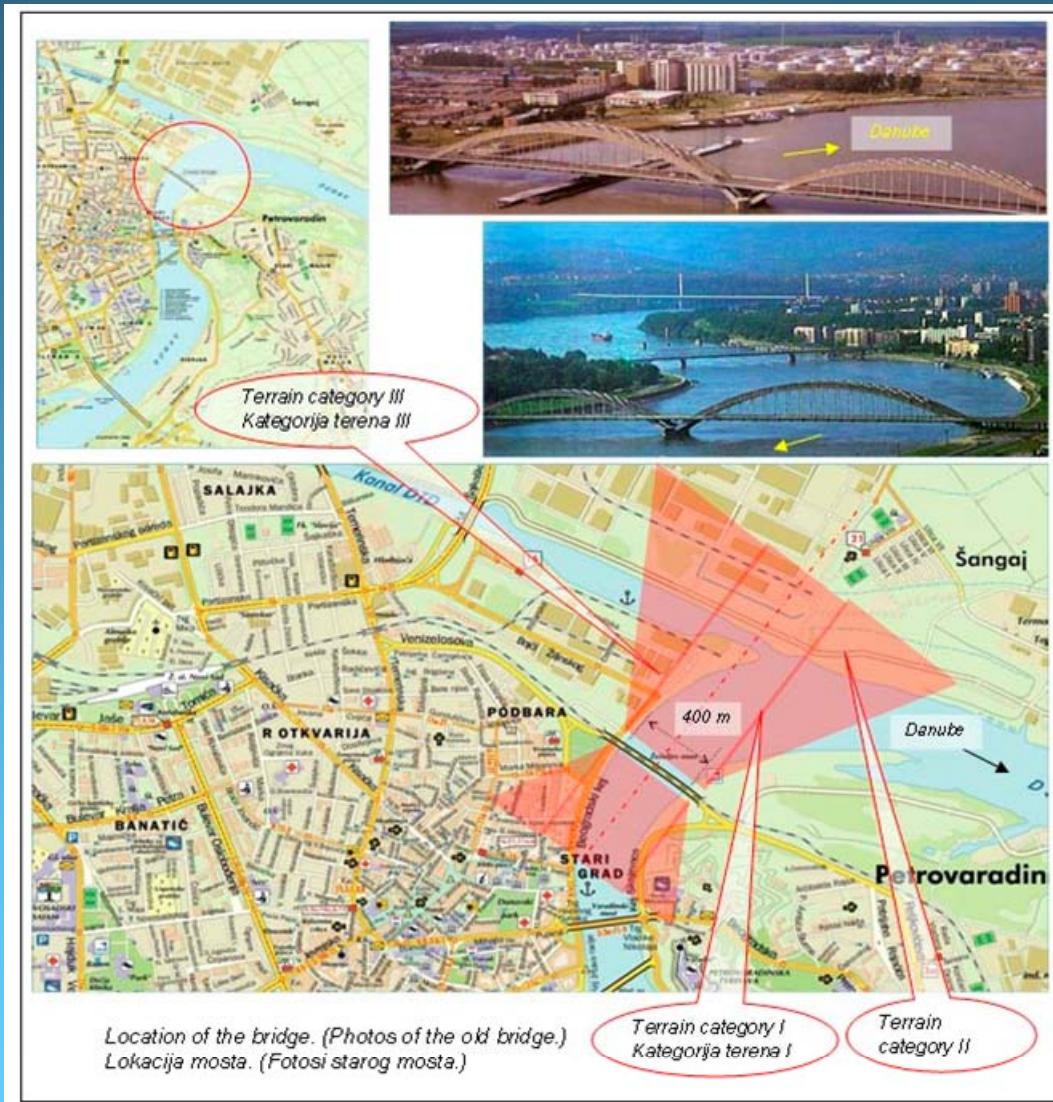
Bearings and expansion joints / Ležista i dilatacione sprave

Arches/Lukovi Ties/Zatege	$\Delta T_{N\text{pos}} = 51 \text{ K}$	$\Delta T_{N\text{reg}} = -46 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \Delta T_{N,15K}$	$\Delta T_{N\text{reg}} + \Delta T_{N,15K}$
	$\Delta T_{N\text{pos}} = 31 \text{ K}$	$\Delta T_{N\text{reg}} = -30 \text{ K}$	$\Delta T_{M\text{pos}} = 12 \text{ K}$	$\Delta T_{M\text{reg}} = -21,6 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
	$\Delta T_{N\text{pos}} = 41 \text{ K}$	$\Delta T_{N\text{reg}} = -40 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
	$\Delta T_{N\text{pos}} = 41 \text{ K}$	$\Delta T_{N\text{reg}} = -40 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
Deck Kolovoznakon.	$\Delta T_{N\text{pos}} = 51 \text{ K}$	$\Delta T_{N\text{reg}} = -46 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
	$\Delta T_{N\text{pos}} = 31 \text{ K}$	$\Delta T_{N\text{reg}} = -30 \text{ K}$	$\Delta T_{M\text{pos}} = 12 \text{ K}$	$\Delta T_{M\text{reg}} = -21,6 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
	$\Delta T_{N\text{pos}} = 41 \text{ K}$	$\Delta T_{N\text{reg}} = -40 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$
	$\Delta T_{N\text{pos}} = 41 \text{ K}$	$\Delta T_{N\text{reg}} = -40 \text{ K}$	$\Delta T_{M\text{pos}} = 18 \text{ K}$	$\Delta T_{M\text{reg}} = -13 \text{ K}$	$\omega_M = 0,75$	$\omega_R = 0,35$	$\Delta T_{N\text{pos}} + \omega_M \Delta T_{M\text{pos}}$	$\Delta T_{N\text{reg}} + \omega_M \Delta T_{M\text{reg}}$

1) Unrealistic, not applied.

Nerealno, ne primjenjuje se.

Opterećenja. Vetur



Vetur, EN 1991-1-4:2005:

Kategorija hrapavosti terena: II;

Osnovna brzina vetra: $v_b = 21,6 \text{ m/s}$;

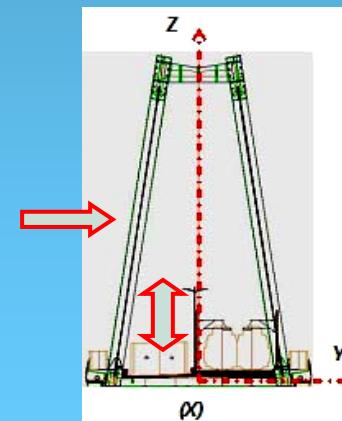
Delovanje vetra:

poprečno,

poduzno,

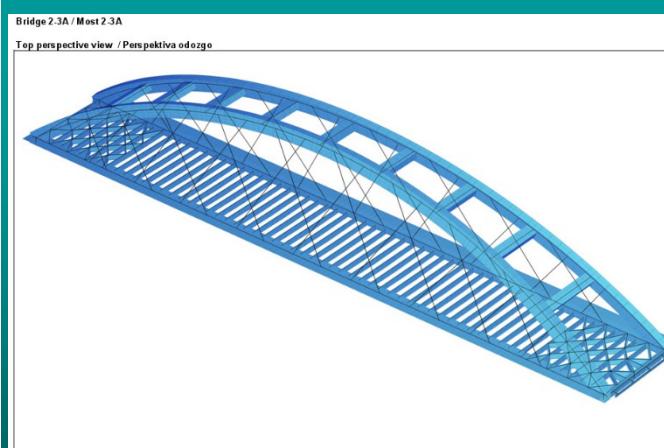
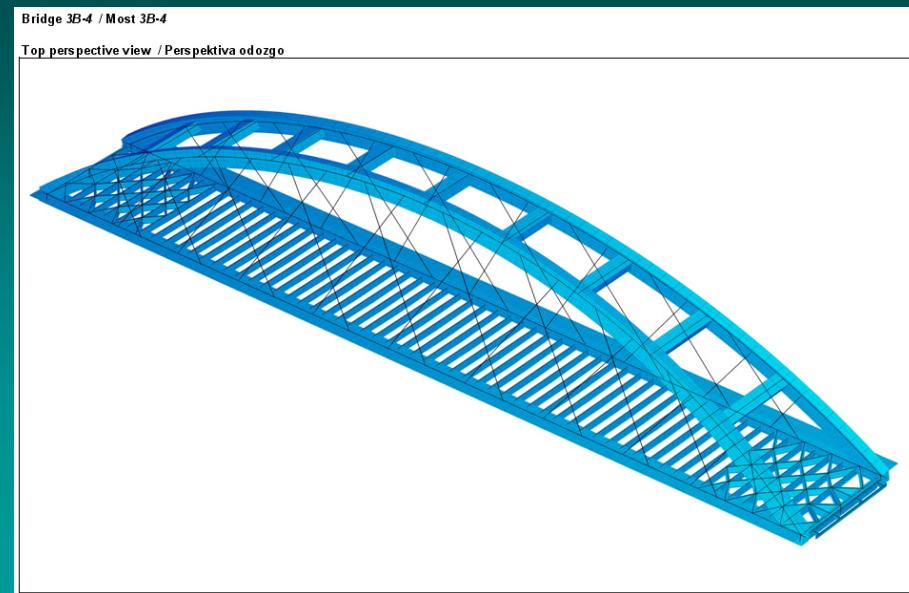
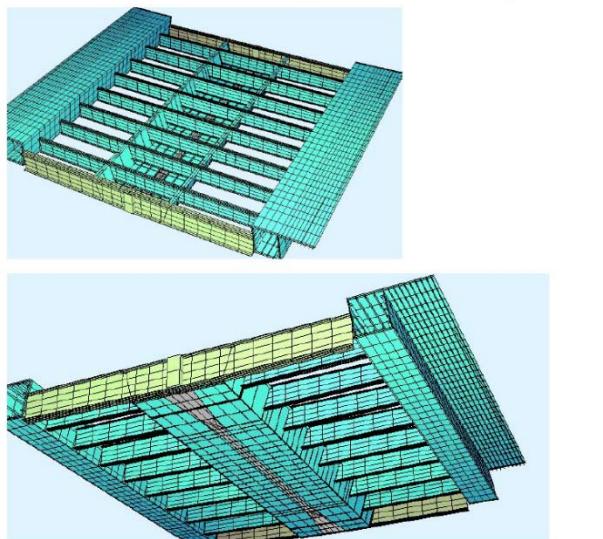
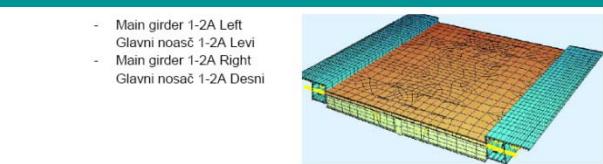
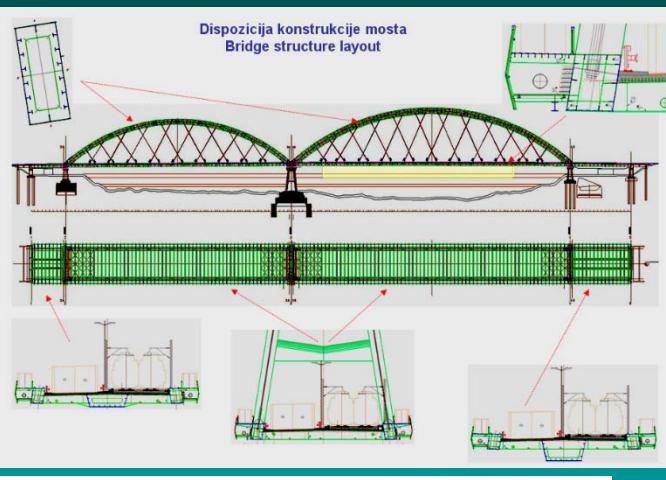
vertikalno,

torziono.



Železničko-drumski most u
Novom Sadu

Modeli konstrukcija



Presečne sile

1-2A:

L
 M
 R

2-3A:

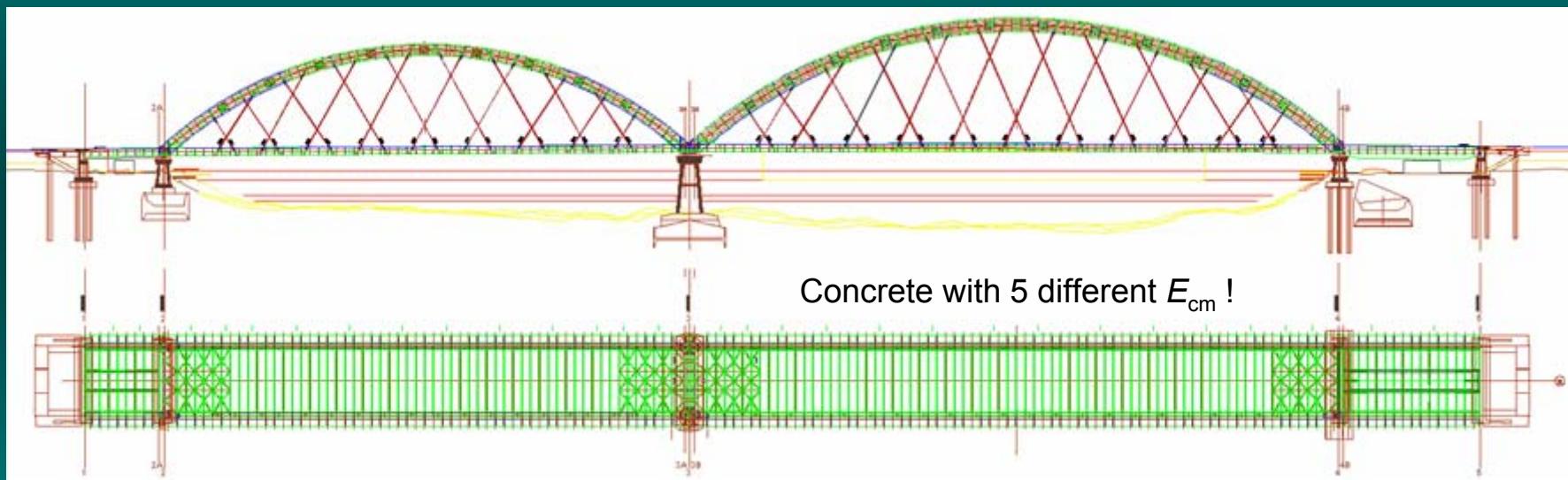
Arches: $L+R$, **2x64** sect.
 Ties: $L+R$, **2x64** sect.
 Hangers: **2x18** elements

3B-4:

Arches: $L+R$, **2x80** sect.
 Ties: $L+R$, **2x77** sect.
 Hangers: **2x22** elements

1-2A:

L
 M
 R



max/min N_x + corr. V_y, V_z, M_x, M_y, M_z .
max/min M_y + corr. N_x, V_y, V_z, M_x, M_z .
max/min M_z + corr. N_x, V_y, V_z, M_x, M_y .

7 railway load combinations
 6 road load combinations
 10 thermal combinations
 2 wind combinations

for

ULS

SLS

Fatigue

Dokazi u proračunu konstrukcije

ULS

Stanja granične nosivosti

$$\sum_{j \geq 1} \gamma_{Gj} \cdot G_{kj} + \gamma_P \cdot P_k + \gamma_{Q1} \cdot Q_{k1} + \sum_{i > 1} \gamma_{Qi} \cdot \psi_{0i} \cdot Q_{ki}$$

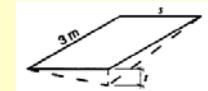
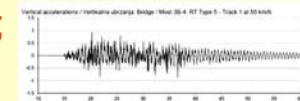
- Statički proračun.
- Dinamički proračun.
- Otpornost preseka: σ_{Ed} , τ_{Ed} , $\sigma_{V,Ed}$;
- Lokalna stabilnost – izbočavanje elemenata (metodom redukovanih napona) i **izbočavanje uzrokovano izvijanjem pojaseva**;
- Globalna stabilnost lukova.

SLS

Stanja granične upotrebljivosti

$$\sum_{j \geq 1} G_{kj} + P_k + Q_{k1} + \sum_{i > 1} \psi_{0i} \cdot Q_{ki}$$

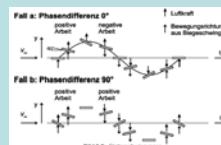
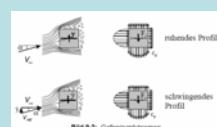
- vertikalna ubrzanja kolovozne konstrukcije;
- vertikalni ugibi konstrukcije;
- horizontalni ugibi i rotacije oko vertikalne ose;
- pomerenja kolovozne konstrukcije iza ležišta;
- ekstremne uglovne rotacije na ležištima;
- uvrtanje kolovoza;
- prsline betonske kolovozne ploče.



Zamor

- lukovi, zatege, čelični delovi kolovozne konstrukcije;
- vešalice (kablovi);
- betonska kolovozna ploča: beton, armatura.

Aerodinamički efekti



- Greda: aerodinamička osjetljivost, odvajanje vrtloga, flater, turbulentacija.
- Vešalice: odvajanje vrtloga, galopiranje, vibracije izazvane kišom i vetrom.

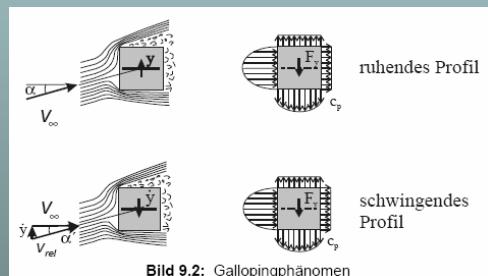
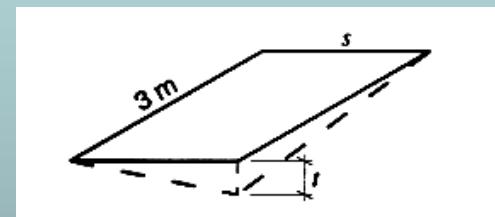
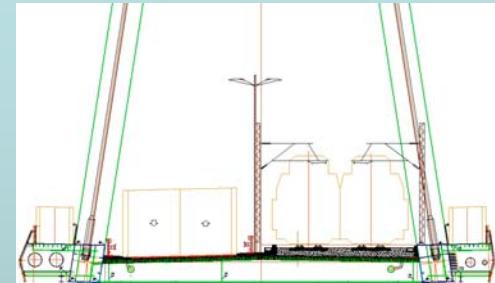
SLS analysis / Proračun SLS

SLS = Granično stanje upotrebljivosti za konstrukciju

(2) Combinations of actions for SLS

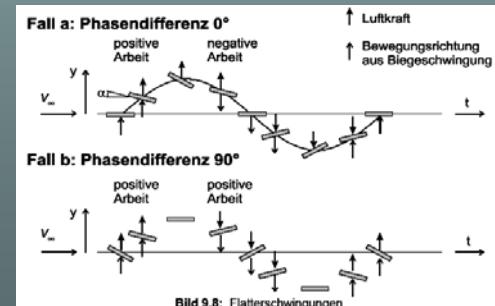
Kombinacije opterećenja za granično stanje upotrebljivosti

Check of / Kontrola	Loaded track No Opt. kolosek br		Loads Opterećenja Characteristical values
	T1	T2	
Traffic safety checks Kontrole sigurnosti saobraćaja	Vertical deformation ¹⁾ Vertikalni ugib		$\alpha\Phi LM71$
	Angular rotation ²⁾ Uglovna rotacija		$\alpha\Phi LM71$ or/ili $\alpha\Phi SW/0$
	Horizontal deformation ³⁾ Horizontalni ugib		$\alpha\Phi LM71 + F_w^{**} + Q_{sk} + \Delta T$ or $\alpha\Phi SW/0 + F_w^{**} + Q_{sk} + \Delta T$
	Deck twist ⁴⁾ Uvrtanje kolovoza		$\Phi LM71$
	Vertical acceleration of deck ⁵⁾ Vertikalno ubrzanje kolovoza		Trains: Type 2, Type 5 Vozovi:



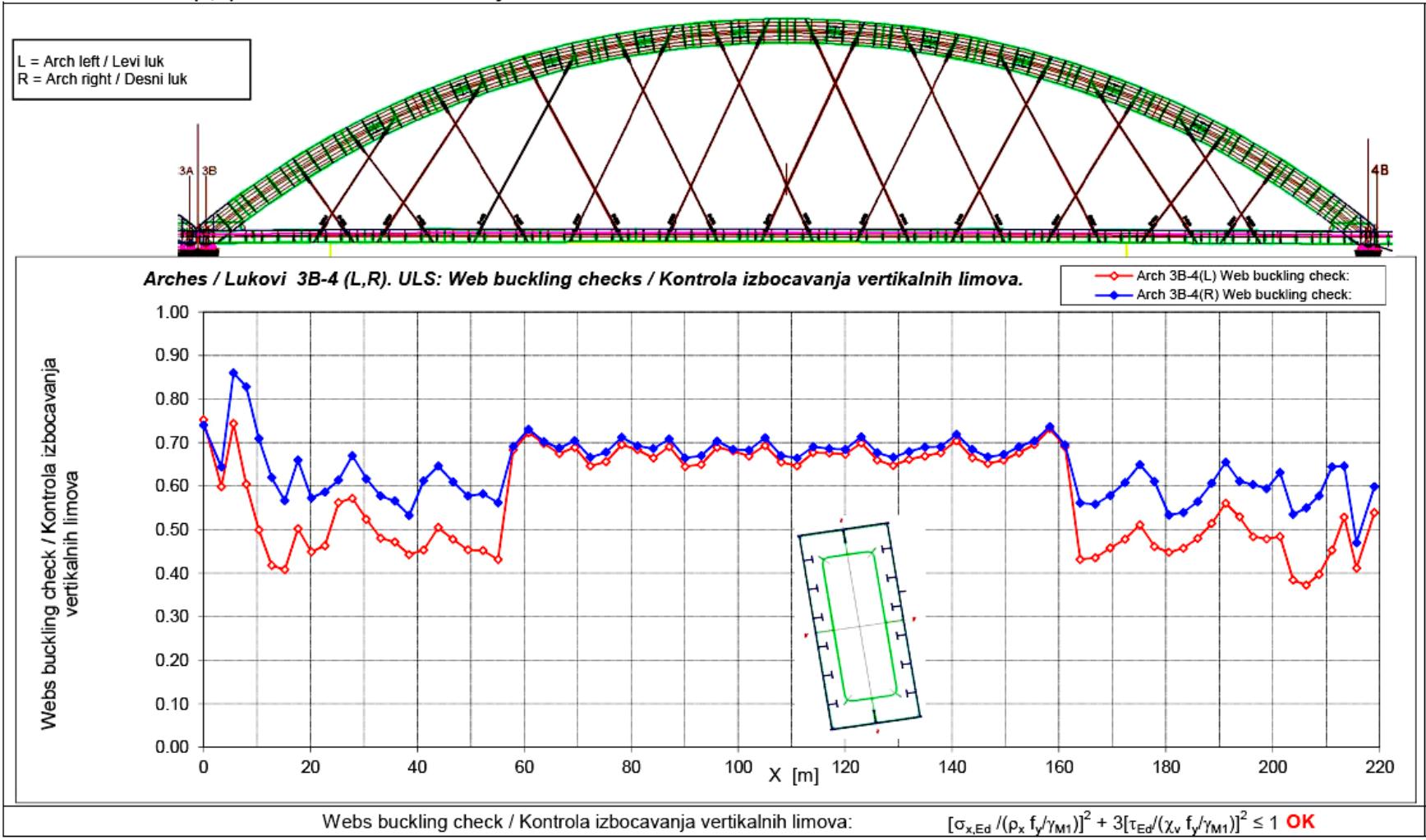
SLS = Aerodynamic effects / Aerodinamički efekti

Structure / Konstrukcija	Hangers / Vešaljke (kablovi)
Odvajanje vrtloga od grede	Odvajanje vrtloga
Galopirajući flater	Galopiranje
Klasični flater	Vibracije izazvane kišom i vетrom
Divergencija	

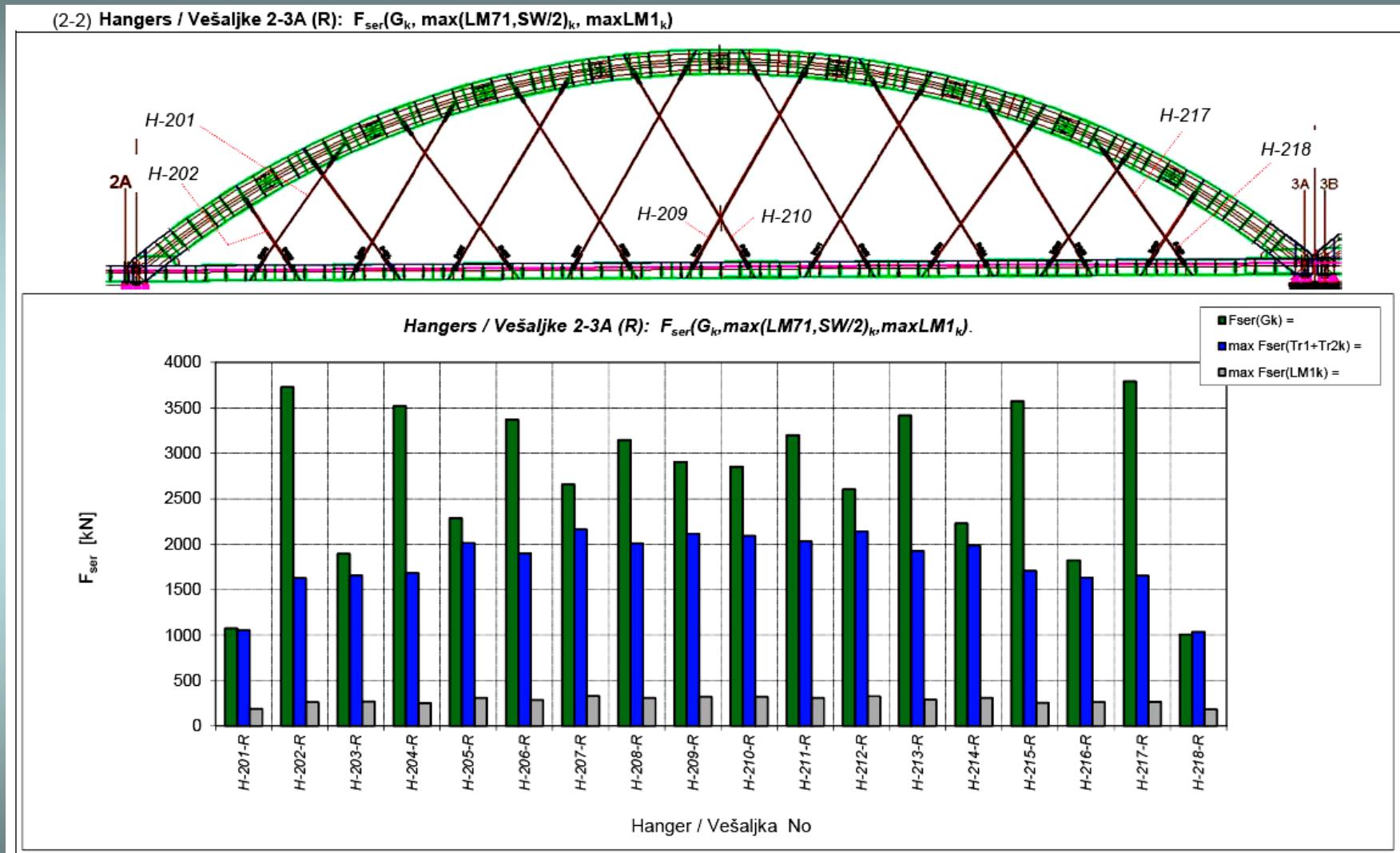


Primeri kontrole ULS: Sigurnost na izbočavanje vert. limova luka 3B-4.

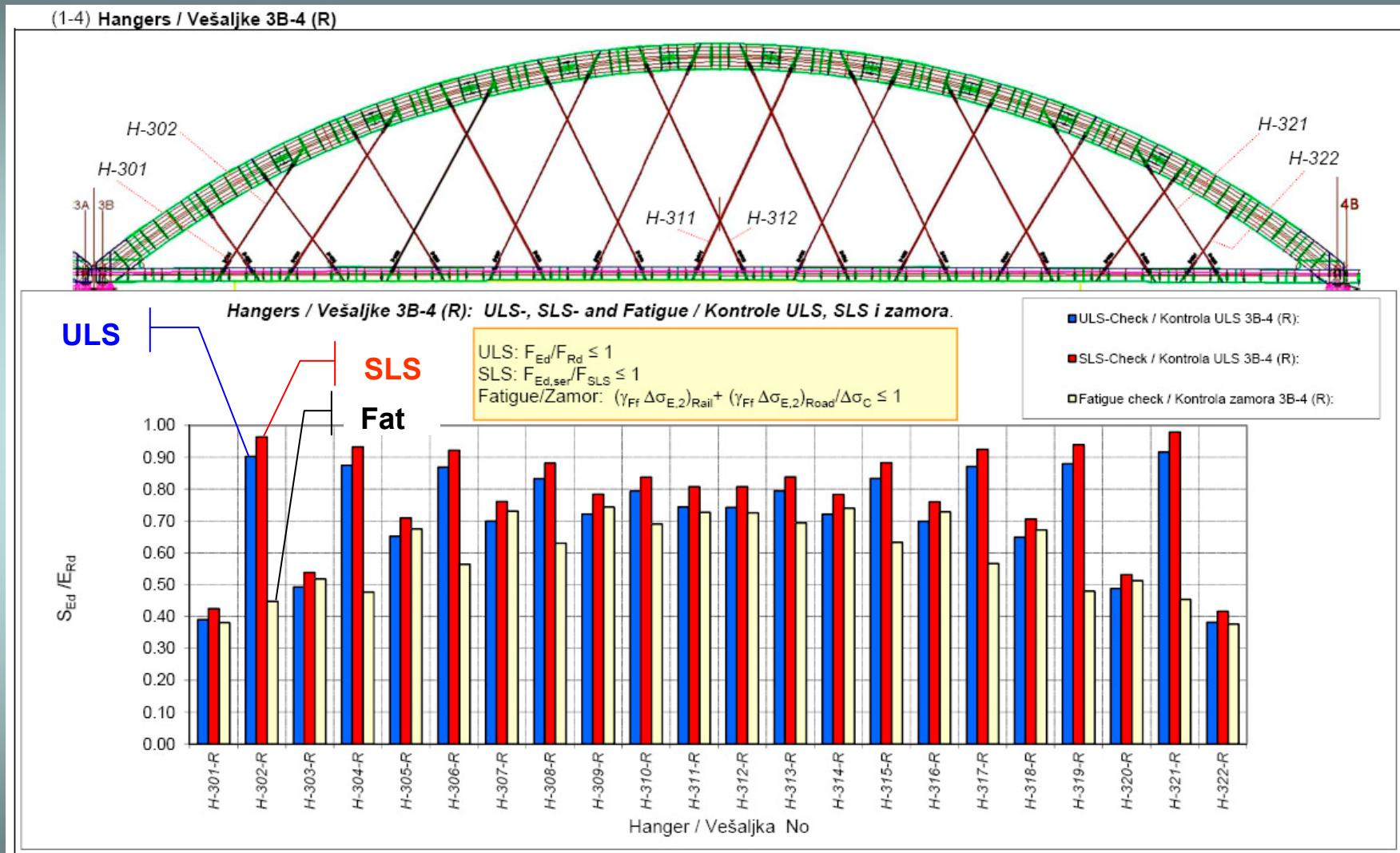
(6) Arches 3B-4 (L,R) / Resume of web buckling checks
 Lukovi 3B-4 (L,R) / Rezime kontrola izbocavanja vertikalnih limova



Primeri sila SLS: ekstremne sile u vešaljkama polja 2-3A(R).



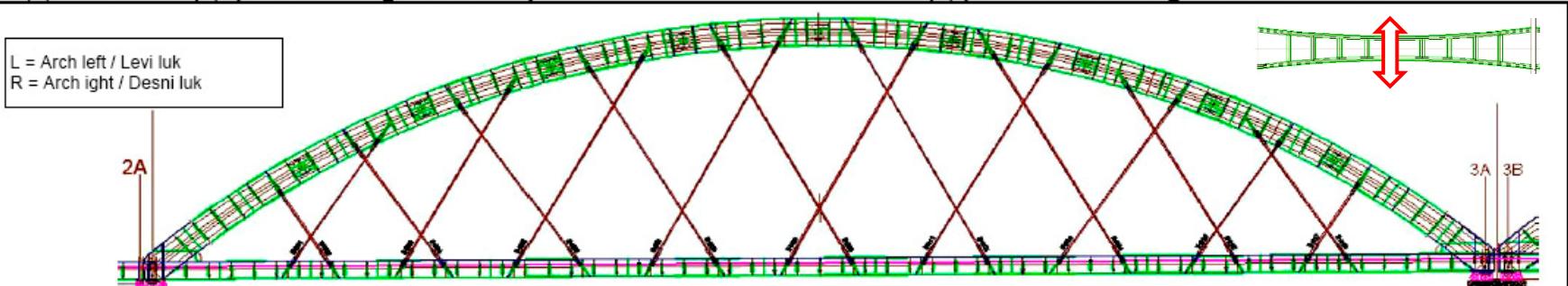
Primeri kontrole ULS, SLS, zamora: Vešaljke luka 3B-4(R).



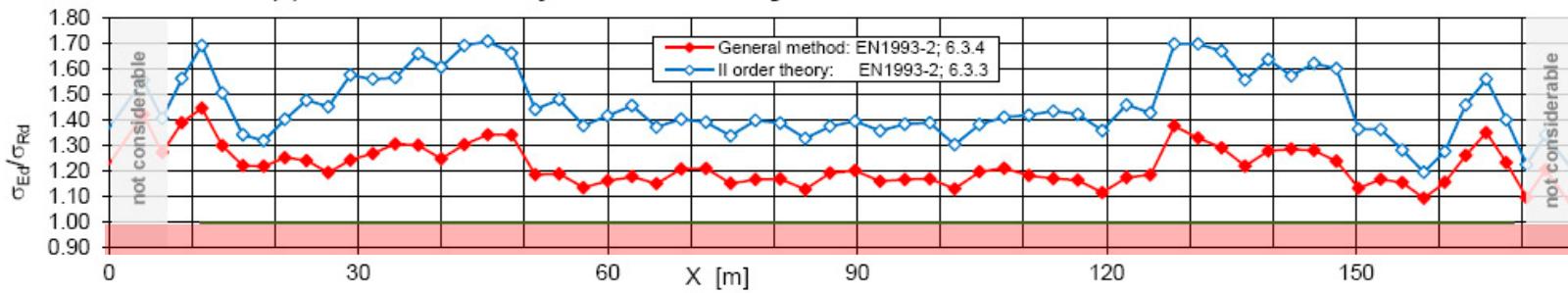
Primeri kontrole ULS: Globalna stabilnost luka 2-3A.

(1) Arch 2-3A (L,R) / Resume of global stability checks

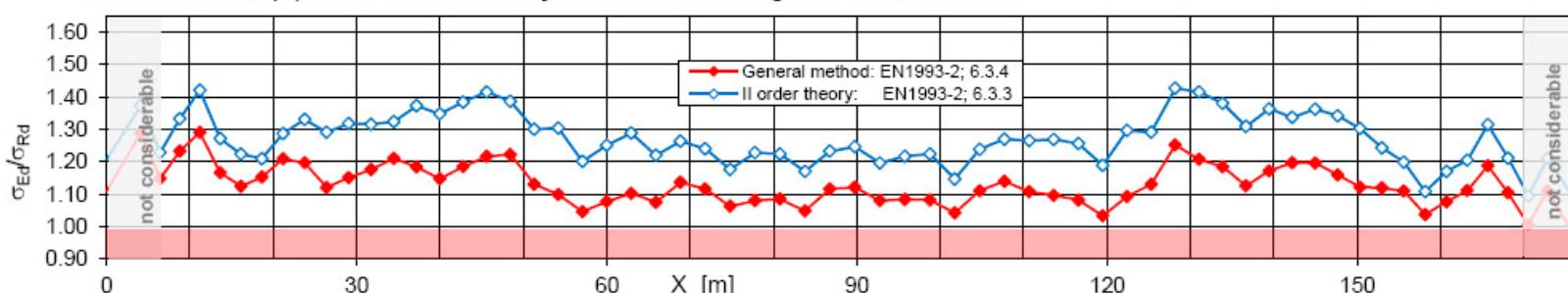
Luk 2-3A (L,r) / Rezime kontrola globalne stabilnosti



Arch/Luk 2-3A (L). ULS: Global stability checks / Kontrola globalne stabilnosti.



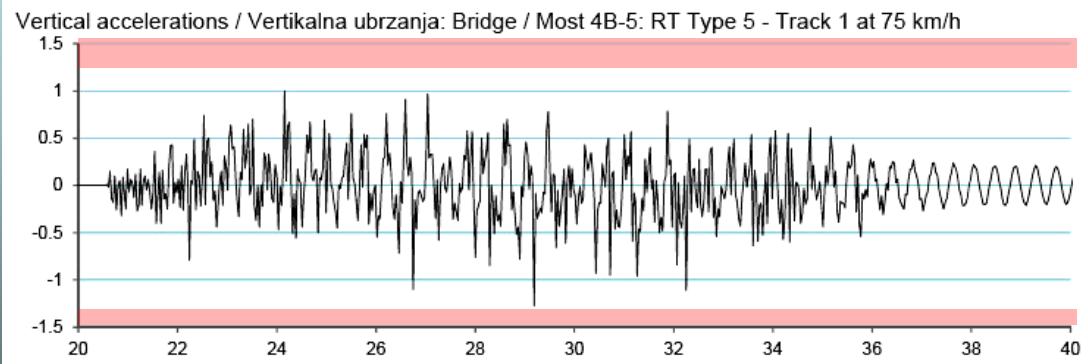
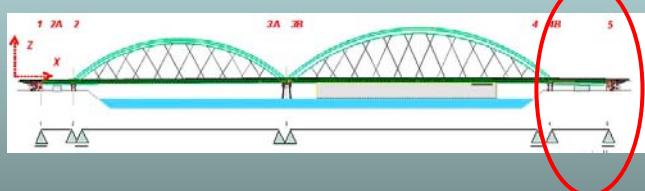
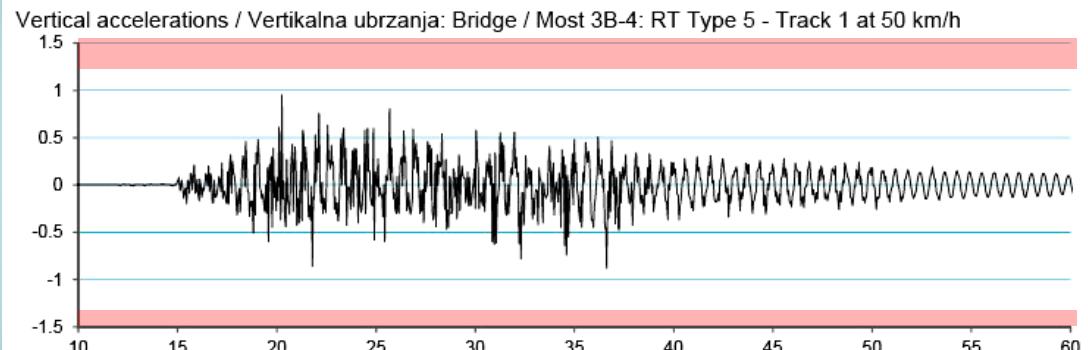
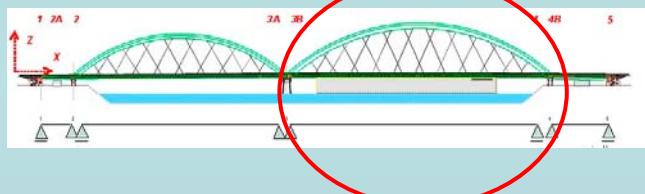
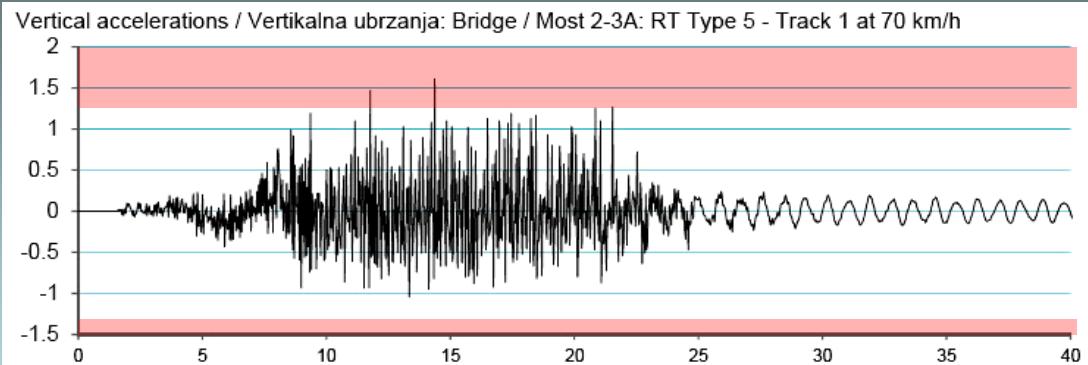
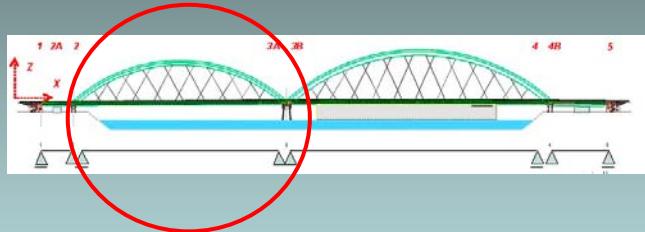
Arch/Luk 2-3A (R). ULS: Global stability checks / Kontrola globalne stabilnosti.



Global stability check / Kontrola globalne stabilnosti:

Global stability ≥ 1 **OK**

Primer kontrole SLS: Vertikalna ubrzanja tačaka zatega.



(2) Load combinations for serviceability limit states (SLS) Kombinacije opterećenja za proračun graničnih stanja upotrebljivosti (SLS) s. Ch. 3.11(2).	SLS-requirement SLS-uslov	Bridge / Most 2-3A	Bridge / Most 3B-4
(3) Scope of fulfillment of SLS-requirements Pregled ispunjenosti SLS-uslova	Unrestrained uplift at the bearings Nekontrolisano odizanje ležišta	All vertical reaction forces > 0 Sve vertikalne reakcije oslonaca > 0 s. Ch. 5. OK OK	
SLS-requirement SLS-uslov	Bridge / Most 2-3A	Bridge / Most 3B-4	
(3-1) Vertical accelerations of the deck Vertikalno ubrzanje kolovozne konstrukcije	s. Ch. 15.1(5). Train type 5 / Voz tipa 5 1,0) Criterion / Kriterijum: Very good: $b_v \leq 0,8 \text{ m/s}^2$ Vrlo dobar: Good: $b_v \leq 1,3 \text{ m/s}^2$ 1) Dobar: Acceptable: $b_v \leq 2,0 \text{ m/s}^2$ Prihvatljiv: 1) Requested by ToR for Preliminary Design. 1) Zahtev po Projektnom zadatku za Idejni pr.	max $\delta = 2,8 \text{ mm}$ $\delta/\delta_m = 0,31$ OK OK OK	Movements of the end of the deck beyond bearings Pomeranja kolovozne konstrukcije iza ležišta s. Ch. 6.9. 2A-2 3A-3B 4-4B max $\delta = 3,8 \text{ mm}$ $\delta/\delta_m = 0,42$ OK OK OK
(3-2) Vertical deflection of the deck Vertikalni ugib kolovozne konstrukcije	L = 177,0 m L = 219,0 m $\delta_{Z,Deck} \approx \delta_{Z,Tie}$ s. Ch. 14.1.1-14.1.4. LM71/T1: max δ_Z Criterion / Kriterijum: for / za $V = 160 \text{ km/h}$ $\max(L/\delta_Z) = 800$ $\delta_Z = 29 \quad 43 \quad 39 \quad 54$ $L/\delta_Z = 6067 \quad 4100 \quad 5550 \quad 4073$ OK OK OK OK LM71/T2: max δ_Z $\delta_Z = 19 \quad 53 \quad 28 \quad 65$ $L/\delta_Z = 9322 \quad 3345 \quad 7861 \quad 3388$ OK OK OK OK	Twist of the deck Uvratanje kolova Twist value / Mera uvratanja: $t < 1 \text{ mm/3 m}$ Limit twist value for $V = 160 \text{ km/h}$: $t_{lim} = 3,0 \text{ mm/3 m}$ OK	Extreme angular rotations at bearings Ekstremne uglovne rotacije na ležištima s. Ch. 5.7.9. 2A-2 3A-3B 4-4B max $(\theta_{Y1} + \theta_{Y2}) = 2,3 \quad 3,7 \quad 3,1 \text{ mrad}$ $\lim (\theta_{Y1} + \theta_{Y2}) = 5,0 \quad 5,0 \quad 5,0 \text{ mrad}$ OK OK OK
(3-3)			
(3-4)			
(3-5)			
(3-6)			

Izrada konstrukcije u firmi Taddei, L'Aquila.

Čelik

Klasa izrade čelične konstrukcije: **EXC4, EN 1990-2:2011.**

Čelik konstrukcije: **S355J0,J2,K2 , EN 10025-2:2004.**

(Male količine: **S460Q,N,L , EN 10025-2:2004)**

Posebni uslovi za čelik:

Ril 804:2003 , BN 918002:2000 , SEL 072:1977,

SEL 072/Beiblatt:1977 , SEP 1390:1996.

Moždanici

Automatski zavareni moždanici sa glavom,

EN ISO 13918:2008, EN ISO 14555:2006.

Kablovi

Grupa C, klasa 5, $f_{uk} \geq 1860,0 \text{ N/mm}^2$,

EN 1993-1-11:2006, SETRA:2002, fib:2005.





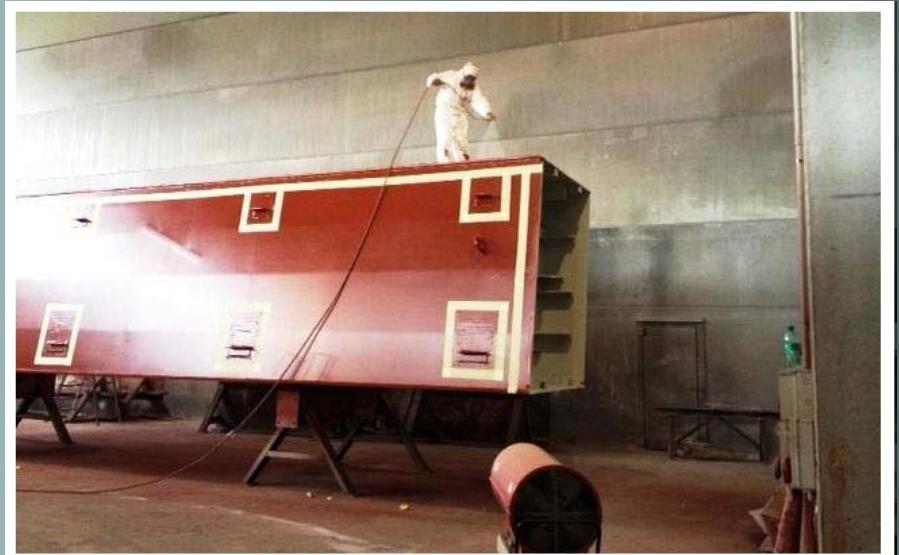
Železničko-drumski most u Novom Sadu



Posao firme
Taddei na izradi
konstrukcije
mosta u Novom
Sadu zabeležen
je u italijanskim
medijima kao
značajan i
referentan.



Zaštita od korozije čelične konstrukcije pre isporuke
konstrukcije



Železničko-drumski most u
Novom Sadu

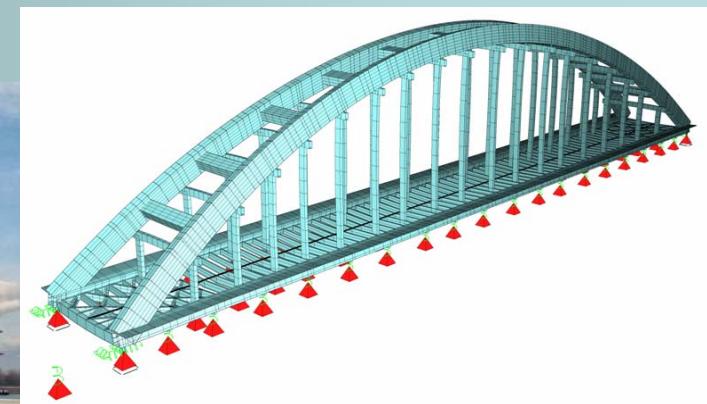
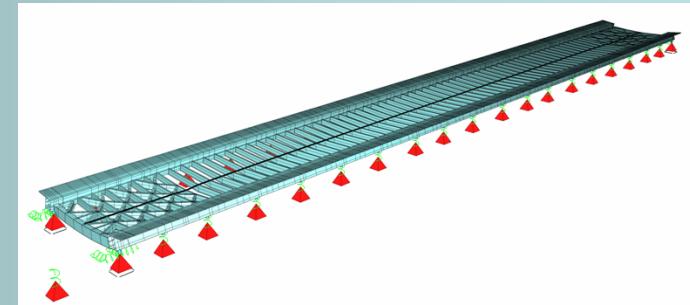
Sastavljanje konstrukcije.

Podizvodač: Mostogradnja a.d., Beograd.



Redosled sastavljanja:

- 1) zatege, leva i desna,
- 2) poprečni nosači i spregovi,
- 3) pomoćni stubovi na zategama za montažu lukova,
- 4) lukovi.



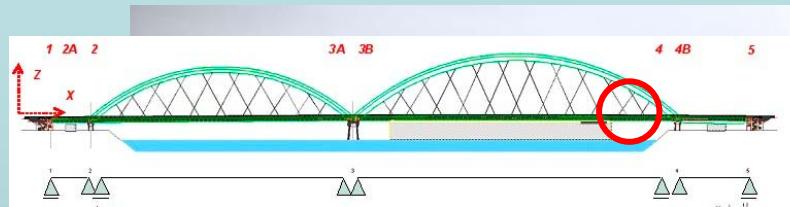
Železničko-drumski most u
Novom Sadu



Most 2-3 (177 m): Zatega sa poprečnim nosačima.



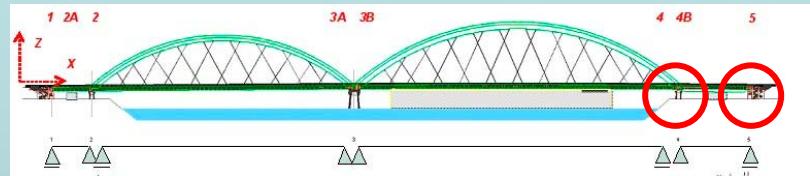
Železničko-drumski most u
Novom Sadu



Železničko-drumski most u
Novom Sadu



12 04 2013



12 04 2013

Železničko-drumski most u
Novom Sadu



Most 2-3 (177 m): Približavanje stubu 1.

Železničko-drumski most u
Novom Sadu



Montaža lučnih mostova.

Globalni redosled lansiranja:

- 1) montaža kablova,
- 2) montaža stubova za lansiranje,
- 3) lansiranje na obali preko sanki i platformi,
- 4) lansiranje na reci preko barži;
- 5) spuštanje na ležišta.

Vođenje montaže: **AZVI S.A., Sevilla, Španija.**

Podizvođači:

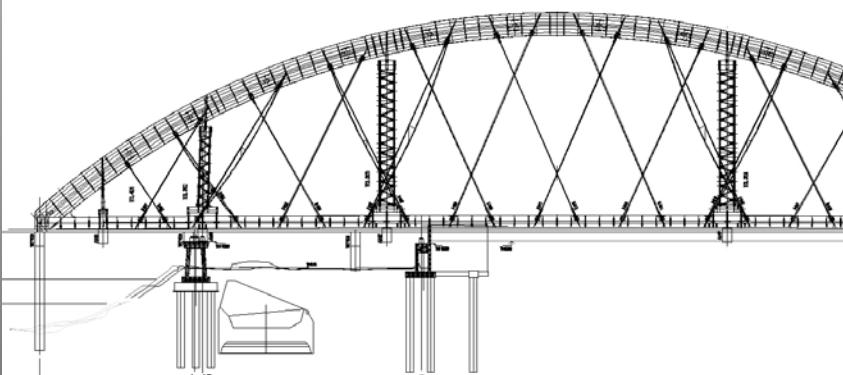
proračun i praćenje montaže: **DEL ING d.o.o., Beograd;**

kabovi: **VSL Ltd., Saint Legier, Švajcarska;**

privremeni stubovi za lansiranje: **Mostogradnja a.d., Bg;**

lansiranje: **Mammoet, Rotterdam, Holandija;**

ležišta i dilatacije: **FIP Industriale, Servazzano, Italija.**

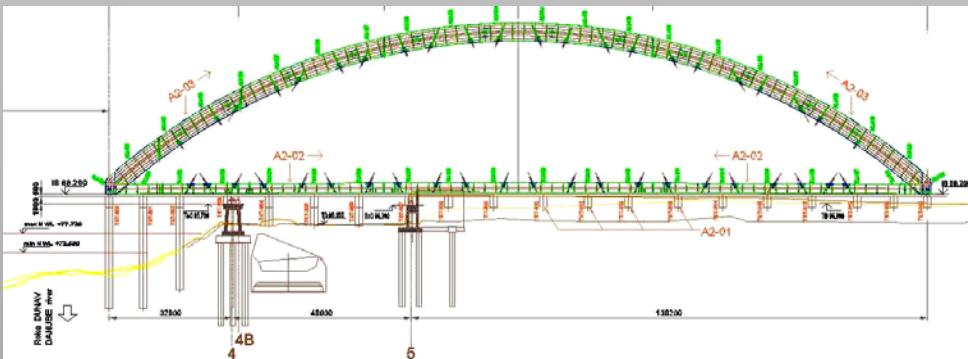


Most 3-4 (219 m): Most sa privremenim stubovima.



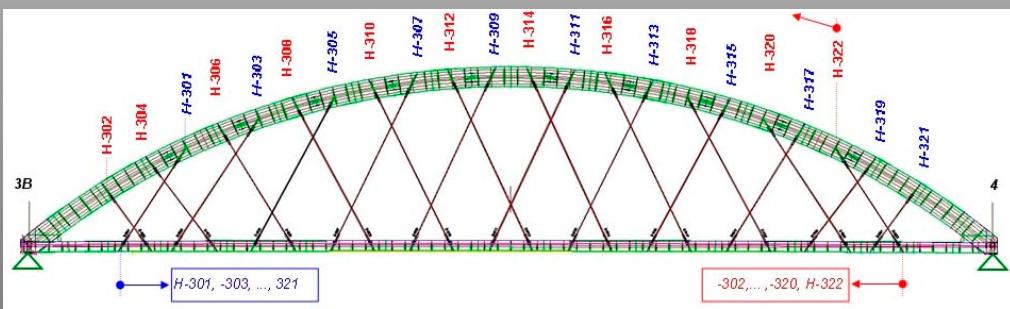
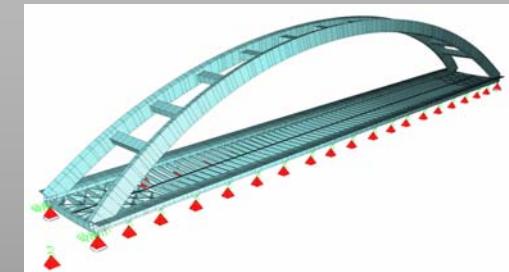
Železničko-drumski most u
Novom Sadu

Montaža lučnog mosta 3-4, L = 219 m.



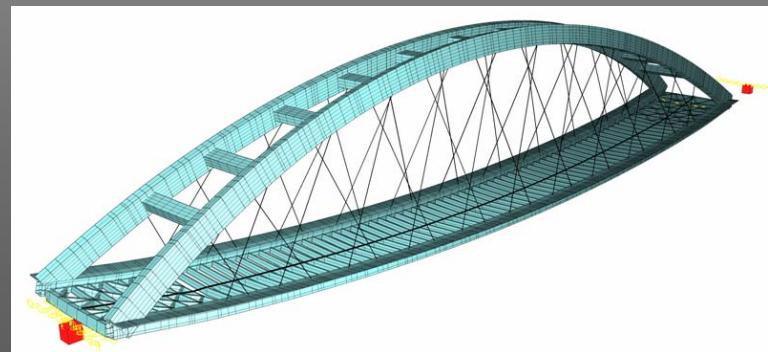
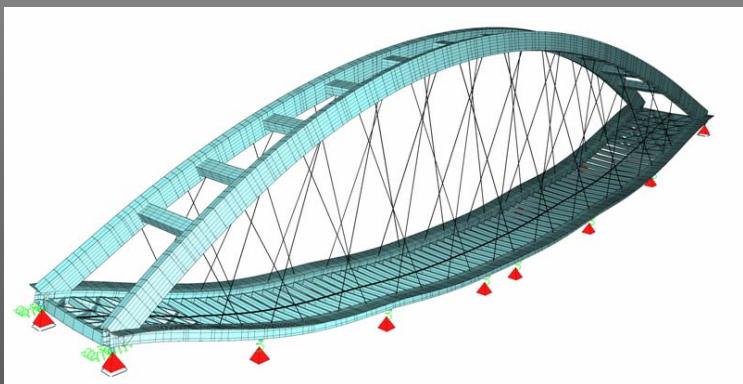
0) Početno stanje:

most sastavljen, bez kablova vešaljki;
zatega na privremenim osloncima.

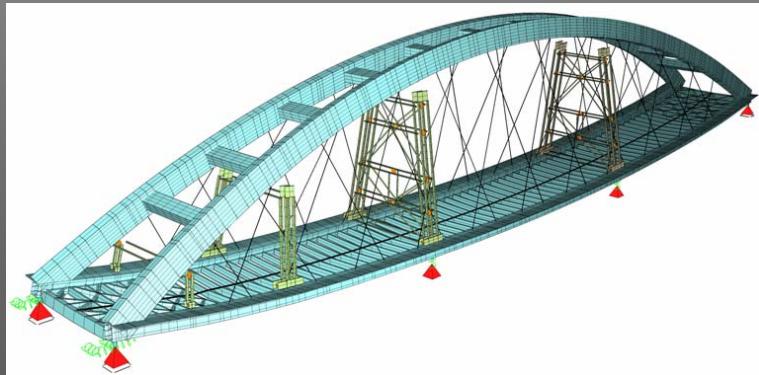
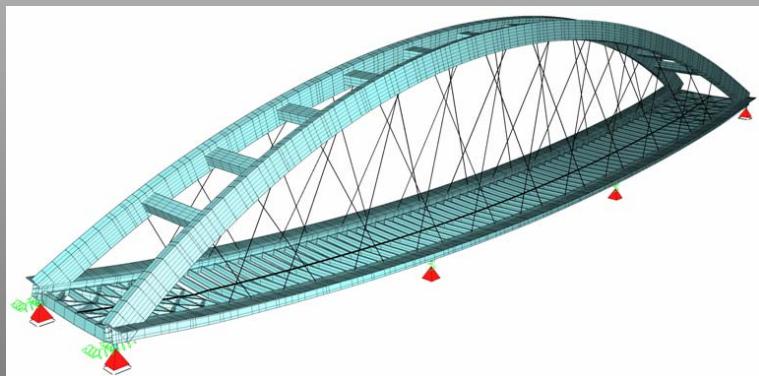
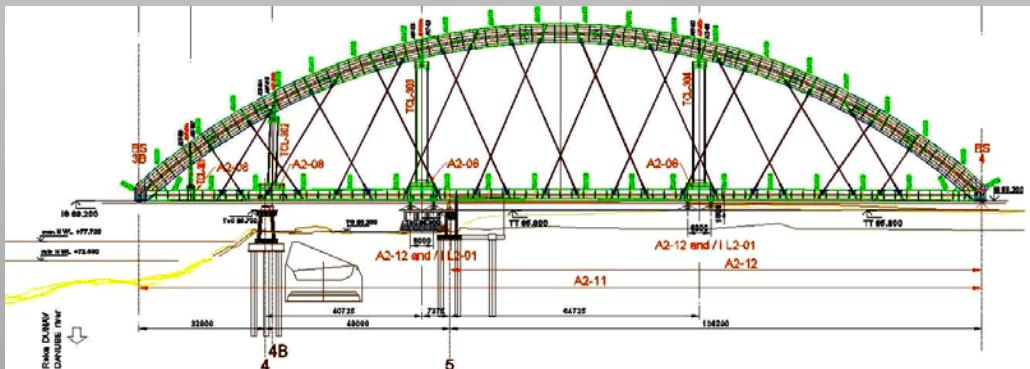


1) Montaža kablova:

- spuštanje zatega na nivo ugiba zatege;
- montaža kablova sa nagibom na desno;
- montaža kablova sa nagibom na levo;
- most oslonjen u četiri tačke.

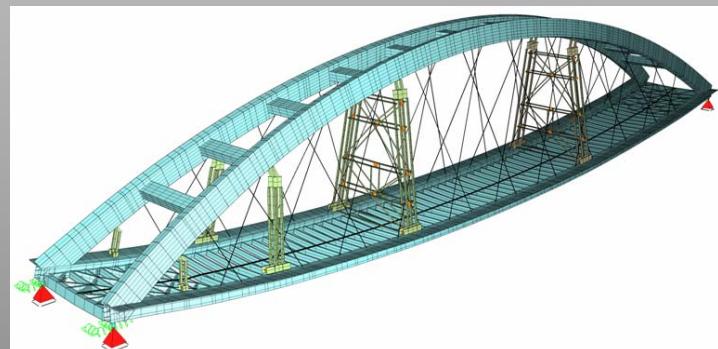
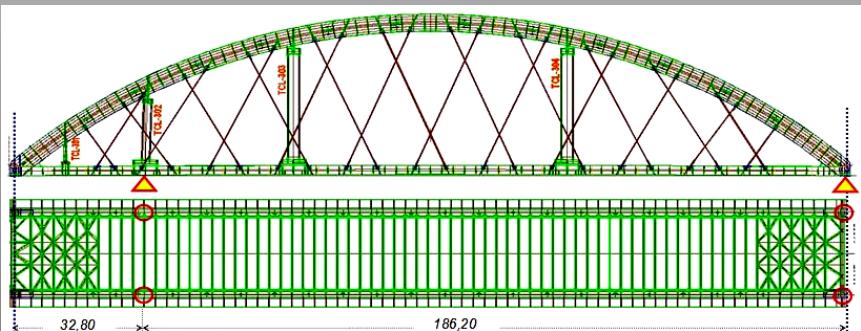
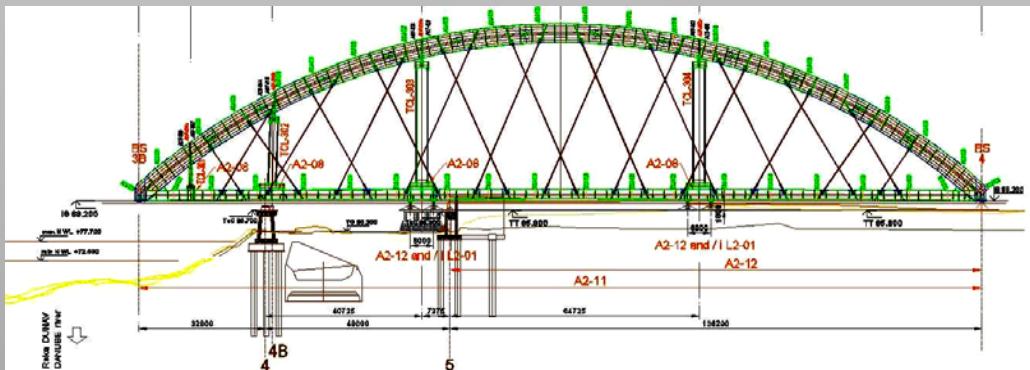


Montaža lučnog mosta 3-4, L = 219 m.



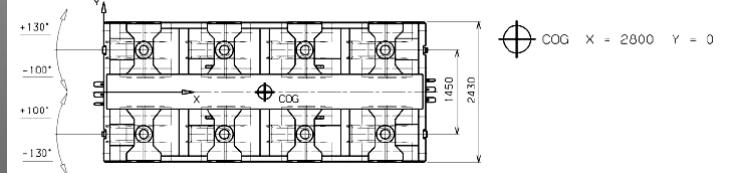
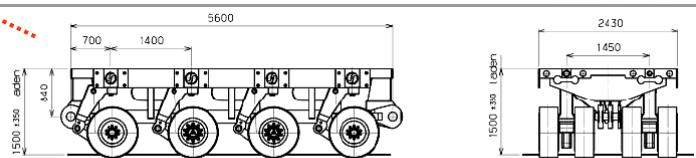
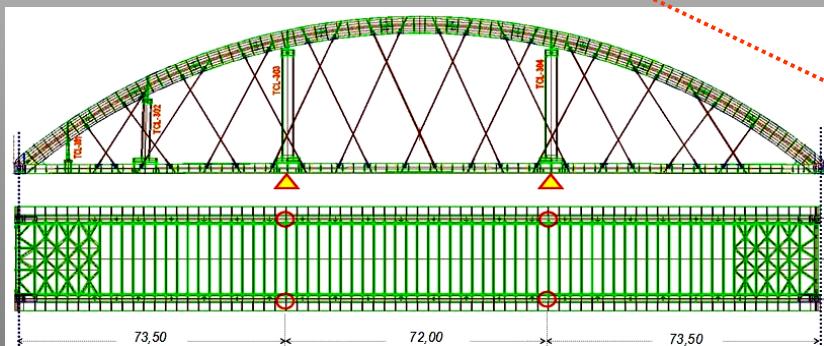
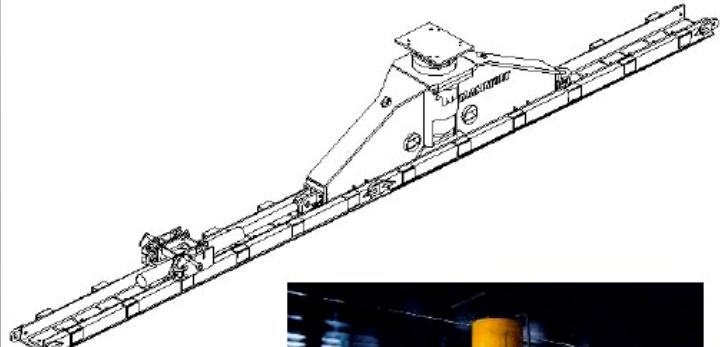
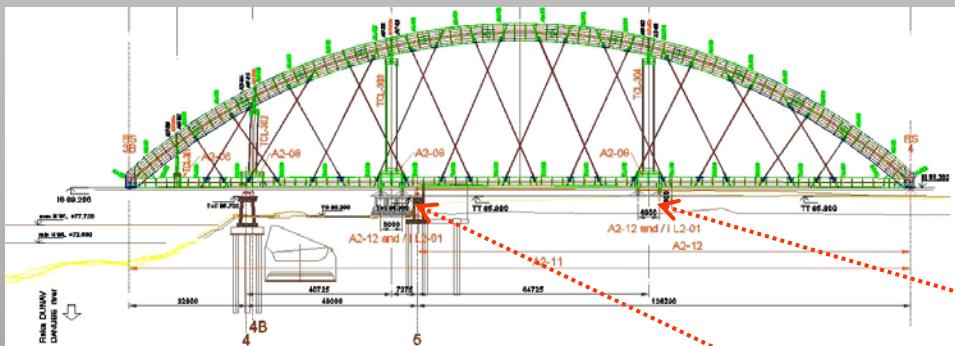
- 2) Montaža privremenih stubova za lansiranje (TCL):
- izrada oslonaca ispod zatega na mestu TCL;
 - montaža TCL oko kablova.

Montaža lučnog mosta 3-4, L = 219 m.



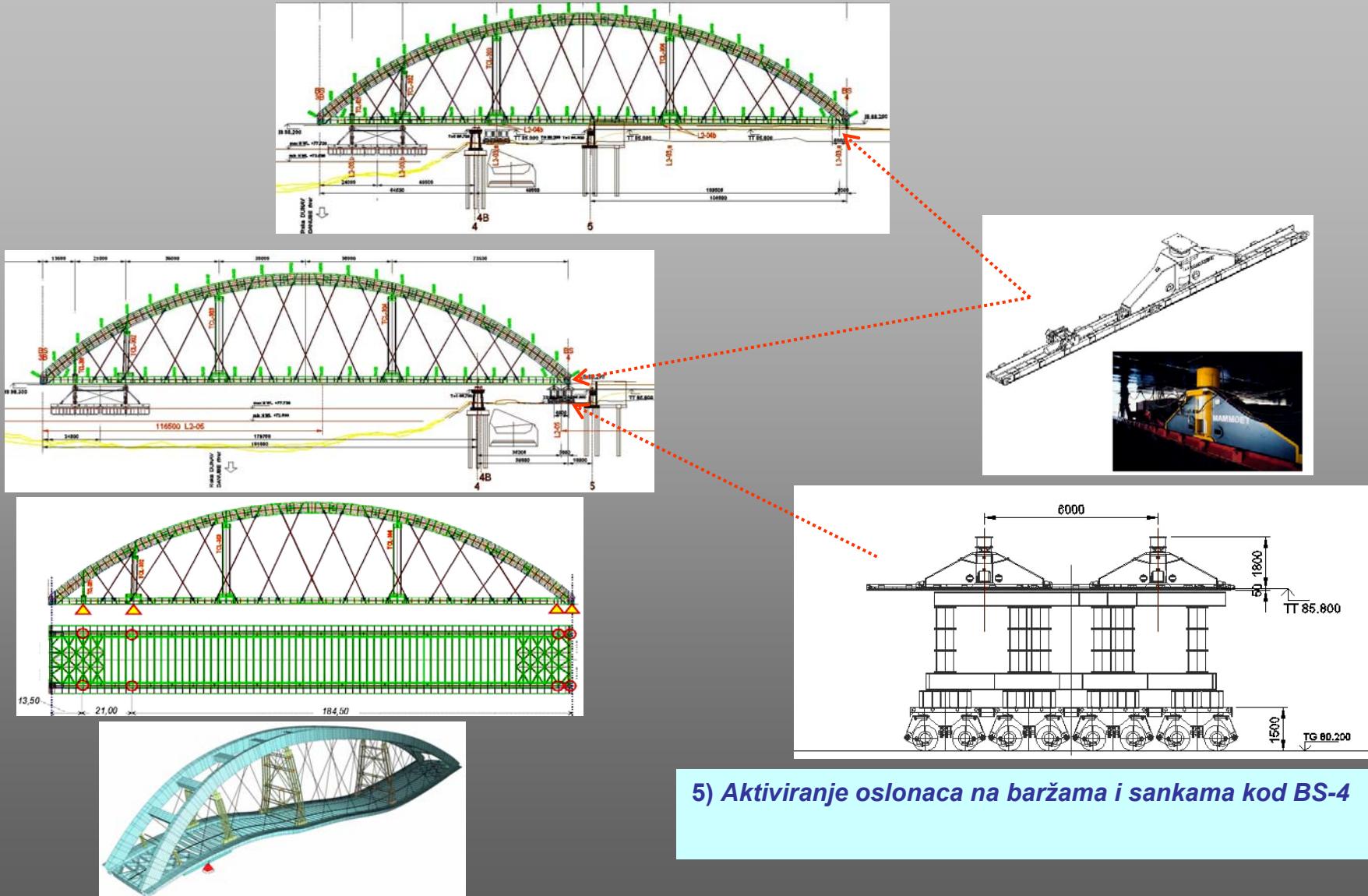
- 3) Aktiviranje oslonaca na stubu 4 kod BS-4:
a) uklanjanje privremenih oslonaca ispod TCL;
b) aktiviranje oslonaca na stubu 4 i kod BS-4.

Montaža lučnog mosta 3-4, L = 219 m.



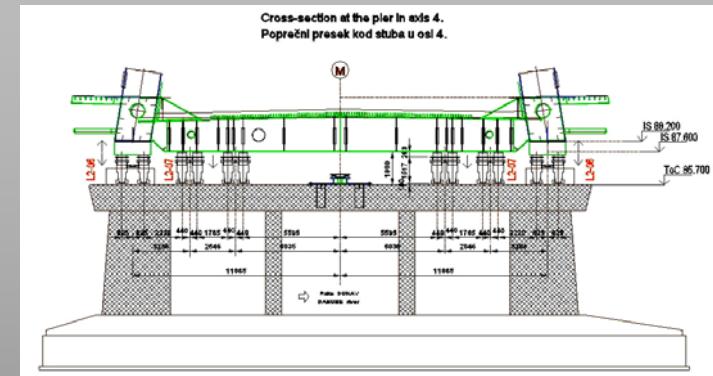
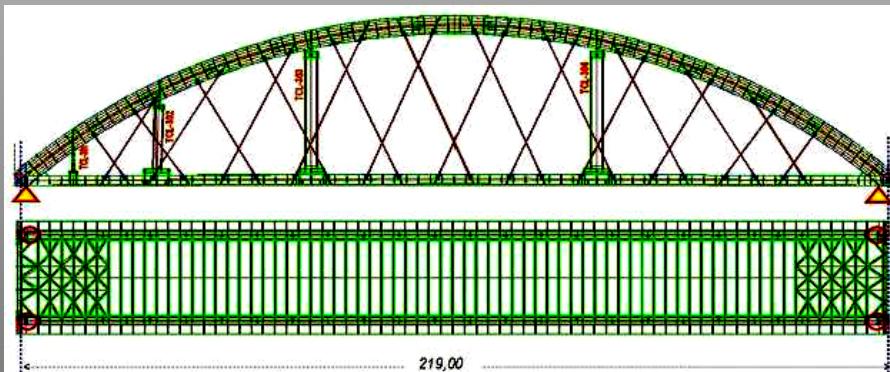
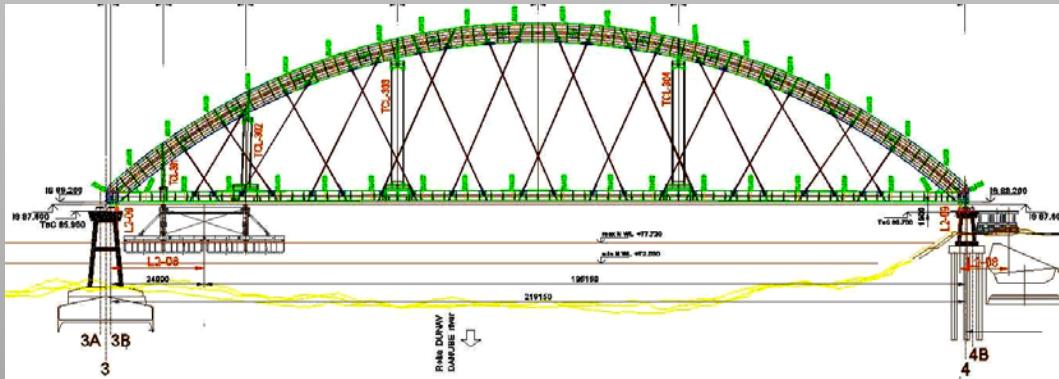
4) Aktiviranje oslonaca na sankama i platformama:

Montaža lučnog mosta 3-4, L = 219 m.

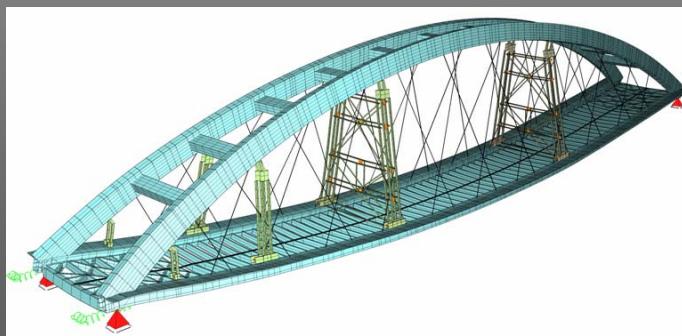
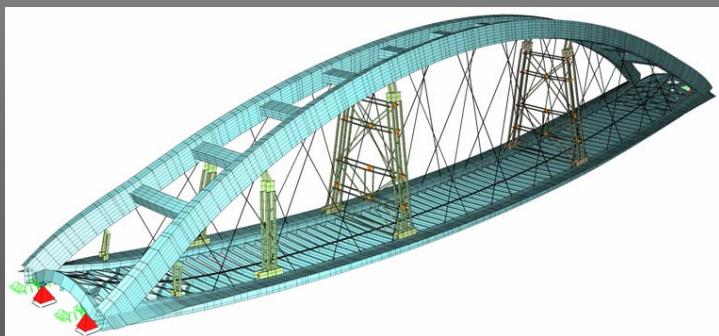


Železničko-drumski most u
Novom Sadu

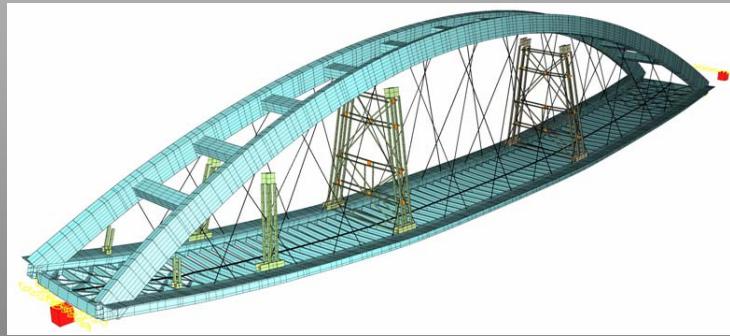
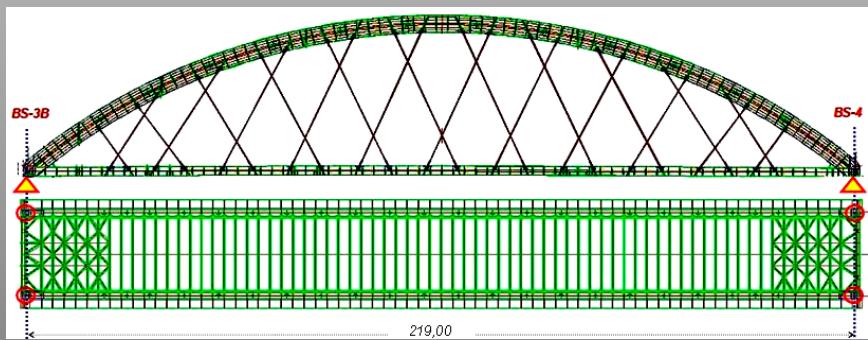
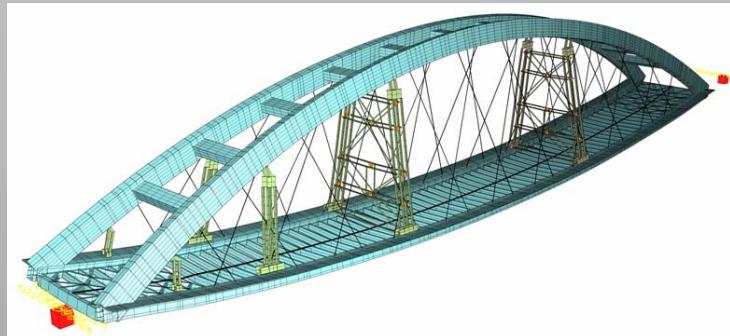
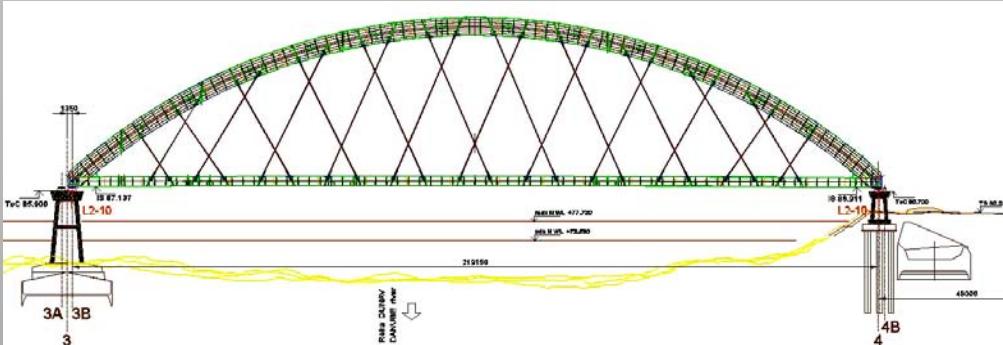
Montaža lučnog mosta 3-4, L = 219 m.



- 6) Prenošenje oslanjanja na poprečne nosače.
- 7) Prenošenje oslanjanja na mesta privremenih oslonaca za zamenu ležišta.



Montaža lučnog mosta 3-4, L = 219 m.

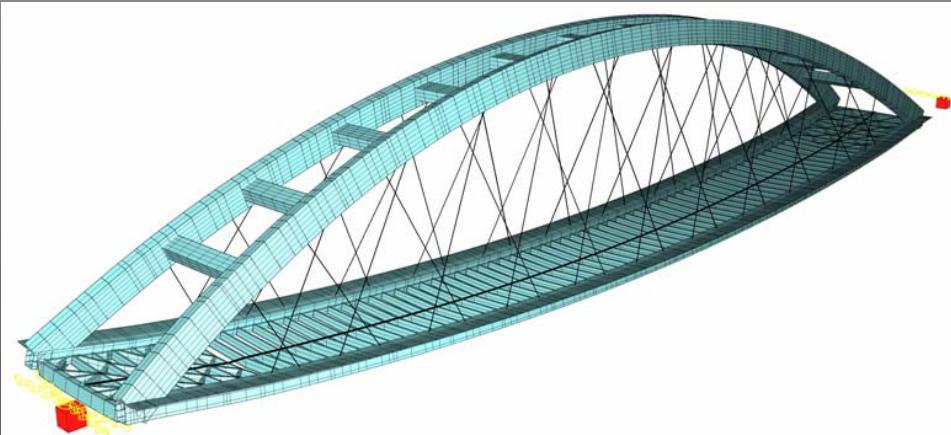


8) Završni koraci:

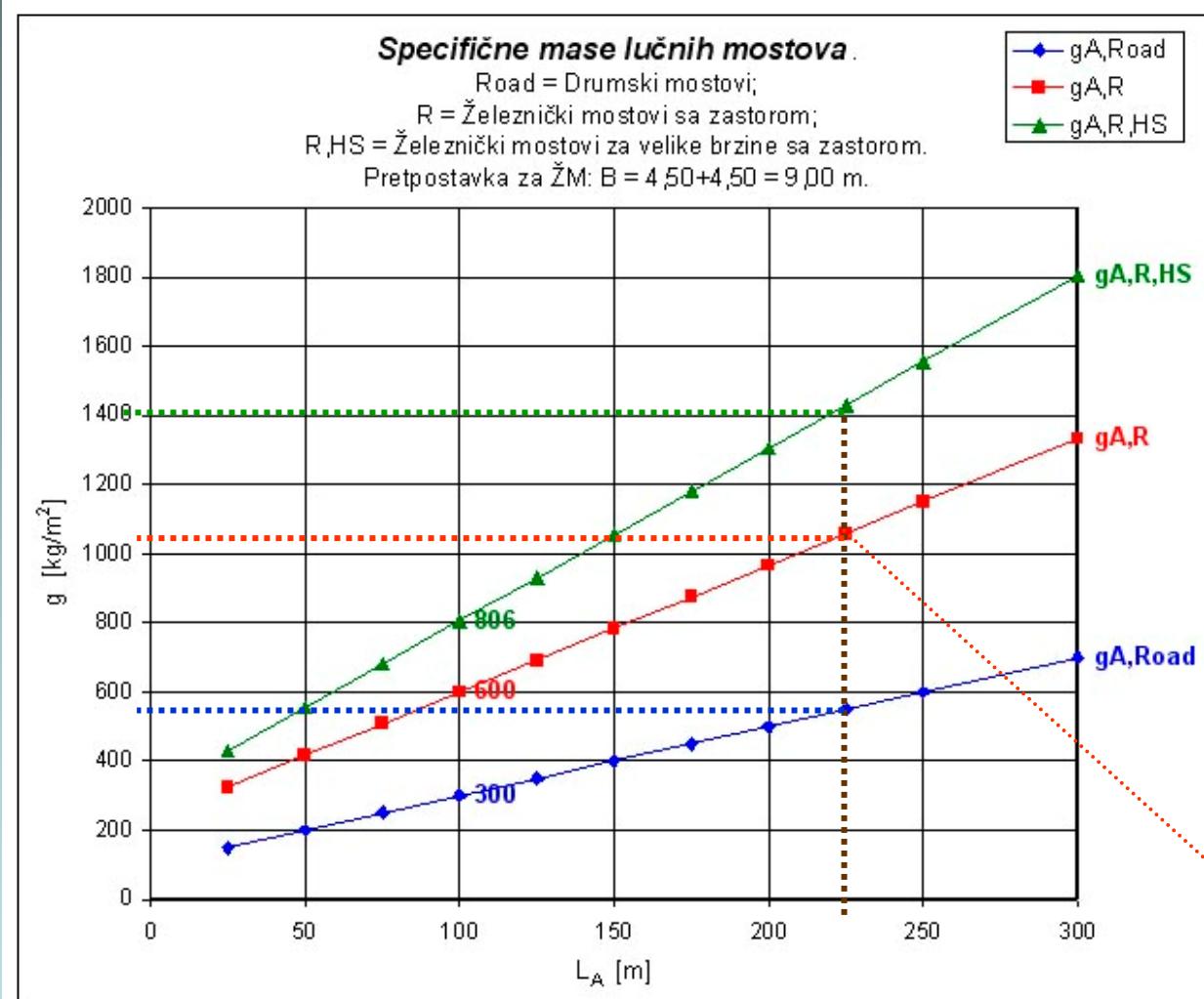
- oslobađanje redom TCL-301 do TCL-304;
- uklanjanje svih TCL;
- most je u konačnom položaju.

9) Betoniranje kolovozne ploče.

10) Nanošenje svih stalnih tereta.



Main structural system. Rationality of the designed structure. Steel structure mass.

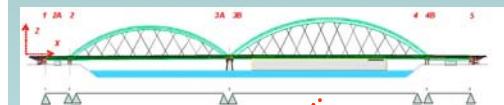


Expected masses [kg/m²]
of the arch bridges acc. to
international literature.

Railway: V ≥ 200 km/h

Railway: V < 200 km/h

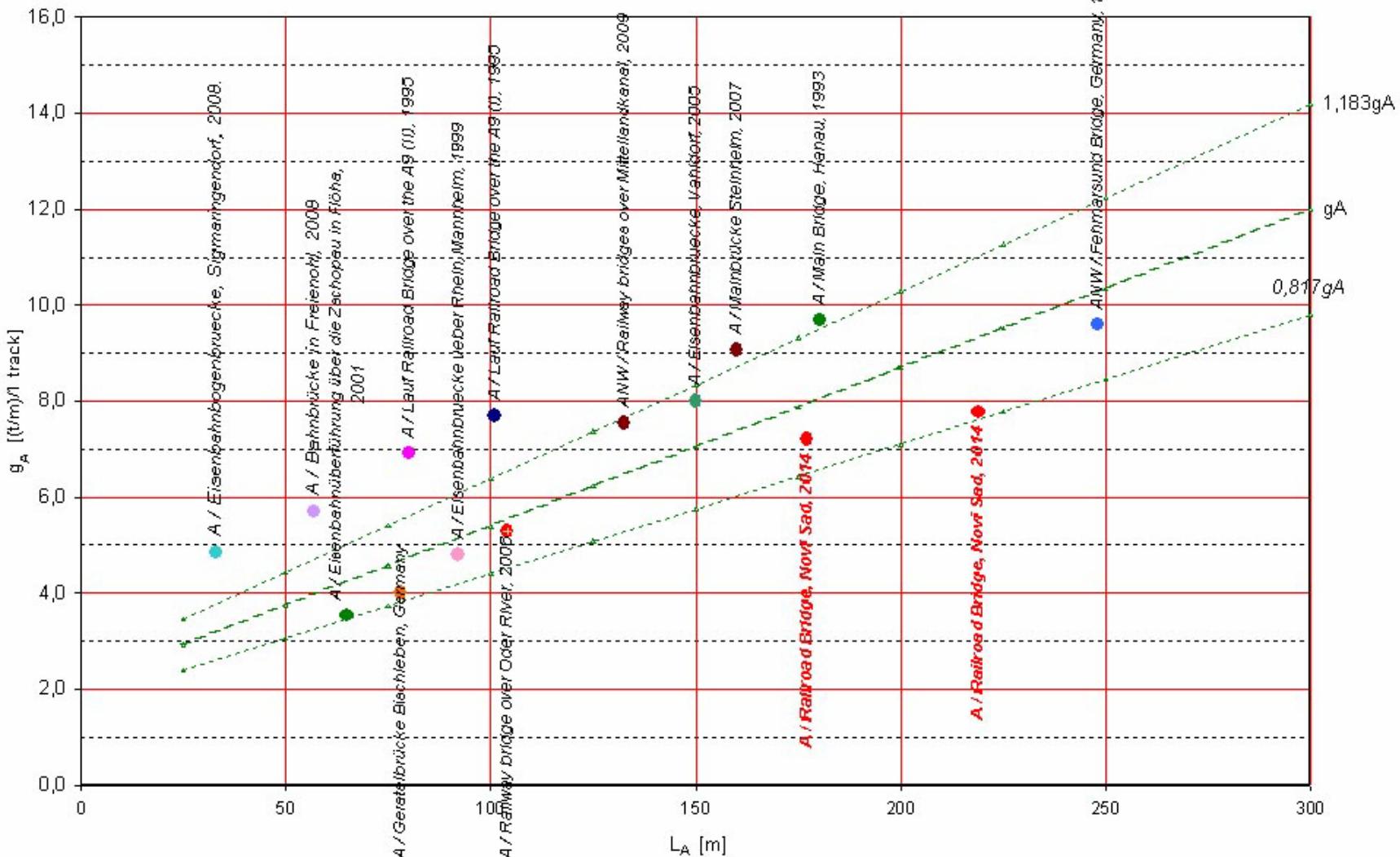
Road bridges



Železnički mostovi - sistem luk sa zategom, sa zastorom

Masa čelične konstrukcije/1 kolosek.

Brzine, v < 200 km/h.



3D-animacije mosta.



Železničko-drumski most u
Novom Sadu



Železničko-drumski most u
Novom Sadu



Železničko-drumski most u
Novom Sadu



Železničko-drumski most u
Novom Sadu



Železničko-drumski most u
Novom Sadu



Železničko-drumski most u
Novom Sadu



Železničko-drumski most u
Novom Sadu

Poređenja sa sličnim mostovima u svetu



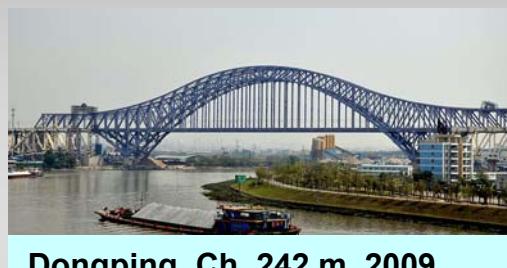
Garabit Viaduct, Fr, 167 m, 1884



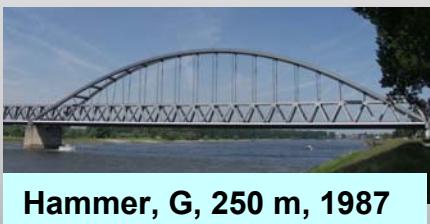
Hell Gate, USA, 298 m, 1918



Chaotianmen, Ch, 552 m, 2009



Dongping, Ch, 242 m, 2009



Hammer, G, 250 m, 1987



Merivale, Aus, 133 m, 1978



Ayub, Pk, 246 m, 1962



Fehmarn, G, 248 m, 1963



Garde Adhemar, Fr, 2x115 m, 2000

Čist luk
kolovoz gore
kolovoz dole

Rešetkasti luk sa
zategom

Luk sa
zategom/gredom
greda rešetkasta
greda puna

Luk sa zategom
luk rešetkast
luk pun

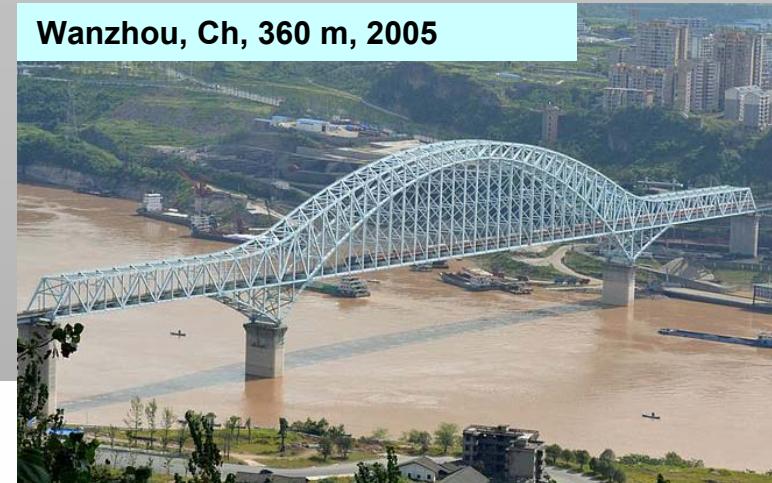
Železničko-drumski most u
Novom Sadu

Na svetskoj listi
155 lučnih mostova
sa najvećim
rasponima (208 do
552 m) ima samo
16 mostova sa
šinskim
saobraćajem,
(železnica, metro,
laka železnica
(tramvaj)).

Chaotianmen, Ch, 552 m, 2009



Wanzhou, Ch, 360 m, 2005



**Rešetkasti lukovi sa zategom
Trussed tied arch bridges**

	Foto	Name	Location	Opened	Type	Carries	Main span m
		Chaotianmen Bridge	Yangtze River China	2009	Trussed tied arch bridges Steel	2 tracks LR 6 lanes	552
1		Wanzhou Bridge	Yangtze River China	2005	Trussed tied arch bridges Steel	2 tracks	360
2		Dashengguan Bridge	Yangtze River China	2009	Trussed tied arch bridges Steel	6 tracks Metro	336
3		Hell Gate Bridge	East River USA	1918	Trussed tied arch bridges Steel	3 tracks	298
4		Ayub Bridge	Indus River Pakistan	1962	Trussed tied arch bridges Steel	2 tracks	246
5		Dongping Bridge	Dongping Channel China	2009	Trussed tied arch bridges Steel	2 tracks	242

Caiyuanban, Ch, 420 m, 2007



Lukovi sa gredom

Tied arch bridges with girder (Bowstring-girder bridge)

	Foto	Name	Location	Opened	Type	Carries	Main span m
1		Caiyuanba Bridge	Yangtze River China	2007	Arch steel/concrete Vertical hangers Trussed girder	2 tracks Metro 6 lanes	420
2		Yiwan Bridge	Yangtze River China	2008	Steel arch Vertical hangers Concrete girder	2 tracks	275
3		Hammer Bridge	Rhein River Germany	1987	Steel arch Vertical hangers Trussed girder	4 tracks (2 S-Bahn)	250
4		Kobe Bridge	Kobe Japan	1970	Steel arch Vertical hangers Trussed girder	2 tracks 4 lanes	217
5		Dintelhaven Railroad Bridge	Rotterdam Netherlands	1999	Steel arch Vertical hangers	2 tracks	170
6		Neue Niederräder Brücke	Frankfurt am Main Germany	1978	Steel arch Vertical hangers	2 tracks S-Bahn	168

Fehmarn, G, 248 m, 1963



**Železnički mostovi sistema sa lukova sa zategom - jedan kolosek
Tied arch railway bridges (Bowstring) - One track**

	Foto	Name	Location	Opened	Type	Carries	Main span m
1		Fehmarnsund Bridge	Grossenbrode Fehmarnsund Germany	1963	Tied arch Network hangers Steel	1 track 2 lanes	248
2		Main Bridge	Main River Hanau Germany	1993	Tied arch Vertical hangers Steel	1 track (S-Bahn)	160
3		Railway Bridge	Vahldorf Germany	2005	Tied arch Vertical hangers Steel	1 track	150
4		Flora Bridge	Mitteland Canal Haldensleben Germany	2009	Tied arch Network hangers Steel	1 track	133
5		Osaka Monorail Yodogawa Bridge	Yodo River Osaka Japan	1997	Tied arch Network hangers Steel	1 track Monorail	126



Železnički mostovi sistema sa lukova sa zategom - dva koloseka

Tied arch railway bridges (Bowstring) - Two tracks

	Foto	Name	Location	Opened	Type	Carries	Main span m
--	------	------	----------	--------	------	---------	-------------

1		Railway Road Bridge 219 m span	Danube River Novi Sad Serbia	2014	Tied arch Network hangers Steel	2 tracks 2 lanes	219
2		Railway Road Bridge 177 m span	Danube River Novi Sad Serbia	2014	Tied arch Network hangers Steel	2 tracks 2 lanes	177
3		Ogatayama Bridge	Yamanashi Japan	1995	Tied arch Network hangers Steel	2 tracks	139
4		Merivale Bridge	Brisbane Queensland Australia	1978	Tied arch Network hangers Steel	2 tracks	133

5		Bonpas Bridge	Rhone River France	1998	Tied arch Vertical hangers Steel	2 tracks HS	124
6		Vénéjan Mornas Viadukt	Vénéjan Mornas Saint-Etienne-des-Sorts France	1999	Tied arch Vertical hangers Steel	2 tracks HS	119
7		Garde Adhémar Viaduct	Pierrelatte France	2000	Tied arch Vertical hangers Steel	2 tracks HS	115

Glavni projekt konstrukcije mosta

Tehnički izveštaj

Proračun konstrukcije

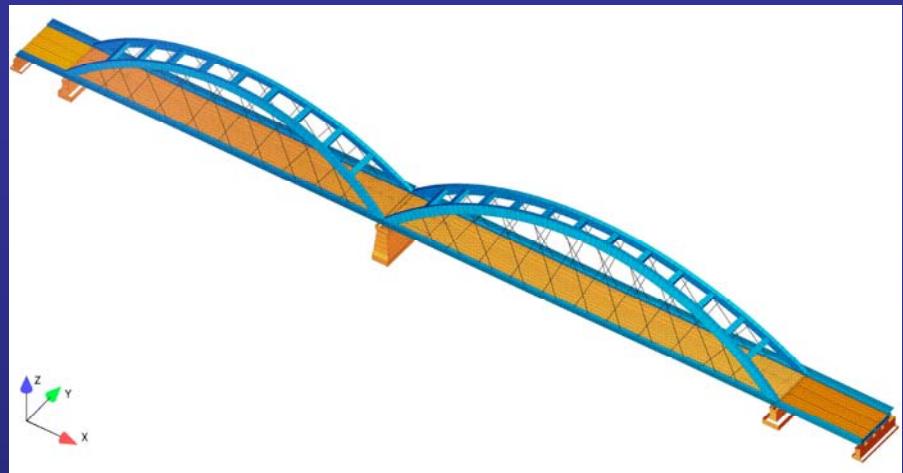
Crteži

Predmer radova

Ukupan obim:

5600 strana A4

100 crteža (oko 150 m²)



Norme za projektovanje – stanje 2011-04:

Nemačke Ril 804, DIN-Fb 101 do 104

Evropske EN 1990, 1991, 1992, 1993, 1994.

+

EN za materijale, proizvode, radove, opremu.

Ukupan obim kosultovanih normi oko 3000 str!

Jezik projekta: engleski i srpski.

Železničko-drumski most preko Dunava u Novom Sadu

Generalni izvođač:

JV Azvi, Taddei, Horta Coslada. www.azvi.es

Projektant konstrukcije mosta:

DEL ING d.o.o., Beograd. www.deling.rs

Projektant stubova i fundiranja:

ENCODE d.o.o., Beograd.

Tehnička kontrola Glavnog projekta:

Institut Kirilo Savić a.d., Beograd.

Inženjer:

JV DB International, Egis International www.db-international.de

ZEZELJ BRIDGE JV

NOVI SAD (Нови Сад)



Azvi // **TADDEI** s.p.a.

HORTA COSLADA
Construcciones Metálicas



Konstrukcija mosta – projektni tim:

Odgovorni projektant: **Aleksandar Bojović**, dipl.ing.građ.

Projektanti:

Prof.Dr. Zlatko Marković, dig, **Dimitrije Aleksić**, dig;

Marko Pavlović,dig, **Mr. Milan Spremić**,dig, **Novak Novaković**,dig, **Boško Janjušević**,dig, **Uroš Kostić**,dig.



Crteži: **Milan Radenković**,teh, **Goran Višnjić**,teh.