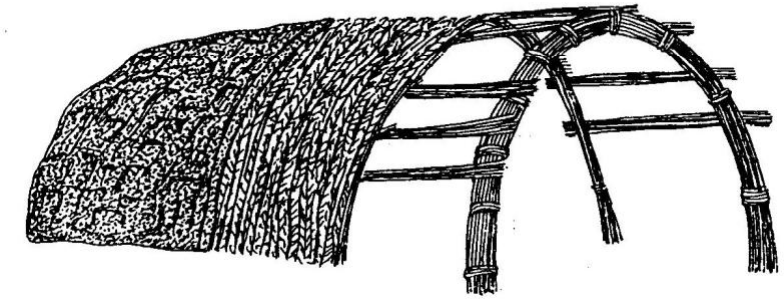
POSEBNA POGLAVLJA GRAĐENJA MOSTOVA

IZVEDBA LUČNIH MOSTOVA

Zlatko Šavor

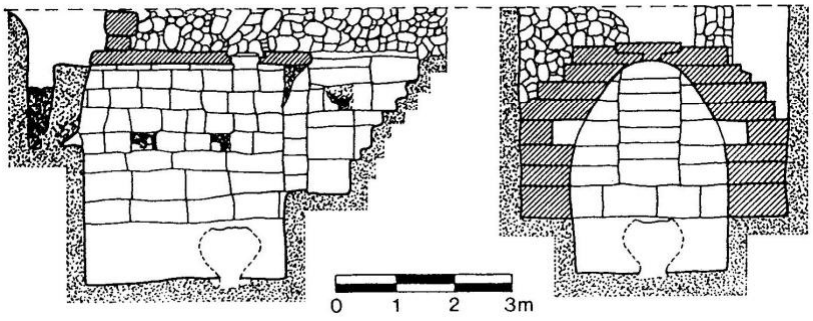


Povijest gradnje

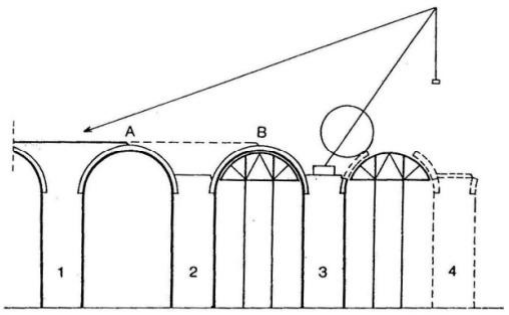


Trščana koliba s pokrovom od blata –
vjerojatno potakla ideju svoda, oko 4000. g. p.K.

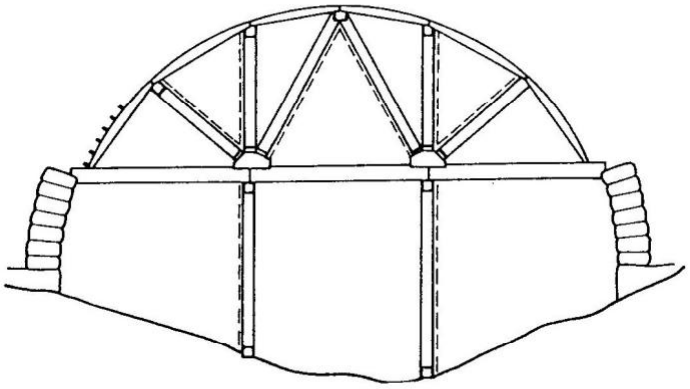




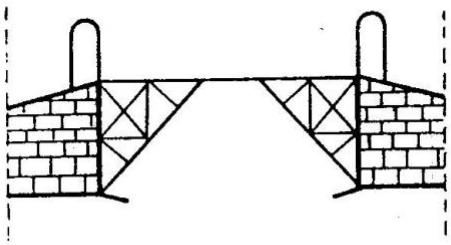
Kreta, Mikenska kultura, grobna komora s kamenim konzolnim svodom u Ugaritu raspona oko 2,6 m.



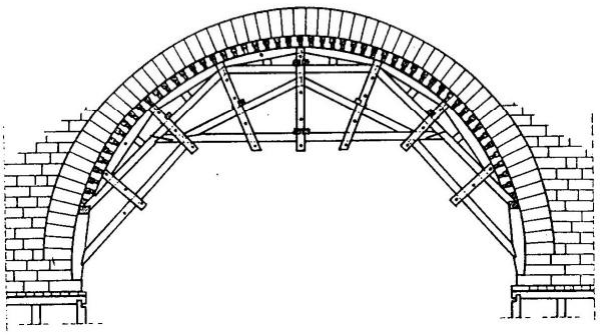
Moguća rekonstrukcija slijeda građenja rimskog mosta. Nakon premještanja krana sa stupa 2 na stup 3 izvodi se nadsloj od A do B kako bi se skela iz polja 1-2 premjestila u 3-4. Izvodi se stup 4 zajedno s petnim dijelom svoda. Postavlja se skela polja 3-4 nakon čega slijedi izvedba samog svoda 3-4 simetrično s obje pete.



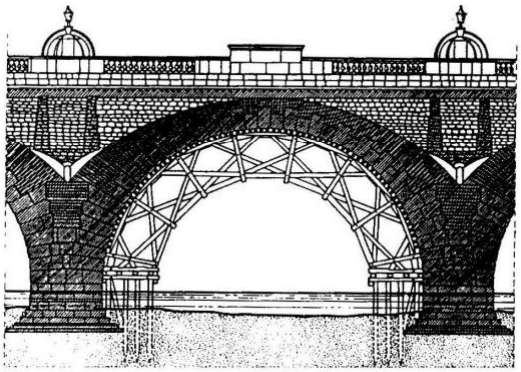
Rekonstrukcija skele rimskog mosta



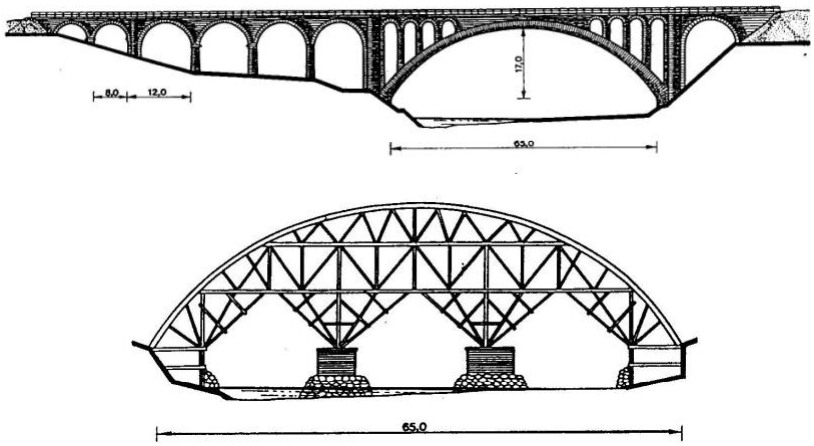
Srednjevjekovna drvena rešetka –
pretpostavljeni oblik donjeg dijela lučne skele,
prema djelu Villarda de Honnecourta.



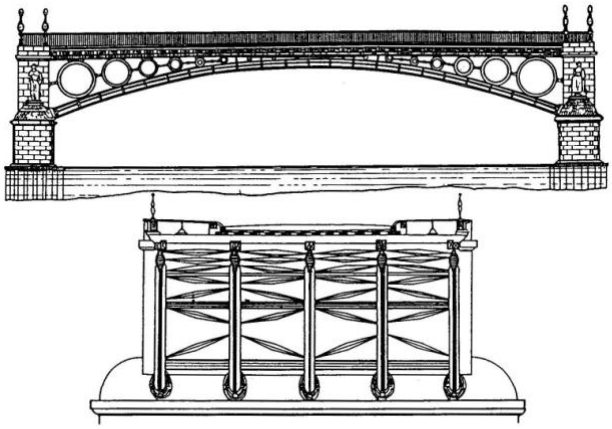
Rešetkasta skela lučnog mosta raspona 18 m
bez oslonaca unutar svijetlog otvora.



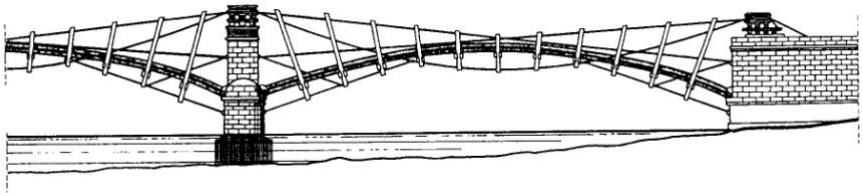
Most Westminster, preko Temze u Londonu, iz 1750.
Prikazana je rešetkasta skela jednog luka i
presjek koji otkriva brižljivo kombiniranje gradiva u svodu.



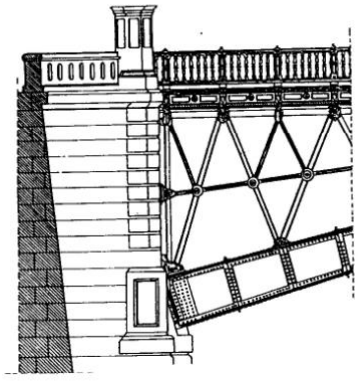
Skica skele i dovršenog željezničkog mosta Jaremcze koji je postao uzor kasnijim ostvarenjima austrijske škole.



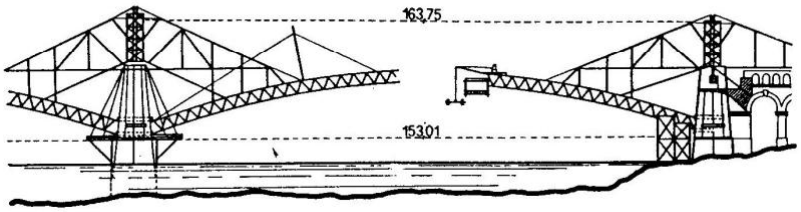
Pogled i poprečni presjek mosta Carrousel preko Seine u Parizu, iz 1834.



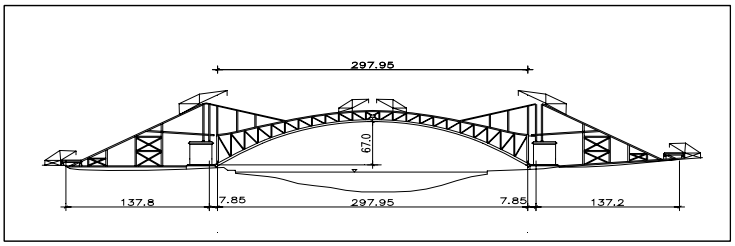
Viseća skela mosta Carrousel



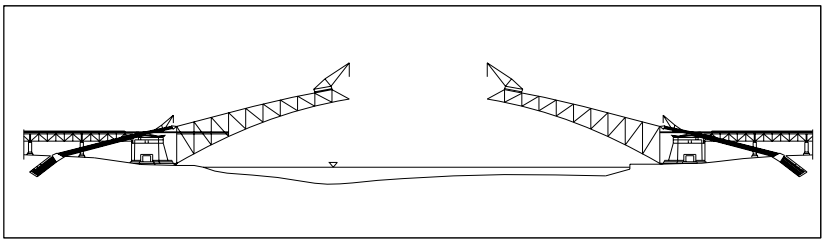
Peta luka mosta Arcole (Pariz 1855.).U poprečnom presjeku most, širok 20 m,sastoji se od 16 usporednih punostijenih nosača I – presjeka.Raspon iznosi 80 m.



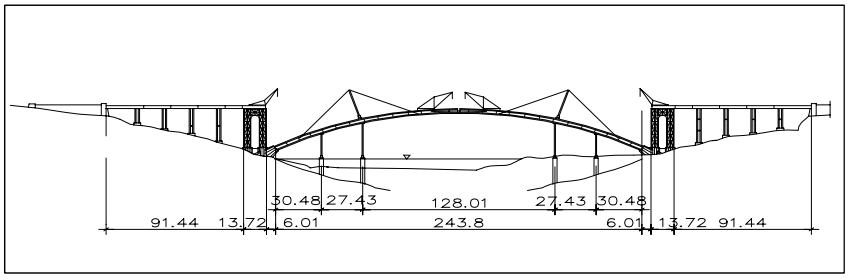
Izvedba mosta J.B.Eads preko rijeke Mississippi u St. Louisu



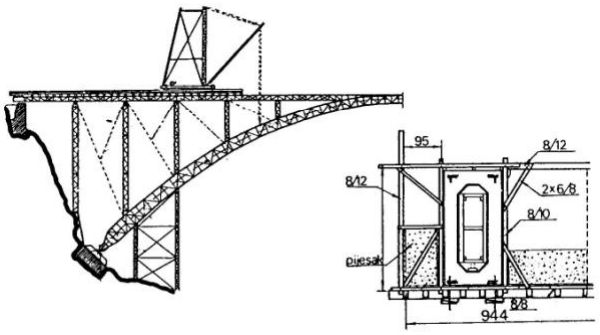
Prikaz montaže mosta Hell Gate



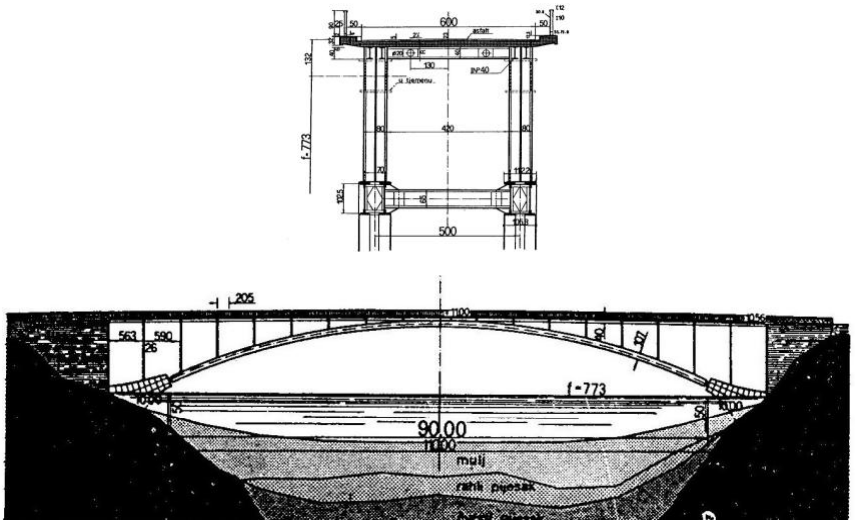
Prikaz izvedbe mosta Sydney Harbour



Prikaz izvedbe mosta Henry Hudson s punostijenim lukom



Građenje mosta Eschelbach uz predopterećivanje
krute čelične konstrukcije (1924.)



Skica mosta preko rijeke Krke kod Skradina
s lukovima ispunjenim betonom (1955.)

Izvedba lučnih mostova

A. Izvedba na skeli
B. Konzolna gradnja uz korištenje privremenih zatega i pomoćnih pilona
C. Konzolna gradnja s privremenim zategama kao dijagonalama rešetke – tip Pratt
D. Postupci sa zaokretanjem luka u konačni položaj
E. Postupci koji koriste krutu armaturu kao skelu tijekom izvedbe luka a u uporabi kao armaturu luka (Melan 1892)
F. Kombinirani postupci

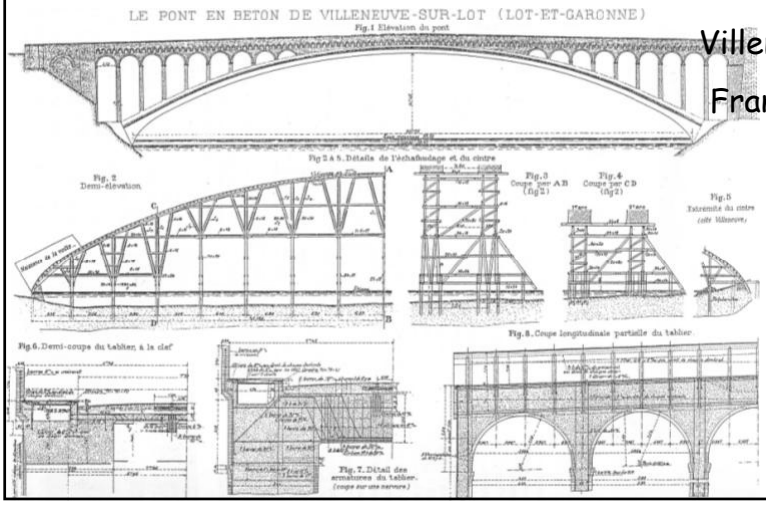


Osnovna ideja svih postupaka, uključivo modernije postupke izvedbe na skeli, je uključivanje što je moguće više već izvedenih dijelova luka odnosno dijelova poprečnog presjeka luka u preuzimanje vlastite težine još neizvedenih dijelova luka.



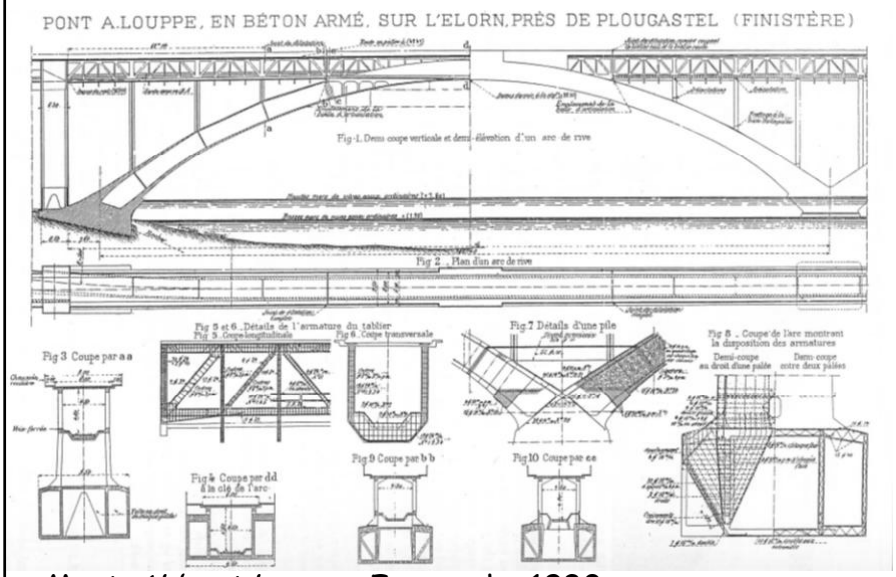
Starije izvedbe mostova na drvenim skelama

- same skele su iznimna inženjerska ostvarenja, nerijetko složenija za statičku analizu i izvedbu od samog mosta.



Villeneuve bridge

Francuska, 1919.



Most *ALbert Louppe*, Francuska 1930.



Most *Albert Louppe*

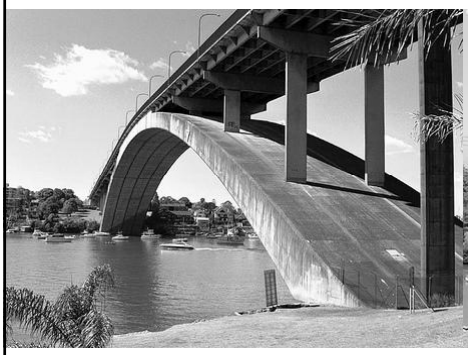


Izdvojeno je pet mostova, izvedena na različitim skelama, i s različitim udjelom predgotovljenih elemenata:

- most *Gladesville* načinjen je najvećim dijelom od predgotovljenih odsječaka na skeli s više oslonaca u prepreci,
- most *Arrabida* izveden je na mjestu, na krutoj čeličnoj skeli oslonjenoj samo na temelje luka,
- viadukt *Fiumarella* izveden je na skeli s privremenim zglobovima u luku uz pete luka,
- most *Lingenau* koji je jedini most statičkog sustava dvozglobnog luka, izveden na čeličnoj cijevnoj skeli,
- most *Nössslach* na rešetkastoj skeli sustava Cruciani oslonjenoj samo na temelje luka.

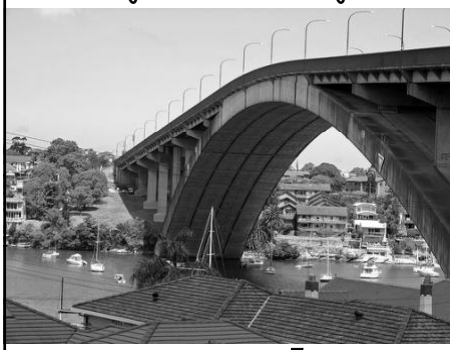
Izvedbe na skeli

- U Sydneyu, Australija, 1964. dovršen je lučni most *Gladesville* koji je s rasponom od 304,8 m držao rekord armiranobetonskih lučnih mostova do dovršenja Krčkog mosta.
- Luk se sastoji od četiri šuplja usporedna luka, širine po 6,1 m, pravokutnog presjeka promjenjive visine (4,27 do 6,9 m).




Izvedbe na skeli

- Luk se sastoji od četiri šuplja usporedna luka, širine po 6,1 m, pravokutnog presjeka promjenjive visine (4,27 do 6,9 m).
- Tijekom gradnje bili su međusobno razmaknuti za 30 cm tako da se mogu izvesti jedan po jedan na istoj skeli.
- Međuprostor je tek naknadno zapunjen betonom na visini od 60 cm.
- Uzdužni odsječci lukova su bez uzdužne armature, a međusobno su spojeni mokrim reškama.
- Predgotovljene dijafragme umetane su između svakog petog odsječka.
- Na taj način ostvaren je izvorni sklop, posebno razvijen za ovaj most.



Izvedbe na skeli

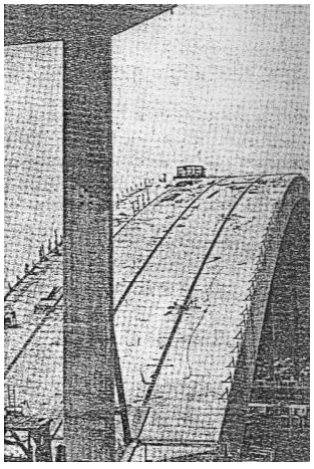
Skela je bila čelična, cijevna, a tijekom izvedbe bočno je pomicana četiri puta.
Rektifikacija luka i odvajanje od skele izvršeno je razupiranjem prešama smještenim u četvrtinama raspona.

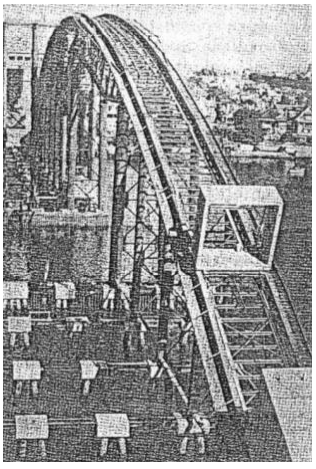




Izvedbe na skeli

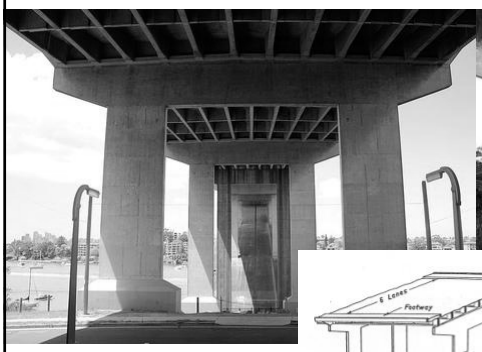
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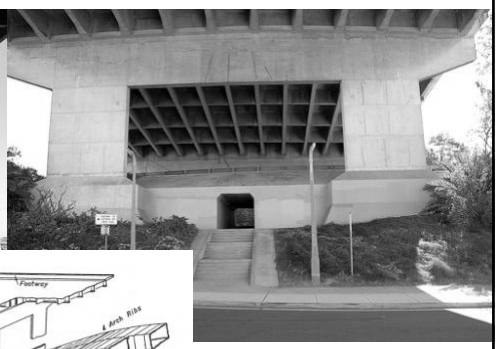


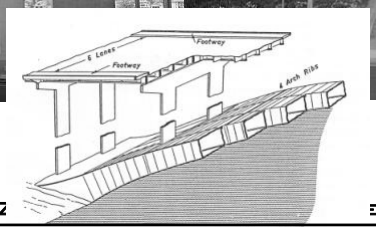


Izvedbe na skeli

Nadlučni sklop izveden je kao roštilj sačinjen od predgotovljenih prednapetih nosača koji se preko predgotovljene naglavnice oslanjaju na vitke stupove izvedene na mjestu.
Nad stupovima je ostvaren kontinuitet nadlučnog sklopa.





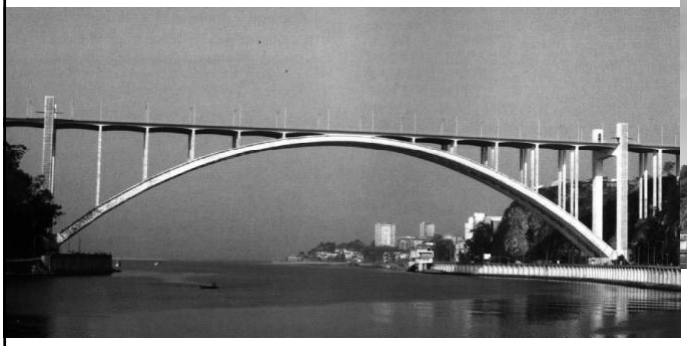


Izvedbe na skeli

U Portugalu je 1963. dovršen most *Arrabida* preko rijeke Douro raspona 270 m.

Poprečni presjek čine dva luka s po dvije ćelije, međusobno povezana uzdužnim spregom.

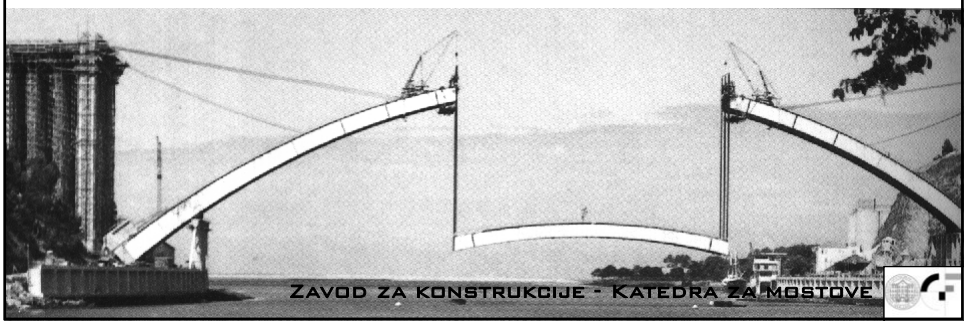




Izvedbe na skeli

Most je izveden na punostijenoj čeličnoj skeli raspona 258 m, visine strelice 50 m, koja je bila oslonjena samo na temelje stalnog luka.

Tijekom izvedbe, skela ukupne mase 2200 tona tri je puta poprečno pomicana za izvedbu lukova i za betoniranje sprega.



Izvedbe na skeli

Viadukt *Fiumarella*, izveden po projektu Ricarda Morandia 1965., zanimljiv je po nagnutim stupovima nadlučnog sklopa, koji povećavaju stabilnost luka, ali estetski ne daju najbolji dojam i po dvostrukom luku kojemu su obje polovice dodatno rastavljane u peti.

Širina luka povećava se od tjemena do pete. Raspon luka je 231 m. Tijekom izvedbe na skeli uz pete luka izvedeni su privremeni zglobovi u luku.

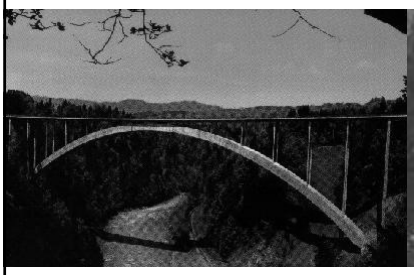


Izvedbe na skeli

Jedini dvozglobni luk velikog raspona izveden je 1967. u Austriji, most *Lingenau*, raspona 210 m.

U pete luka ugrađeni su čelični ležaji.

Most je izveden na čeličnoj cijevnoj skeli s pomoćnim zategama u poprečnom smjeru za horizontalnu stabilizaciju tijekom izvedbe.



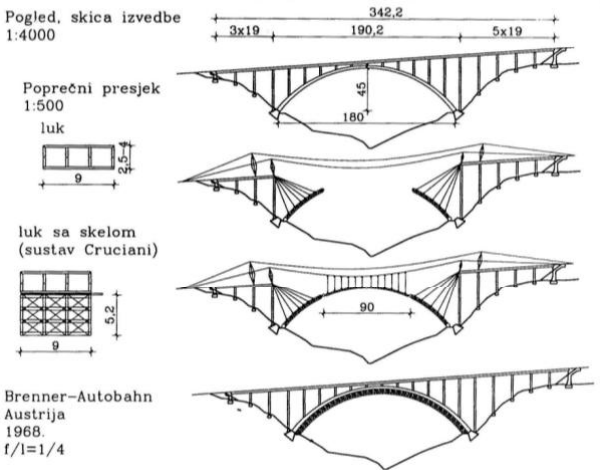


Izvedbe na skeli

Na skelama sustava Cruciani, koji se razvija od 50-ih godina 20. stoljeća, izveden je veći broj (oko 50) lučnih mostova među kojima je najveći dvokolosječni željeznički most *Pfaffenbergbrücke* raspona 200 m.




Cestovni most *Nösslach* u Austriji sastoji se od dva luka blizanca sandučastog poprečnog presjeka s tri ćelije, raspona 180 m.



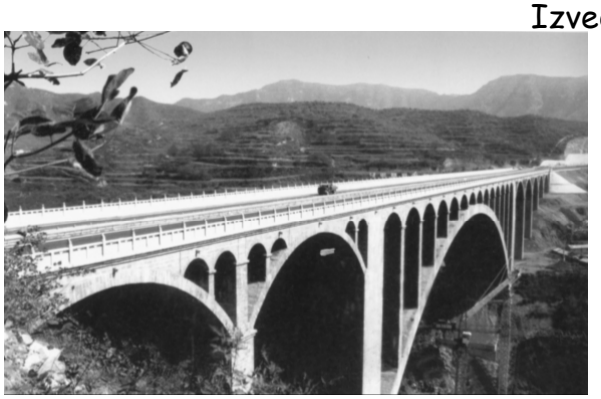
Nösslach



Kameni mostovi u Kini



Kameni most Wuchao, Hunan, Kina, (1990)

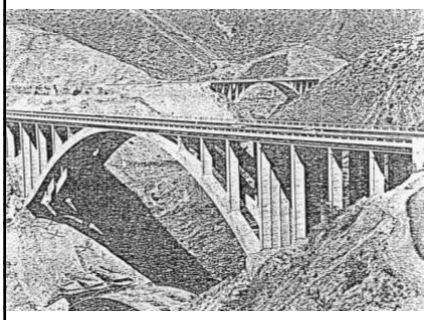


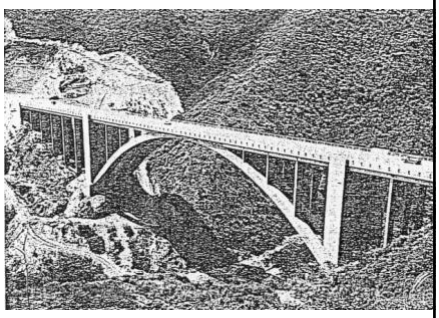
Most s kamenim lukom rekordnog raspona l=146 m je most Danhe, izveden u Kini 2000. godine. Strelica luka iznosi 32,444 m (f/l=1/4,5). Luk je u tjemenu debljine 2,5 m, a kod peta 3,5 m. Za izradbu luka korišten je kamen čvrstoće 100 MPa i mikrobeton C40 za spojnice. Stupovi i nadlučni sklop izvedeni su od kamena čvrstoće 60 MPa i spojnicama zapunjenim mikrobetonom C30.

Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

Idejni začetnik je Freyssinet

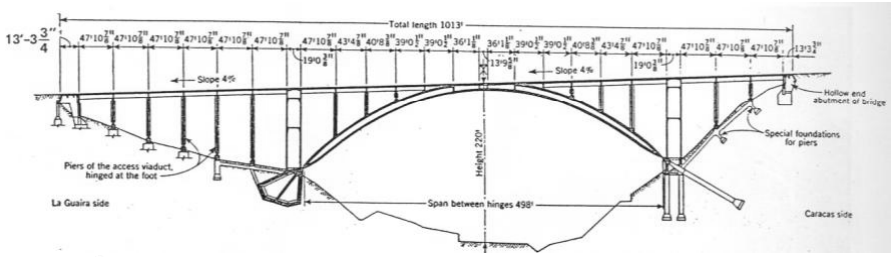
Vijadukti *Caracas,* Venezuela, 1950-1953.

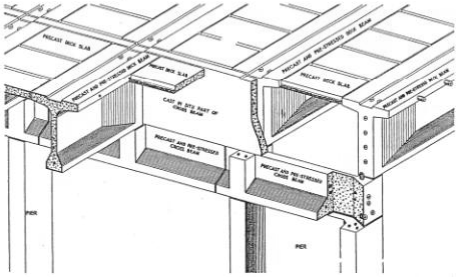


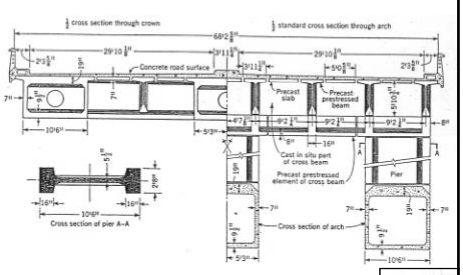


Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

Vijadukti *Caracas,* Venezuela, 1950-1953.

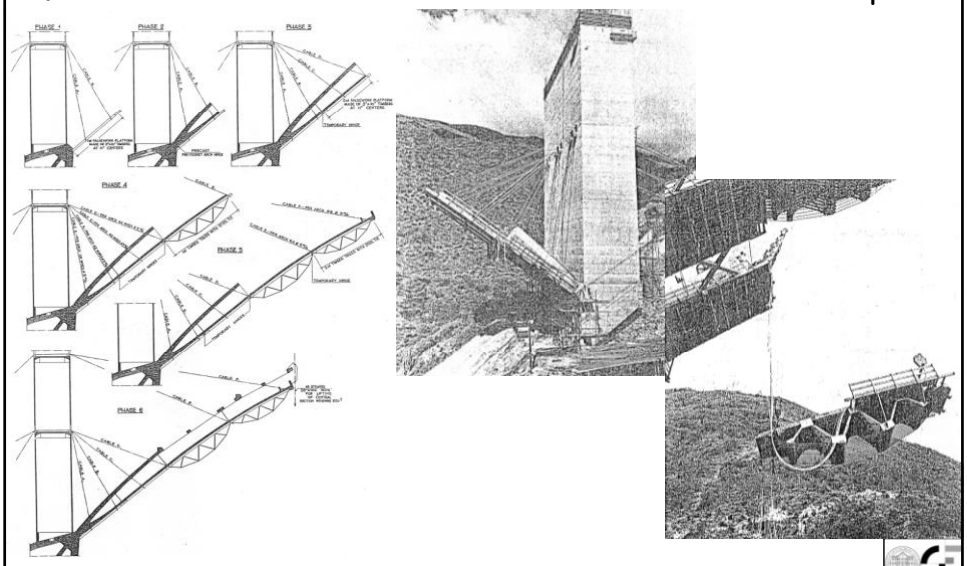






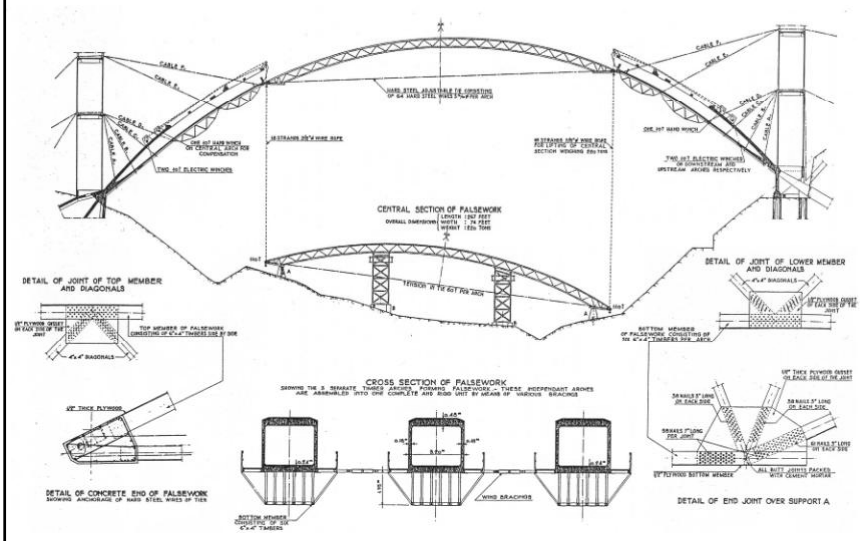
Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

Vijadukti *Caracas,* Venecuela, 1950-1953.



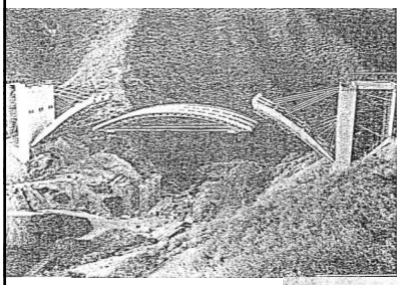
Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

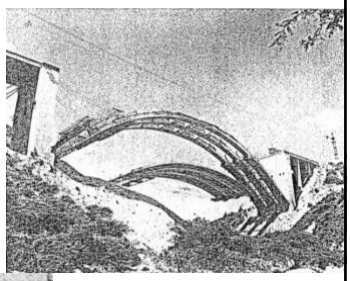
Vijadukti *Caracas,* Venecuela, 1950-1953.

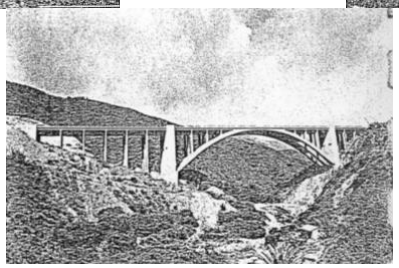


Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

Vijadukti *Caracas,* Venecuela, 1950-1953.

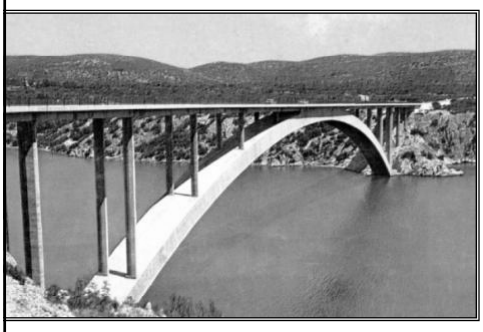


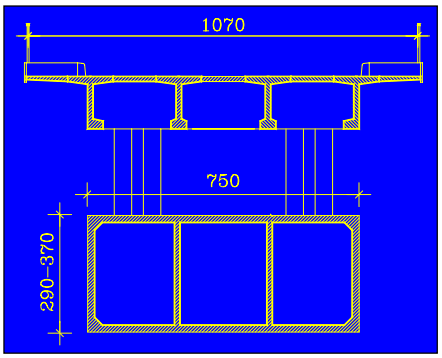


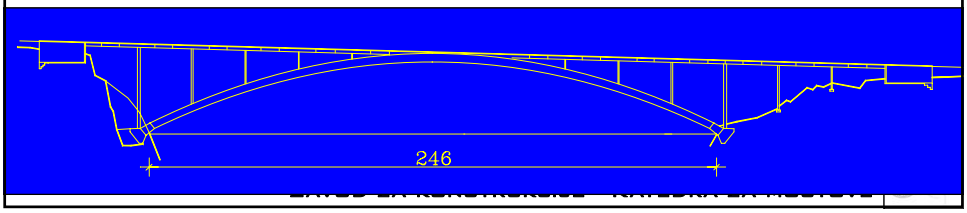


Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

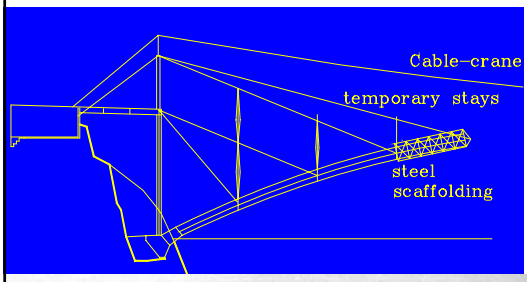
MOST PREKO KRKE
KOD ŠIBENIKA, 1965.

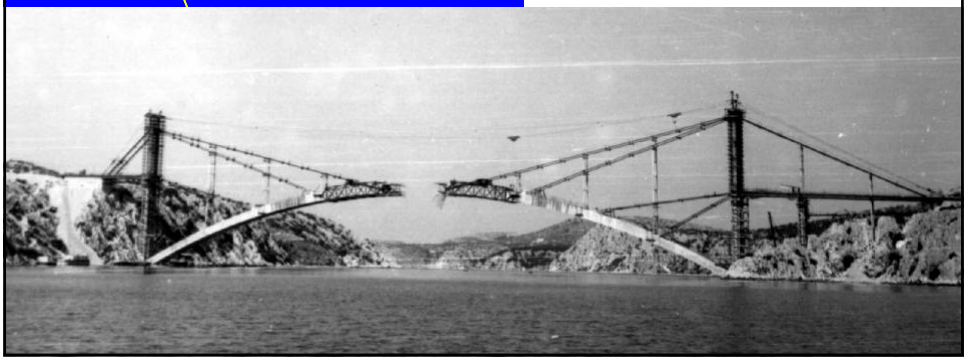






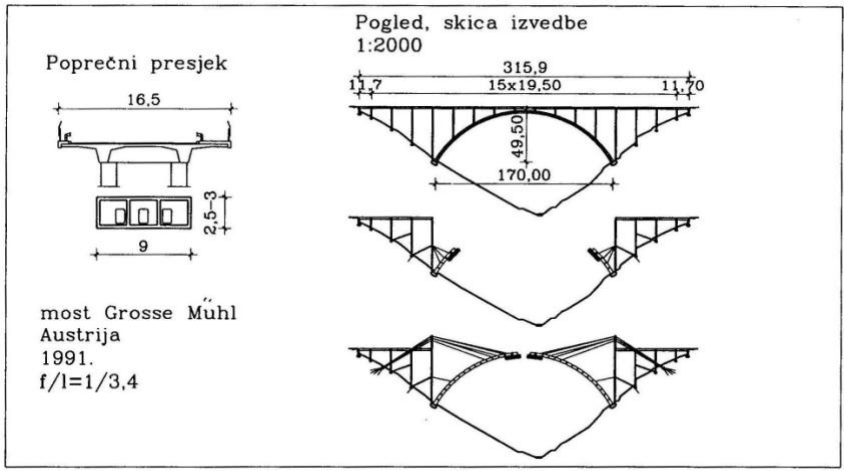
Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona





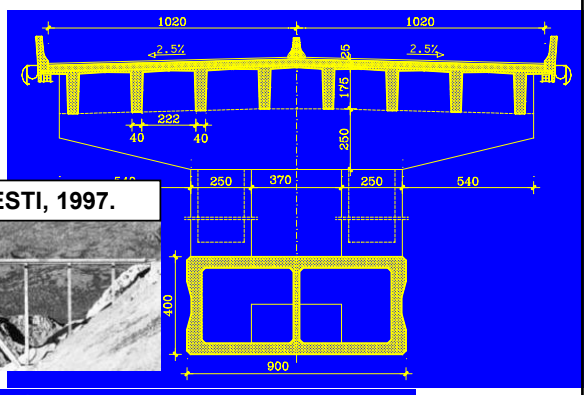
Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

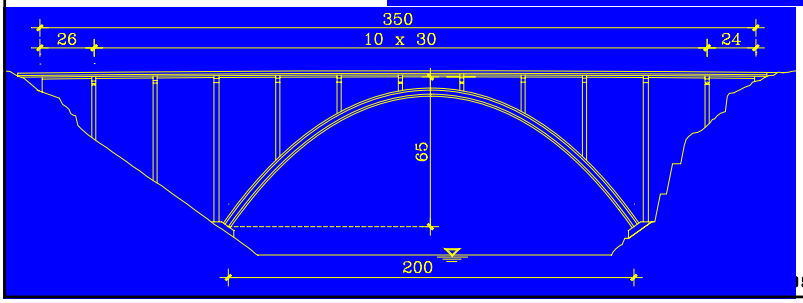
MOST *GROSSE MÜHL* (1991)

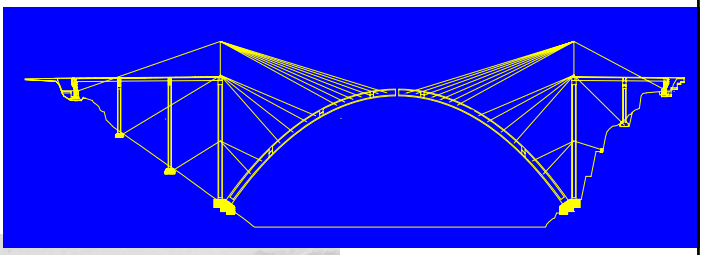


MASLENIČKI MOST NA AUTOCESTI, 1997.









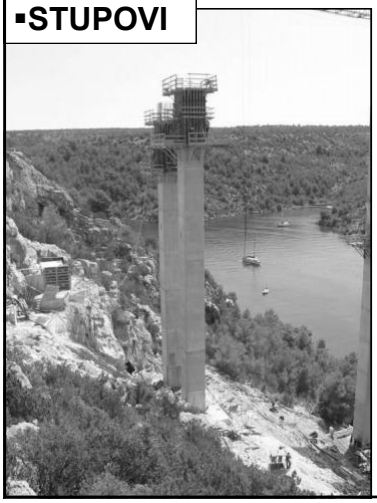


MASLENIČKI MOST NA AUTOCESTI, 1997.

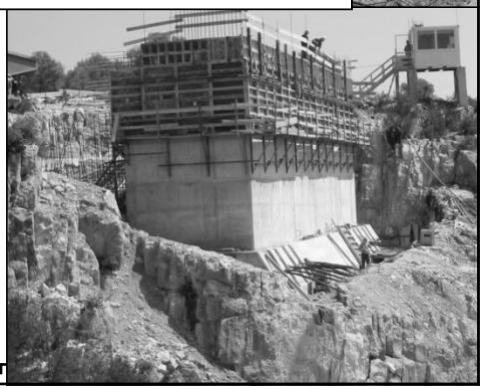
MOST PREKO KRKE
KOD SKRADINA



▪STUPOVI

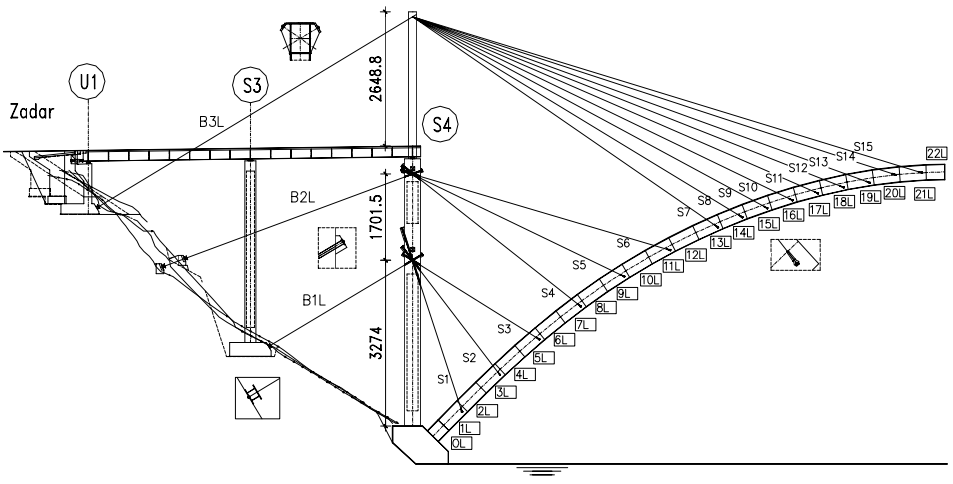


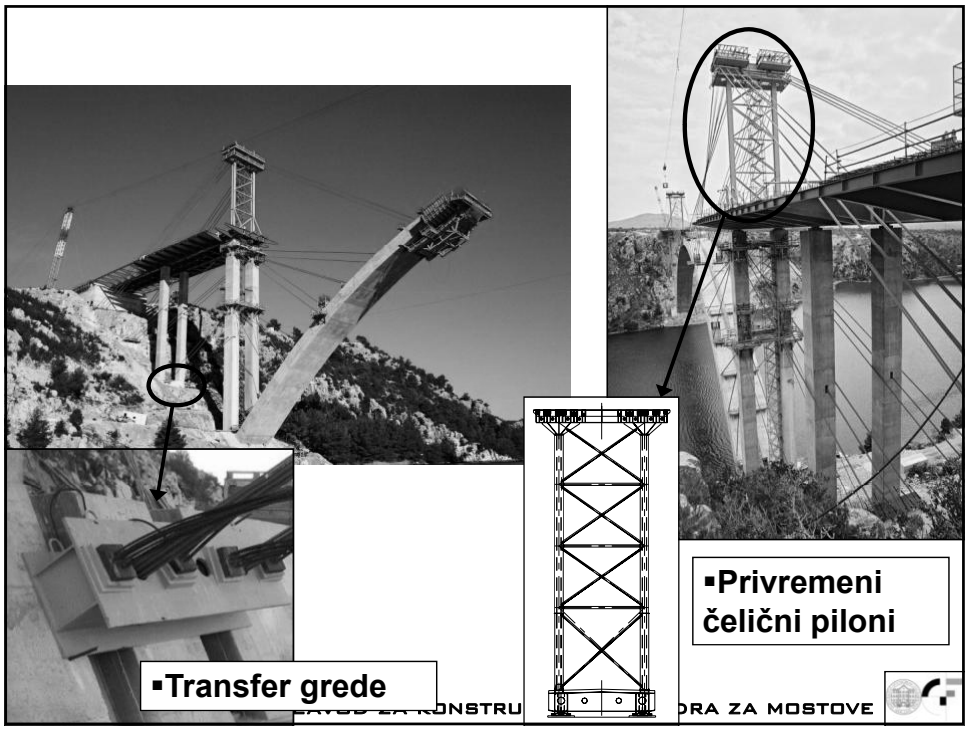
▪TEMELJI STUPOVA, UPORNJACI I PETE LUKA



ZA KONST

▪Slobodna konzolna gradnja, duljina odsječaka 5,25 m.




▪Transfer grede
▪Privremeni čelični piloni

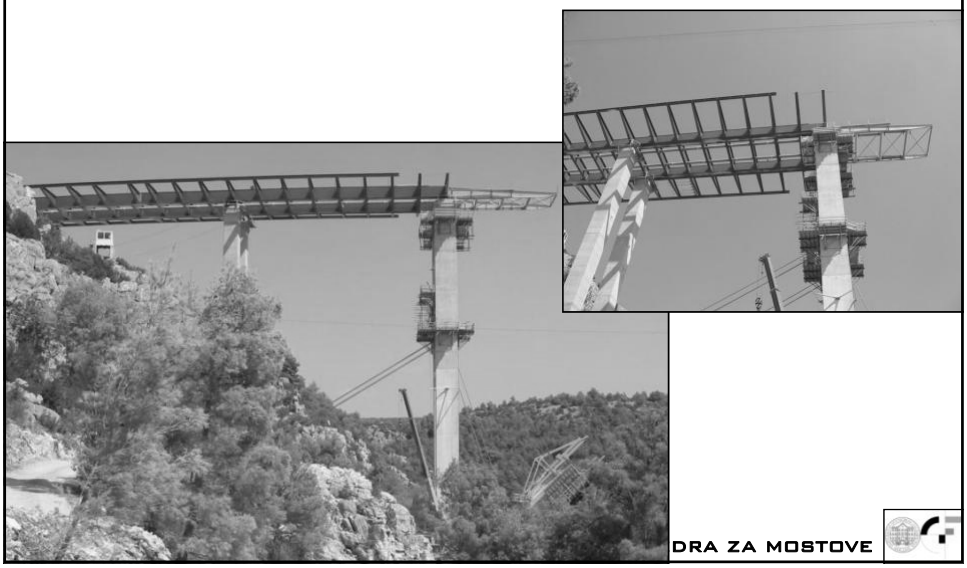




▪Spajanje luka

ZAVOD ZA KONSTRUKCIJE - KATEDRA ZA MOSTOVE

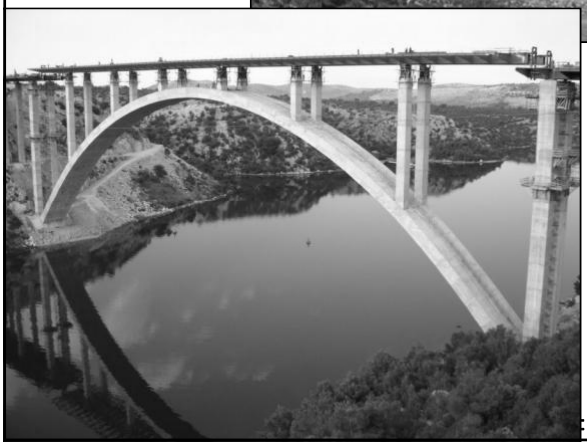
▪Uzdužno potiskivanje čeličnog roštilja



DRA ZA MOSTOVE

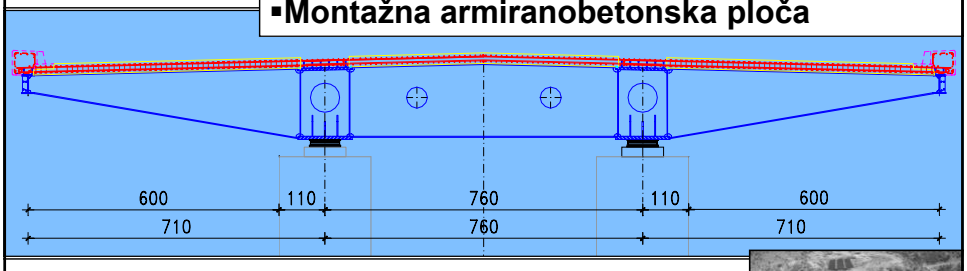
▪Uzdužno potiskivanje čeličnog roštilja



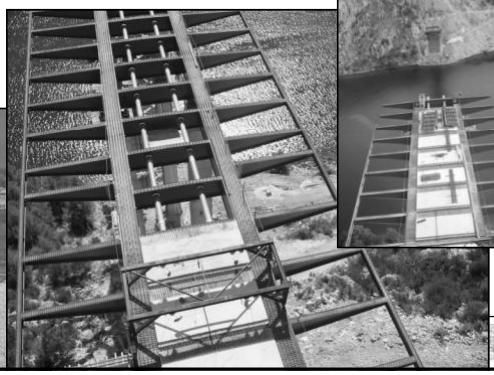


- KATEDRA ZA MOSTOVE

▪Montažna armiranobetonska ploča



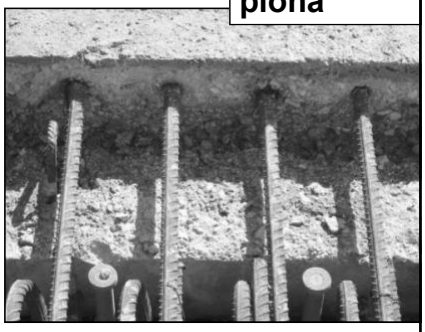




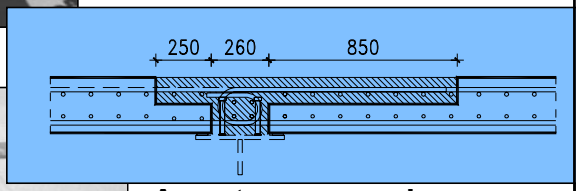
▪Uzdužne i poprečne reške



▪Obrada ploha







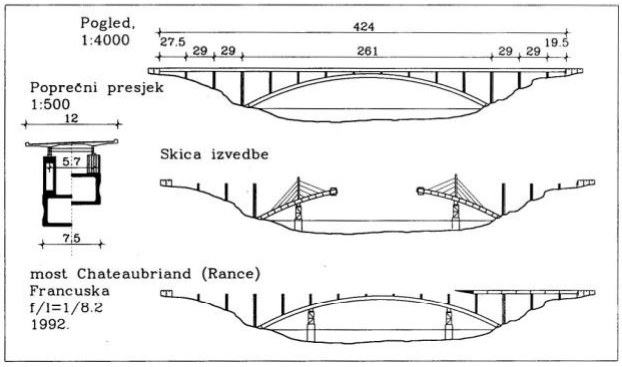
▪Armatura na spoju montažnih ploča



MOST JE DOVRŠEN POČETKOM 2005. GODINE

Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

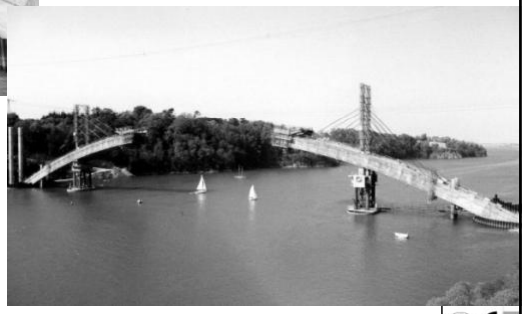
MOST *CHATEAUBRIAND*, 1992.



Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

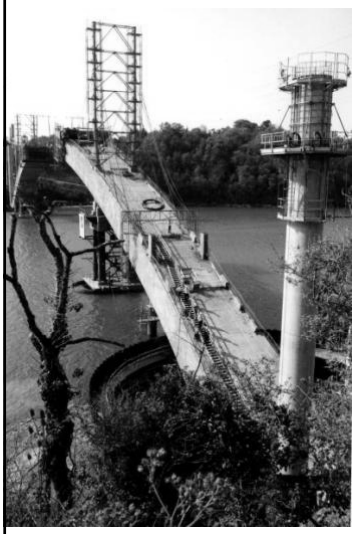
MOST *CHATEAUBRIAND*, 1992.





Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

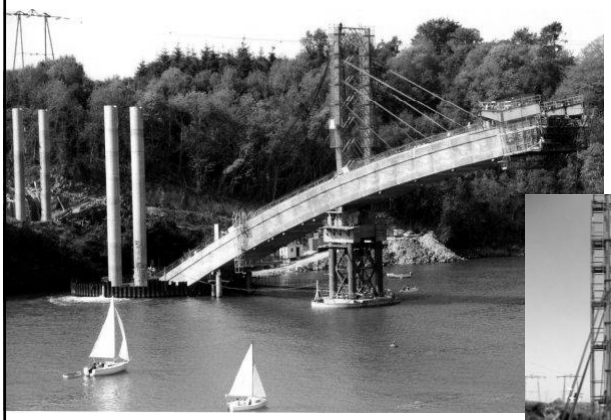
MOST *CHATEAUBRIAND*, 1992.





Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *CHATEAUBRIAND*, 1992.





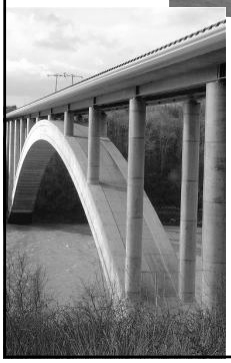


ZAVOD ZA KONSTRUKCIJE - KATEDRA ZA MOSTOVE

Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *CHATEAUBRIAND*, 1992.







Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *LA ROCHE-BERNARD (MORBIHAN*), 1994.





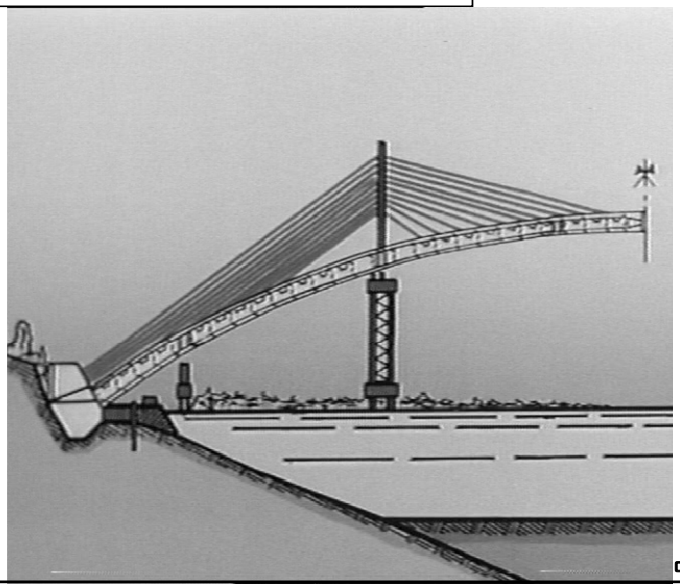
Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *LA ROCHE-BERNARD (MORBIHAN)*, 1994.



Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *LA ROCHE-BERNARD (MORBIHAN)*, 1994.



Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *LA ROCHE-BERNARD (MORBIHAN),* 1994.



Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

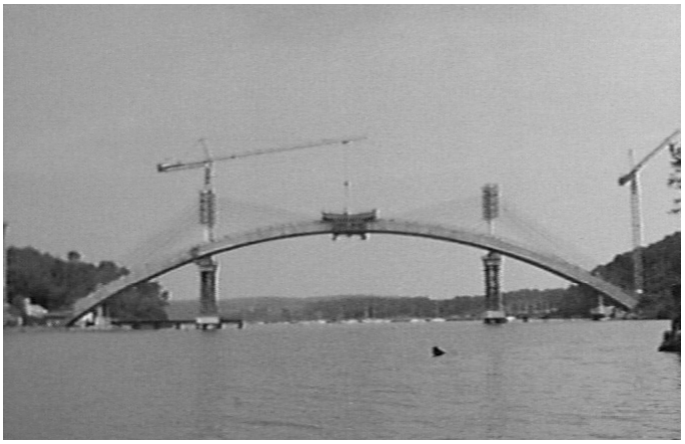
MOST *LA ROCHE-BERNARD (MORBIHAN),* 1994.



ZAVOD ZA KONSTRUKCIJE - KATEDRA ZA MOSTOVE

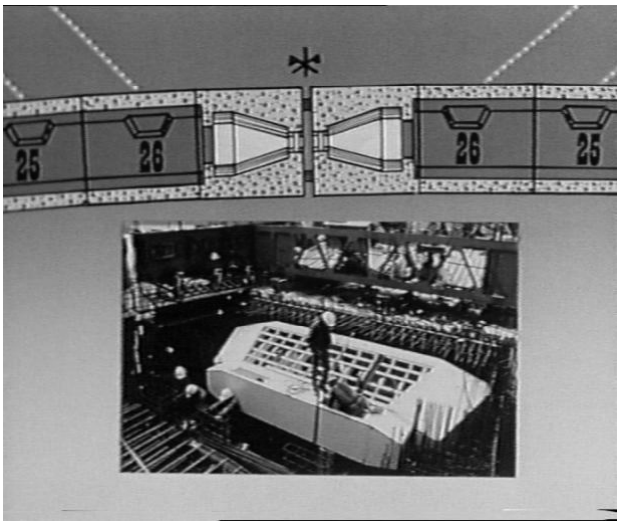
Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *LA ROCHE-BERNARD (MORBIHAN),* 1994.



Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *LA ROCHE-BERNARD (MORBIHAN),* 1994.



Zavod za konstrukcije - Katedra za mostove

MOST *LA ROCHE-BERNARD (MORBIHAN),* 1994.

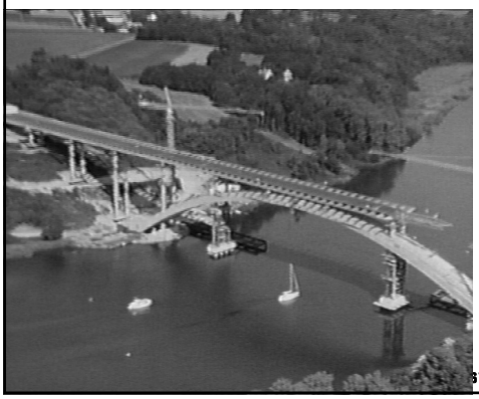




Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *LA ROCHE-BERNARD (MORBIHAN),* 1994.





Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *LA ROCHE-BERNARD (MORBIHAN),* 1994.

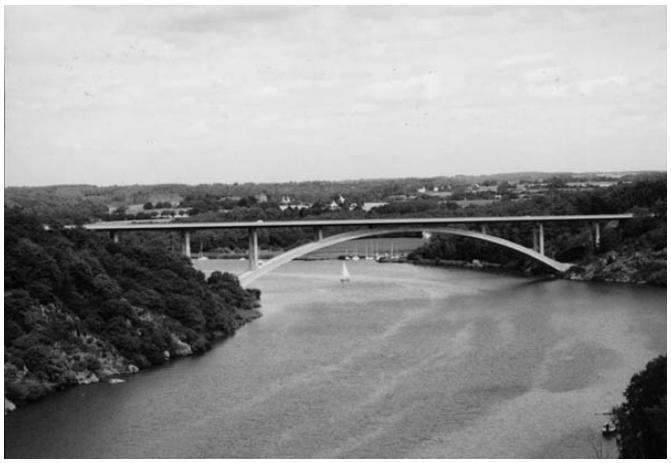






Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

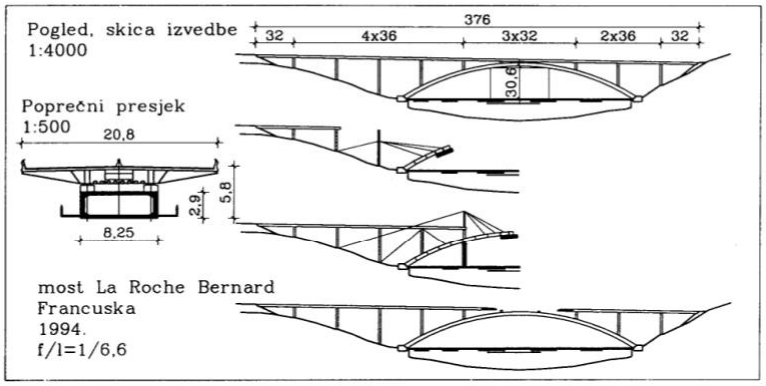
MOST *LA ROCHE-BERNARD (MORBIHAN),* 1994.



ZAVOD ZA KONSTRUKCIJE - KATEDRA ZA MOSTOVE

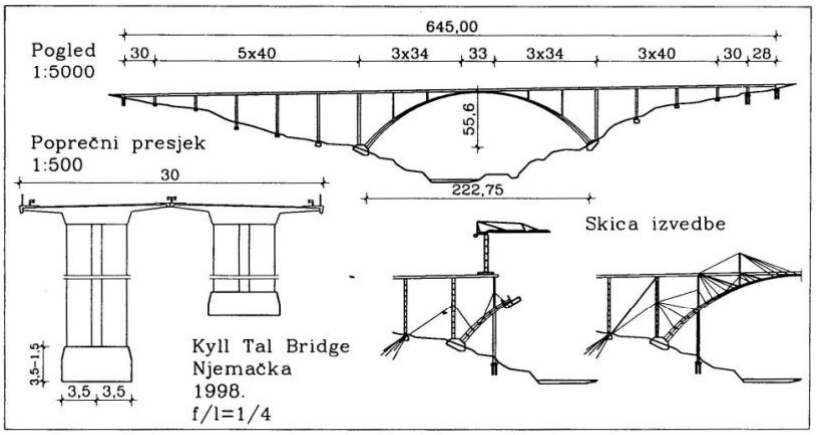
Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *LA ROCHE-BERNARD (MORBIHAN)*, 1994.



Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

MOST *KYLL*, 1997.



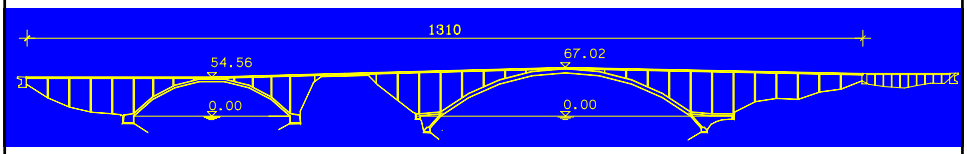
MOST *KYLL*, 1997.

Konzolna gradnja uz korištenje privremenih zatega i pomoćnog pilona

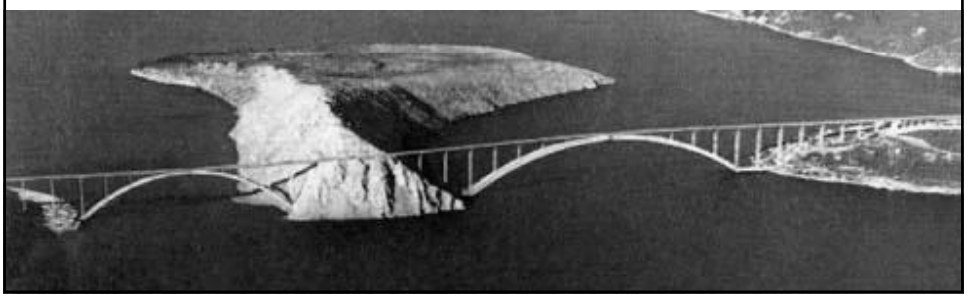


MOST *KRK*, 1981.

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt

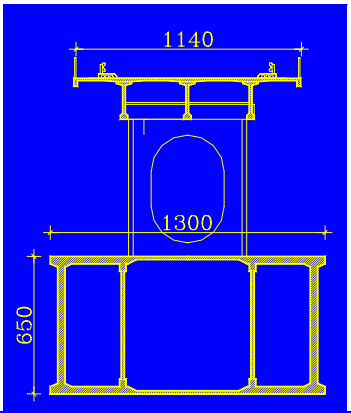


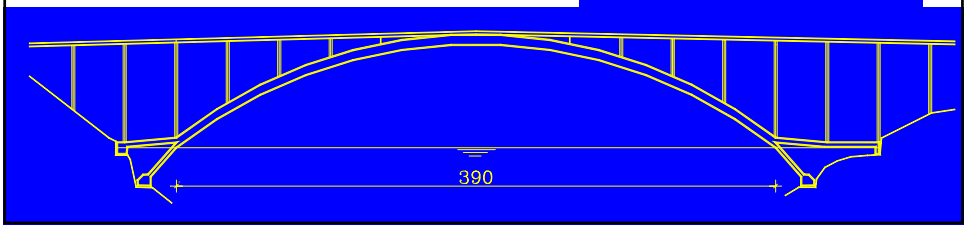
Krk island | Island of St. Marc | 430 m wide strait | Mainland



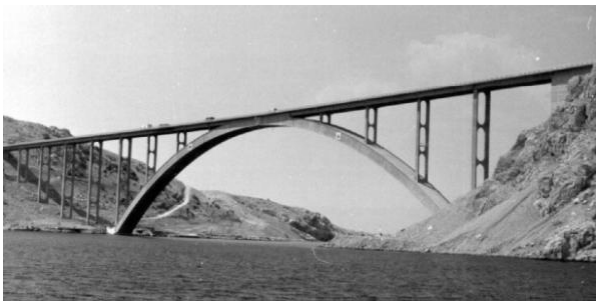
KRK I

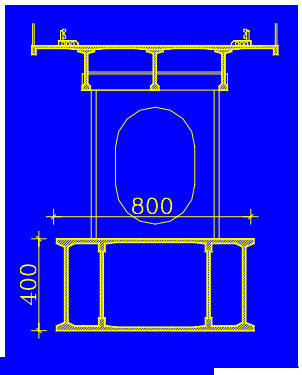


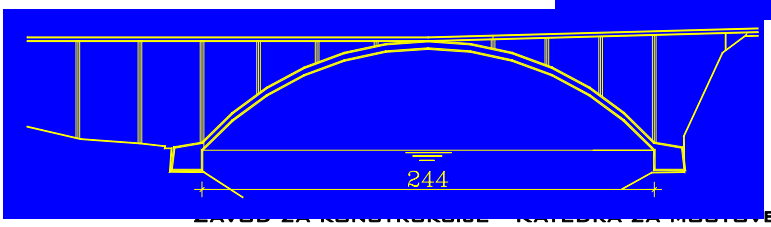


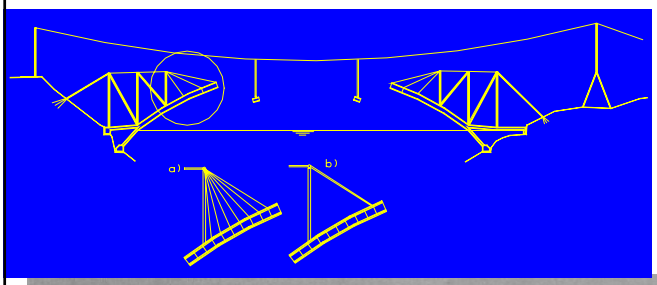


KRK II

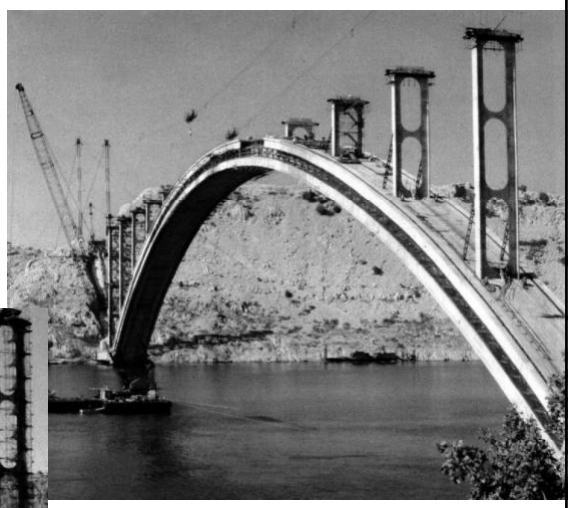


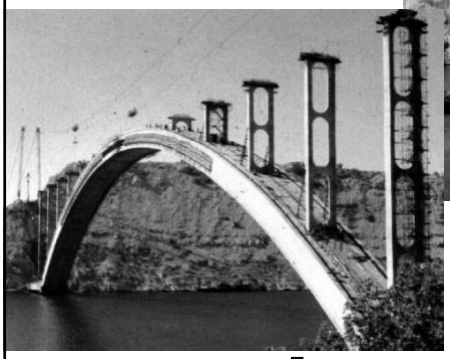





a)
b)

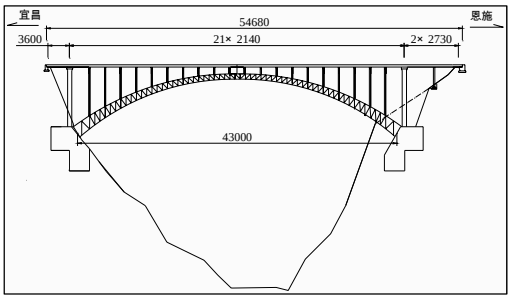






Zhijinghe Bridge





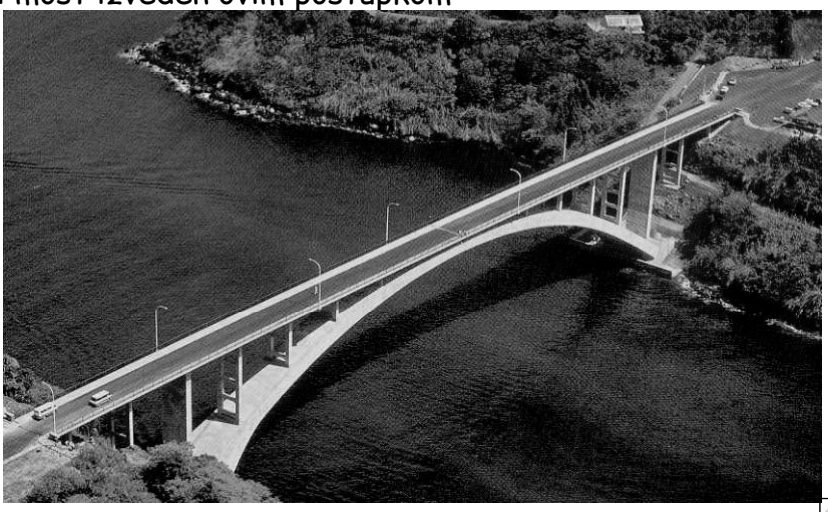


- **430m span**
- **Under construction**
- **Cantilever method**

MOST *HOKAWAZU*, JAPAN, 1974.

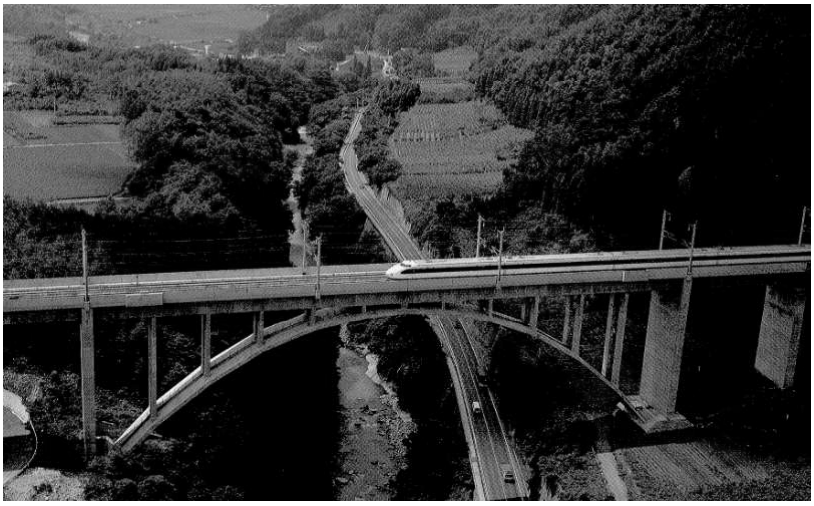
Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt

Prvi most izveden ovim postupkom



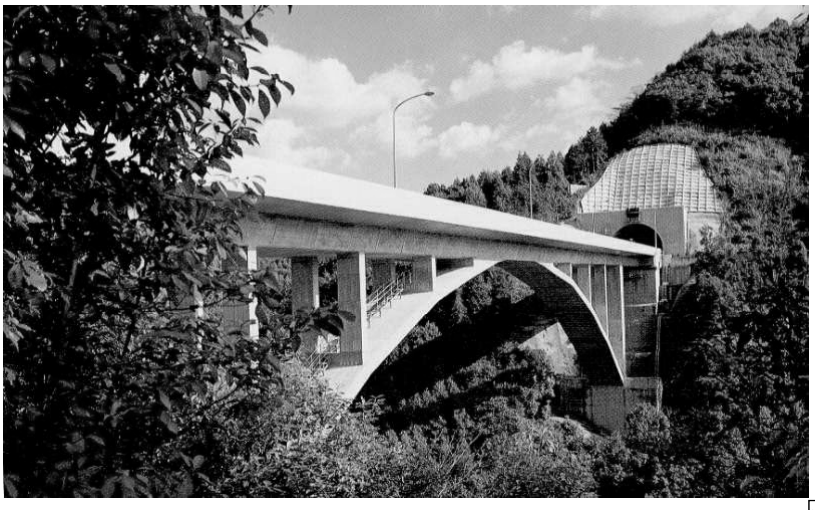
MOST *AKAYAGAWA*, JAPAN, 1979.

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt



MOST *NAKATANIGAWA*, JAPAN, 1988.

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt



MOST *RIP*, AUSTRALIA

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt







MOST *RIP*, AUSTRALIA

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt





Zavod za konstrukcije - Katedra za mostove



MOST *LA REGENTA*, 1996.

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt





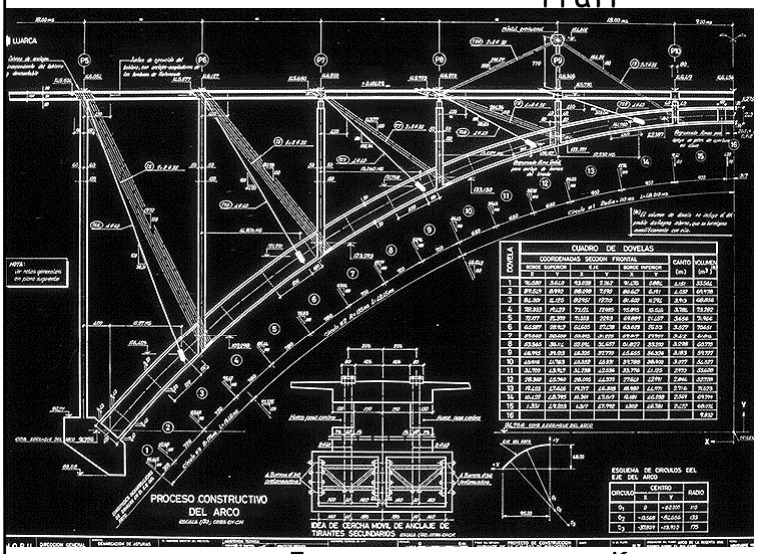






MOST *LA REGENTA*, 1996.

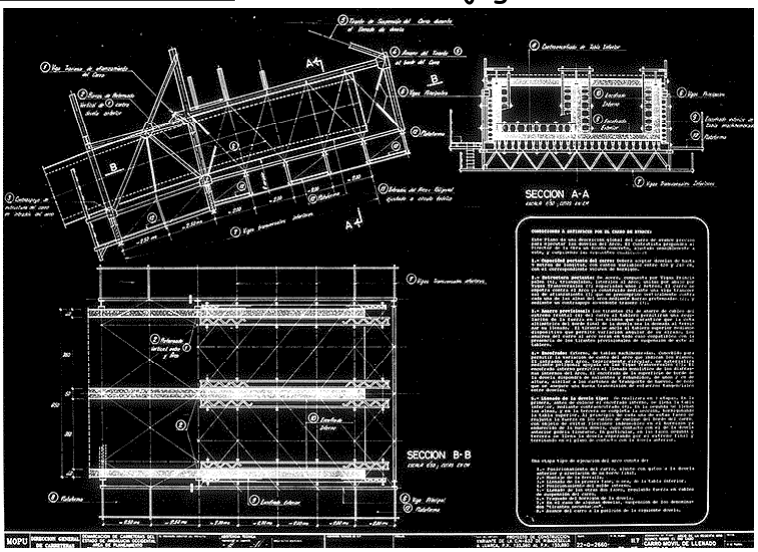
Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt





MOST *LA REGENTA*, 1996.

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa



MOST *LA REGENTA*, 1996.

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt





MOST *JIANGJIE*, 1995.

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt

Najveći most izveden tim postupkom





MOST *JIANGJIE*, 1995.

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt

Najveći most izveden tim postupkom



Zavod za konstrukcije - Katedra za mostove

MOST *LOS TILOS*

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt



MOST *LOS TILOS*

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt



ZAVOD ZA KONSTRUKCIJE - KATEDRA ZA MOSTOVE

MOST *LOS TILOS*

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt





MOST *LOS TILOS*

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt





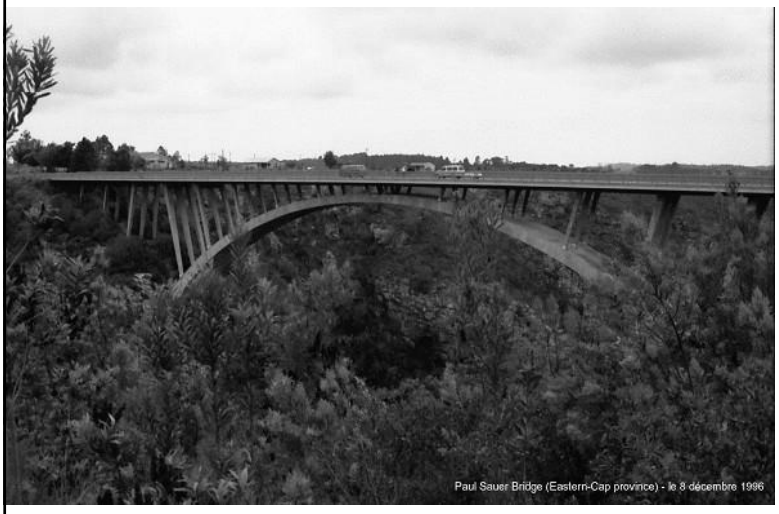
MOST *LOS TILOS*

Konzolna gradnja s privremenim zategama kao dijagonalama rešetke tipa Pratt



MOST *STORMS RIVER*, JUŽNA AFRIKA, 1956.

Postupci koji uključuju zaokretanje luka u konačni položaj



Postupci koji uključuju zaokretanje luka u konačni položaj

MOST *STORMS RIVER*, JUŽNA AFRIKA, 1956.



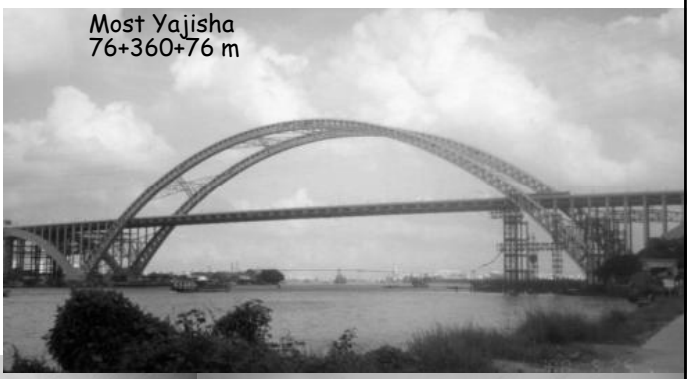


Postupci koji uključuju zaokretanje luka u konačni položaj

MOST *ARGENTOBEL*, 1985.



MOST *YAJISHA*



kombinacija zaokretanja u horizontalnoj i vertikalnoj ravnini

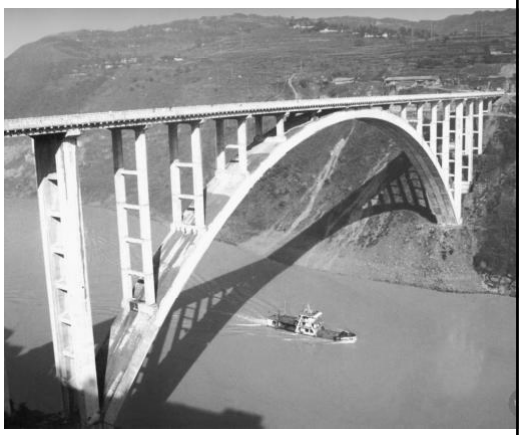


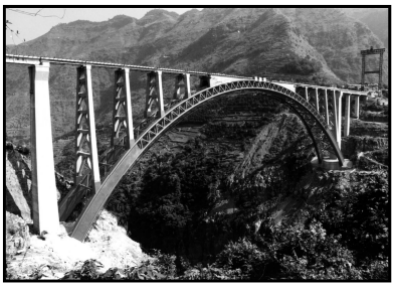


Postupci koji uključuju zaokretanje luka u kanačni položaj

MOST *FULING WUIJANG*, 1989.











Bei-Pan-Jiang Bridge
Railway bridge

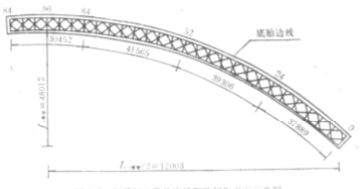
- **236m span**
- **Lifted-basket arch**

MOST *SYIBIN JINSHAIANG*, 1990.

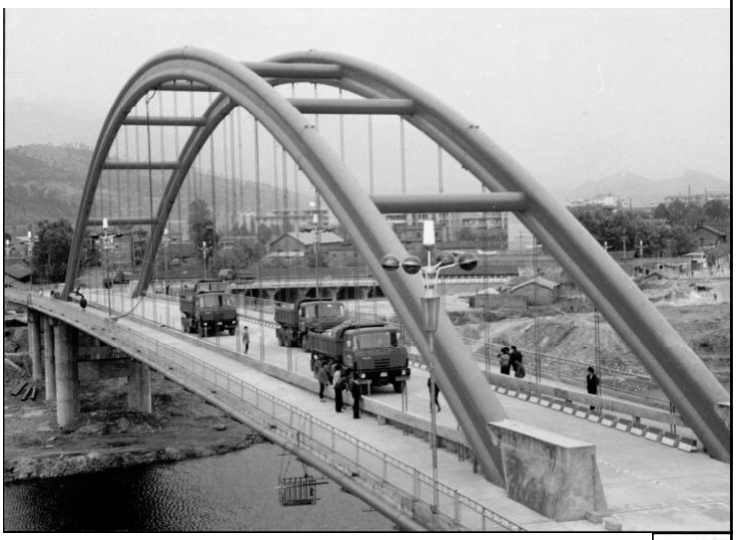
Postupci koji koriste krutu armaturu koja služi kao skela tijekom izvedbe luka, a u uporabi kao armatura luka

(Melan-ov patent iz 1892.)





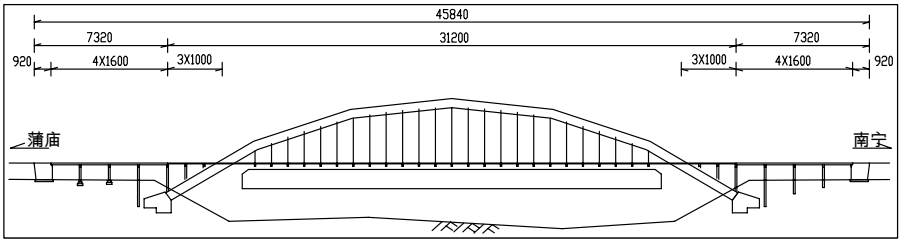
MOST *WANGCANG DONGHE*, 1990.



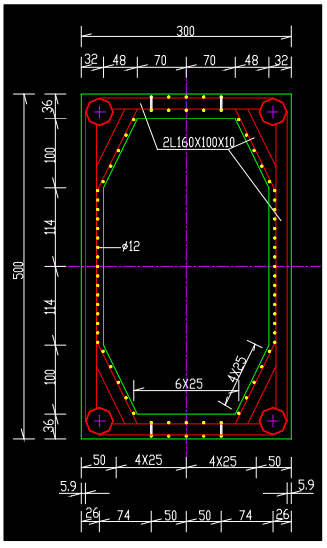
MOST *YONGJIANG*, 1996.

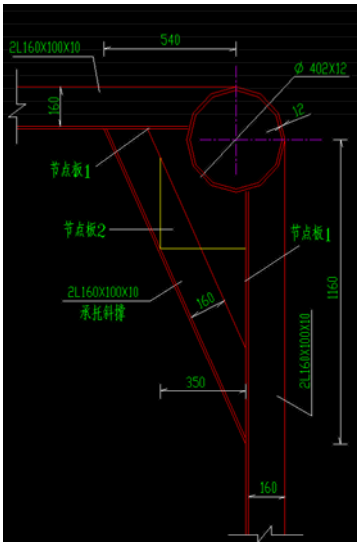


MOST *YONGJIANG*, 1996.



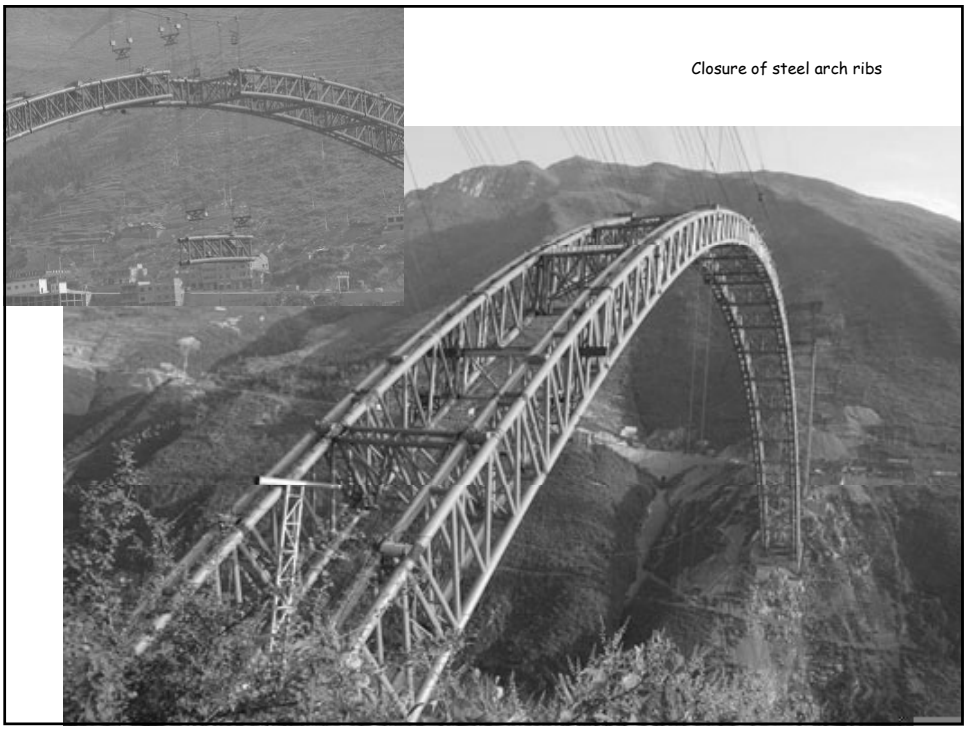
MOST *YONGJIANG*, 1996.





Wushan Yangtze River Bridge , completed in 2005, is the longest CFST arch bridge in the world. The span is 460m and the rise to span ratio is 1/3.8.





Closure of steel arch ribs

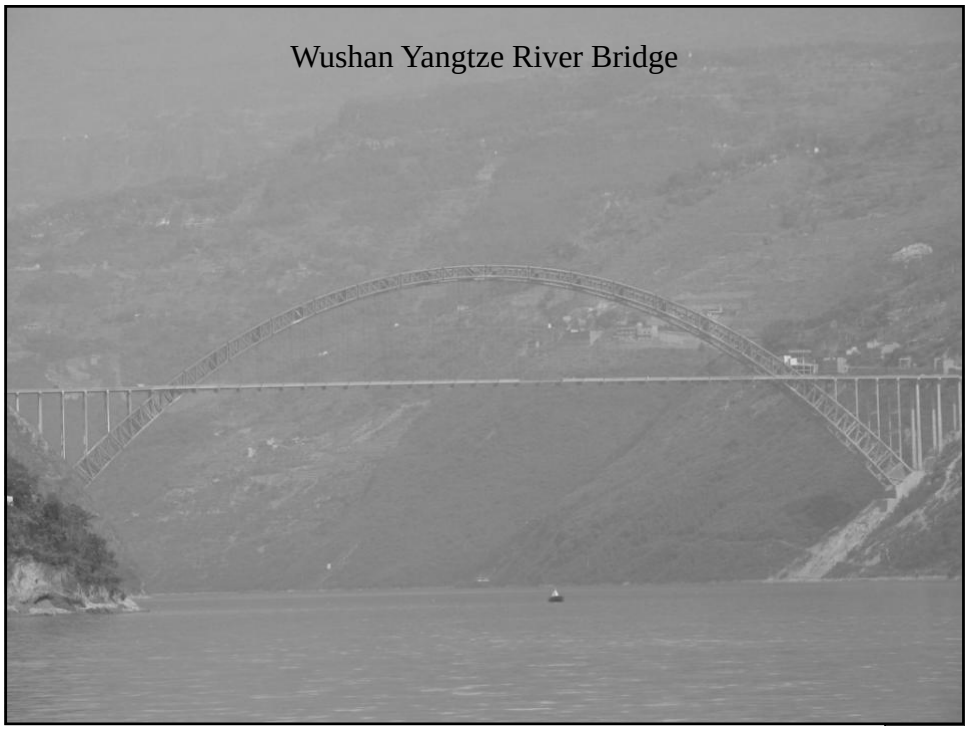




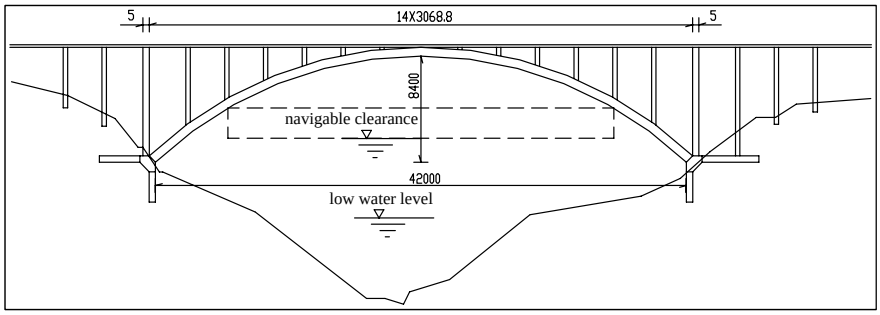
Experiment on pumping concrete into steel tubes



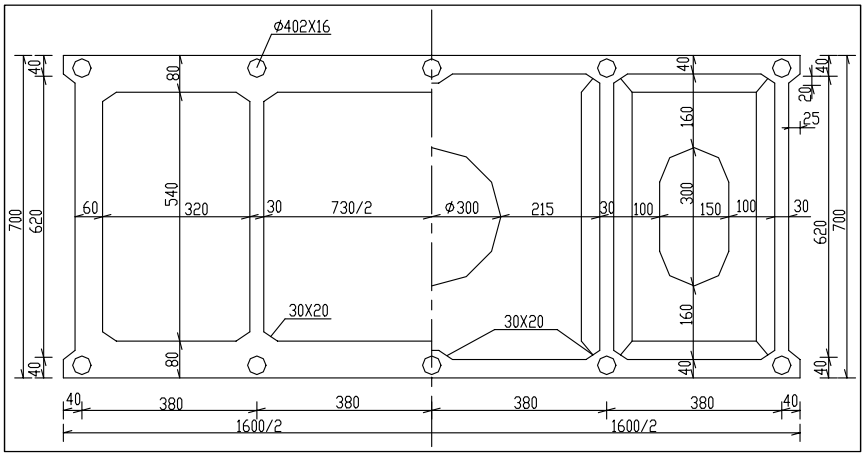
Fabrication of cross girder



MOST *WANXIAN YANGTZE*, 1997.



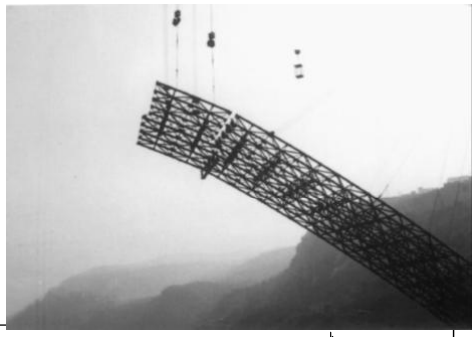
MOST *WANXIAN YANGTZE*, 1997.

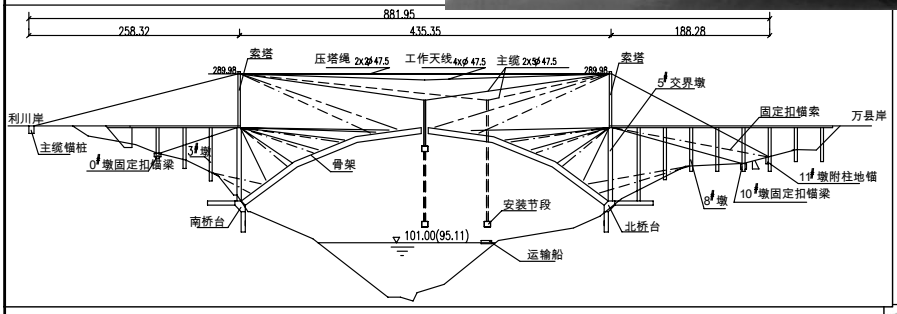


Skeleton

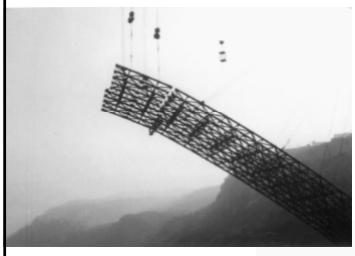


MOST *WANXIAN YANGTZE*, 1997.

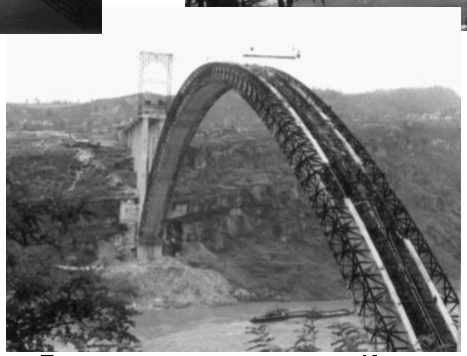




MOST *WANXIAN YANGTZE*, 1997.



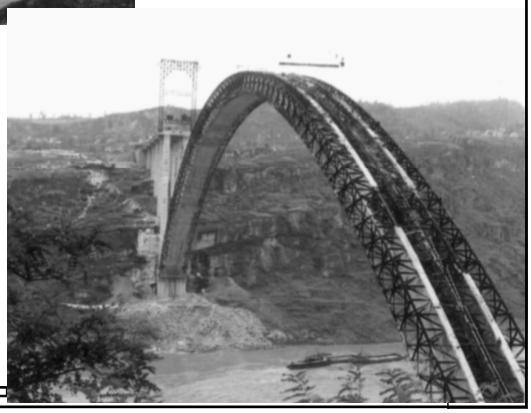




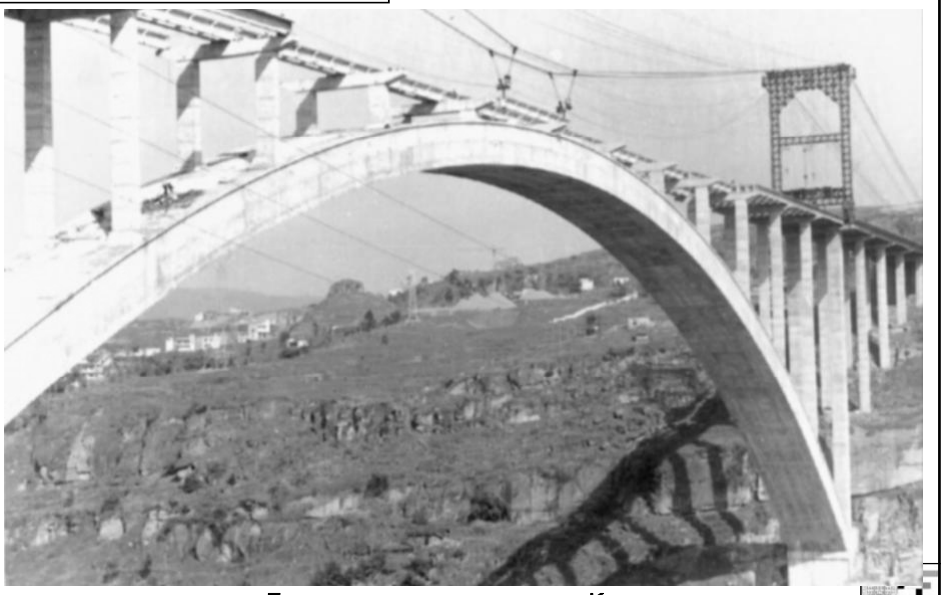


Pumping concrete into steel tubes

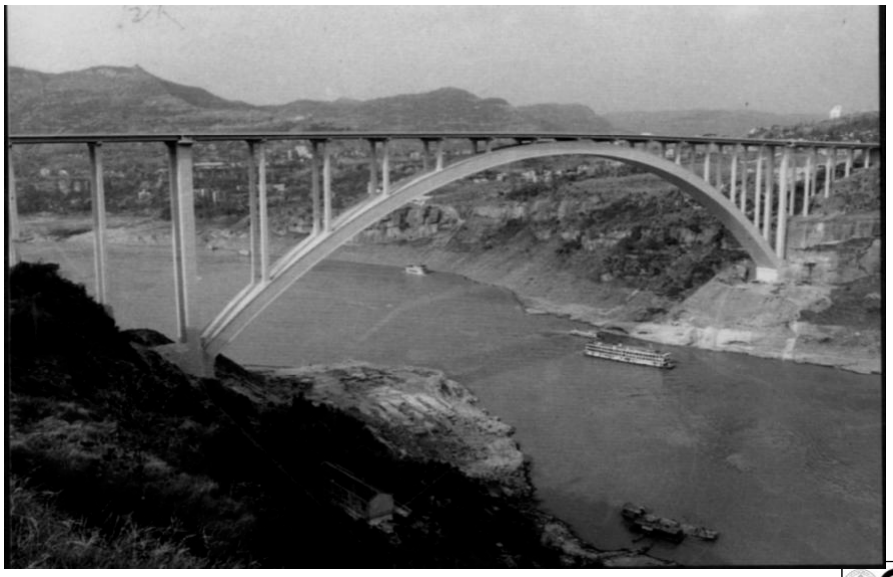
Cast concrete in site to form the RC ring



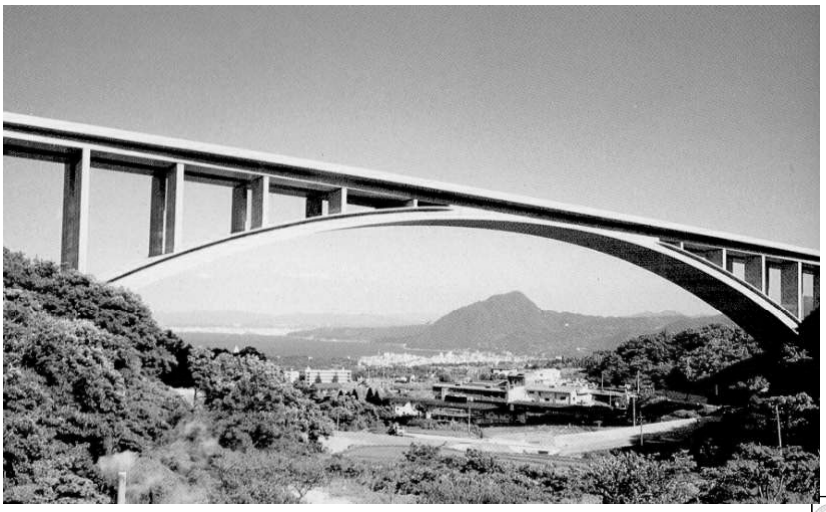
MOST *WANXIAN YANGTZE*, 1997.



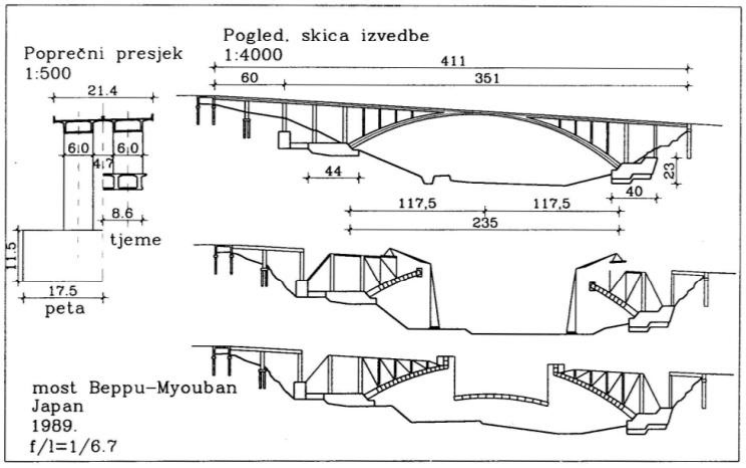
MOST *WANXIAN YANGTZE*, 1997.



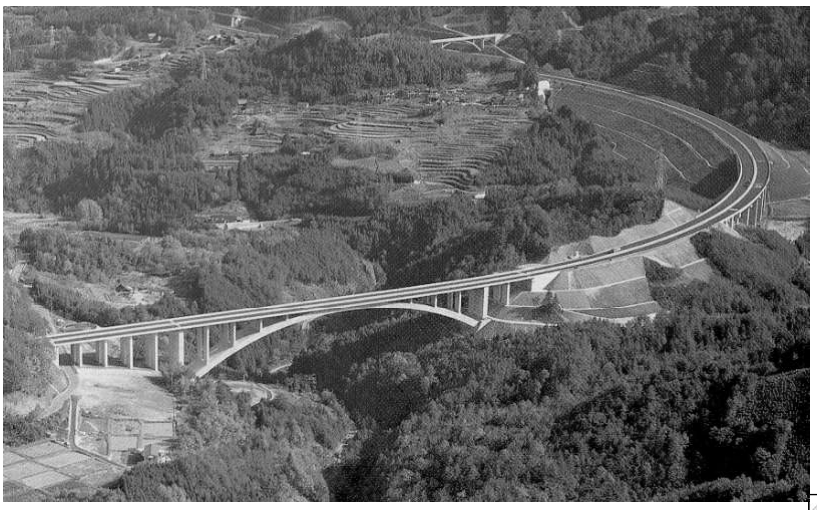
MOST *BEPPU-MYOUBAN*, JAPAN, 1989.



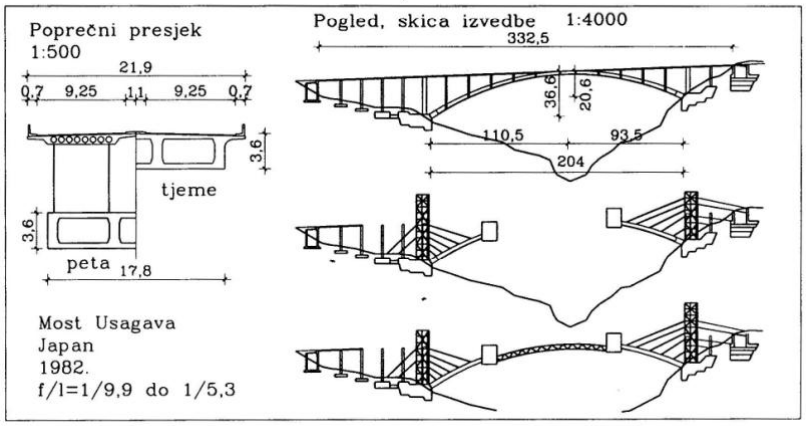
MOST *BEPPU-MYOUBAN*, JAPAN, 1989.



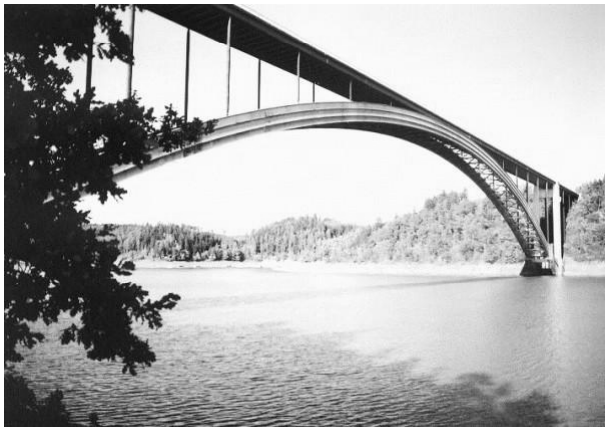
MOST *USAGAWA*, JAPAN, 1982.



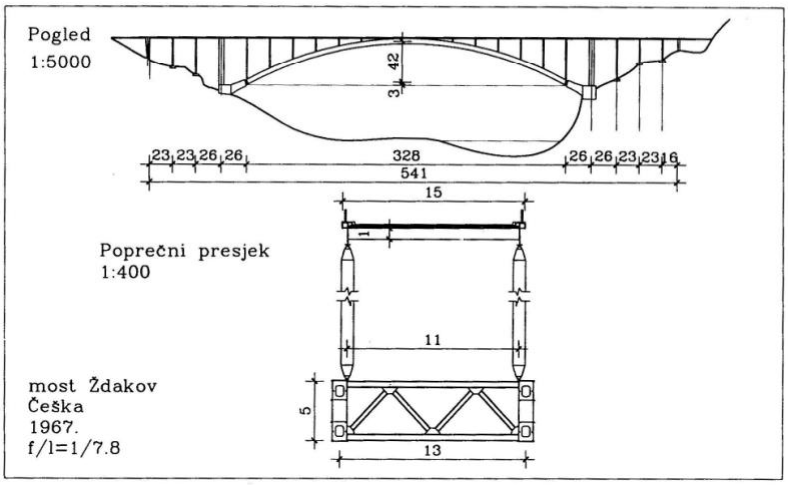
MOST *USAGAWA*, JAPAN, 1982.



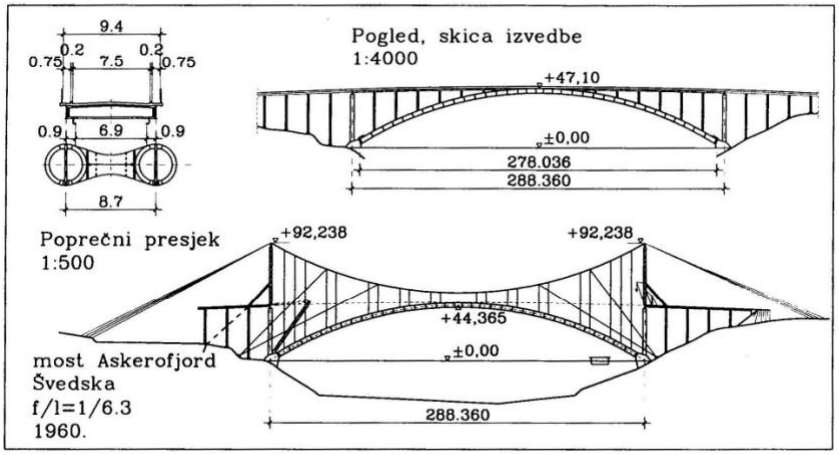
MOST *ŽDAKOV*, ČEŠKA, 1967.



MOST *ŽDAKOV*, ČEŠKA, 1967.

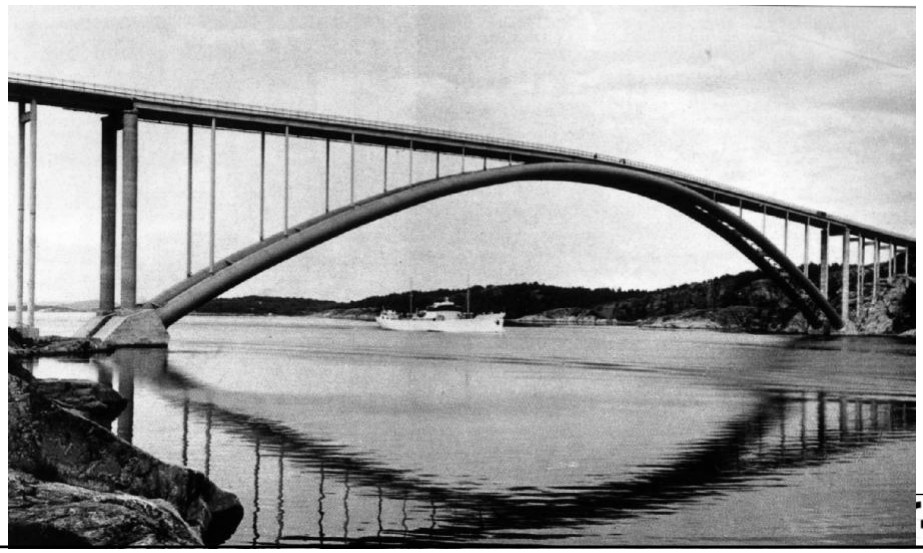


MOST *ASKERÖFJORD*, ŠVEDSKA, 1960.

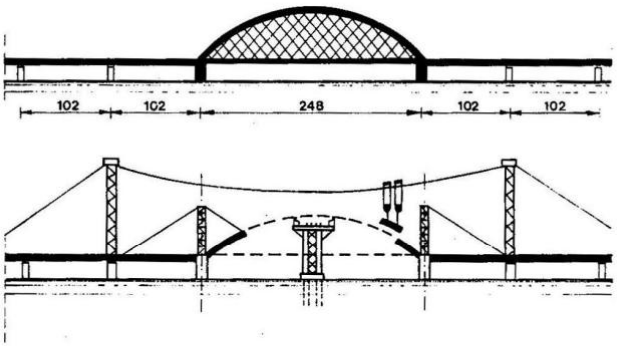


Čelični mostovi

MOST *ASKERÖFJORD*, ŠVEDSKA, 1960.

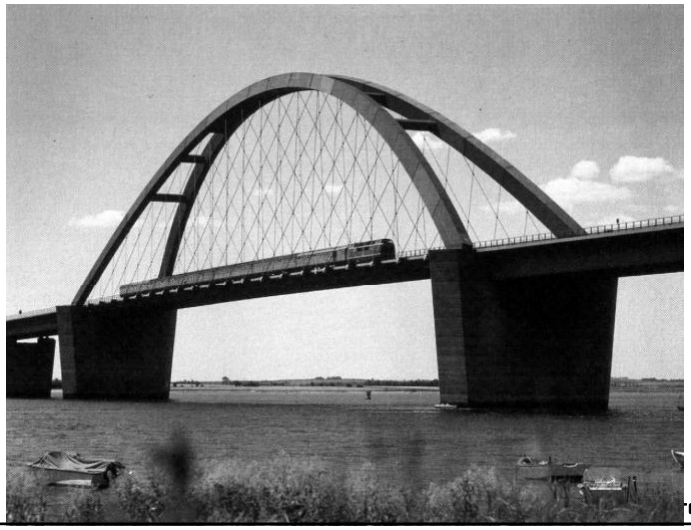


MOST *FEHRMARSUND*, 1963.

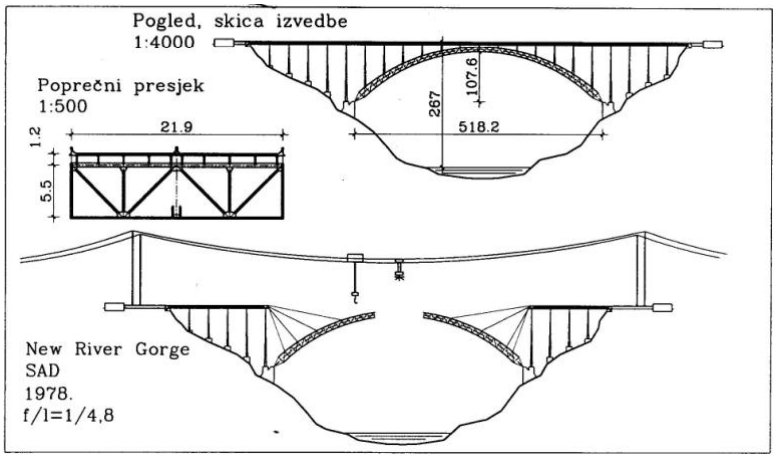


Čelični mostovi

MOST *FEHRMARSUND*, 1963.



MOST *NEW RIVER GORGE*, SAD, 1977.



Čelični mostovi

MOST *NEW RIVER GORGE*, SAD, 1977.



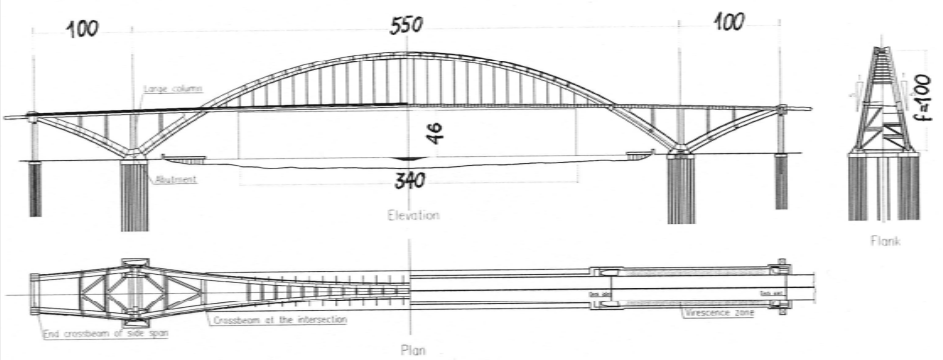
ZAVOD ZA KONSTRUKCIJE - KATEDRA ZA MOSTOVE

MOST *NEW RIVER GORGE*, SAD, 1977.





MOST *LU PU*, KINA, 2003.



MOST *LU PU*, KINA, 2003.





Čelični mostovi

MOST *LU PU*, KINA, 2003.



ZAVOD ZA KONSTRUKCIJE - KATEDRA ZA MOSTOVE

MOST *LU PU*, KINA, 2003.





Half side view of the bridge



Tied cables

MOST *LU PU,* KINA, 2003.



Čelični mostovi

MOST *LU PU*, KINA, 2003.




2005/05/16


2005/05/05


2005/08/01


2005/08/29


2005/09/17


2005/12/15


2005/10/15


2005/10/03


2005/12/15



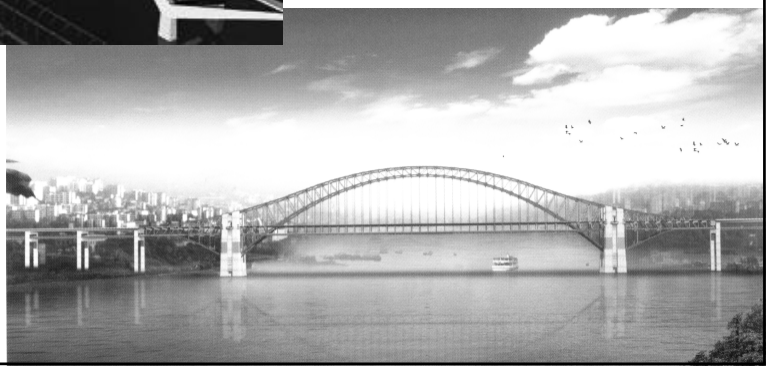






Čelični mostovi

MOST *CHONGQING CAIYUANBA*, KINA, 2003.



Caiyuanba Yantze River Bridge, located in Chongqing, is under construction. The main span is 420m with double decks.













Chaotianmen Bridge, located in Chongqing. The span arrangment is 140+552+140m. The main span is 552m with double decks.



Liuyanhe Bridge



Guotai Bridge



Dongping Bridge



Wuyuan Bridge



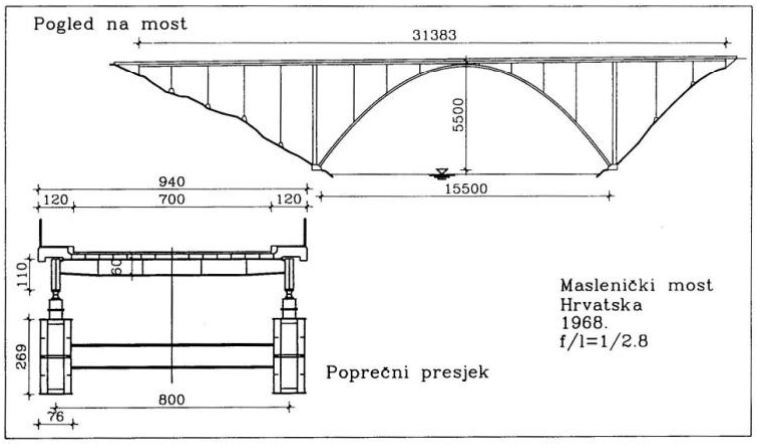
Yong-Jiang Bridge is a steel arch bridge with three main spans of 100+450+100m.





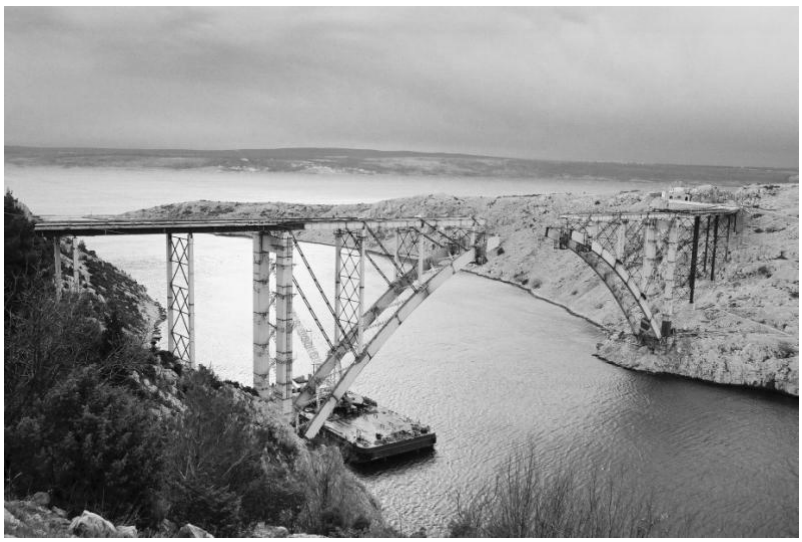
Test of the segment of the arch rib was conducted by Fuzhou University.

STARI MASLENIČKI MOST



Čelični mostovi

STARI MASLENIČKI MOST



ZAVOD ZA KONSTRUKCIJE - KATEDRA ZA MOSTOVE

STARI MASLENIČKI MOST



MOST *XIALAO*, KINA, 1996.





MOST CHUN'AN NANPU, KINA, 2003.





ZAVOD ZA KONST