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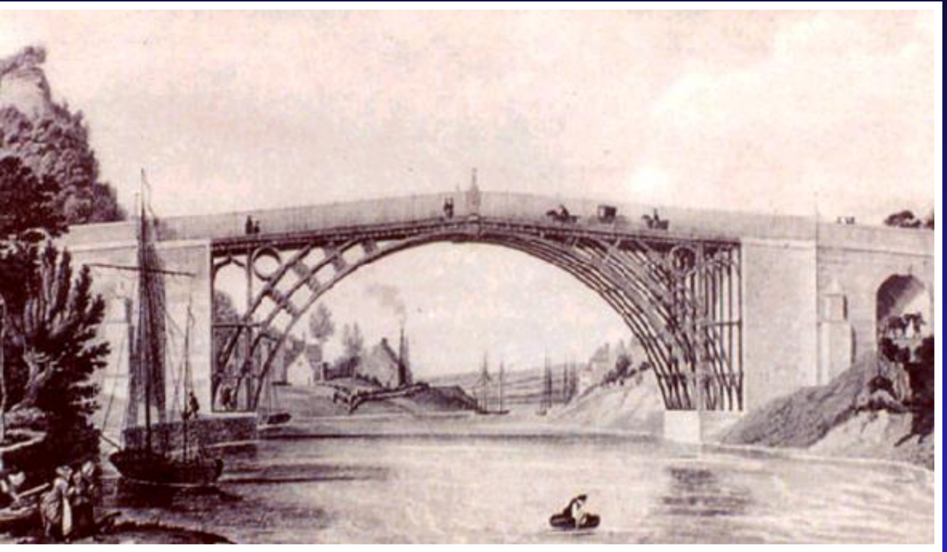
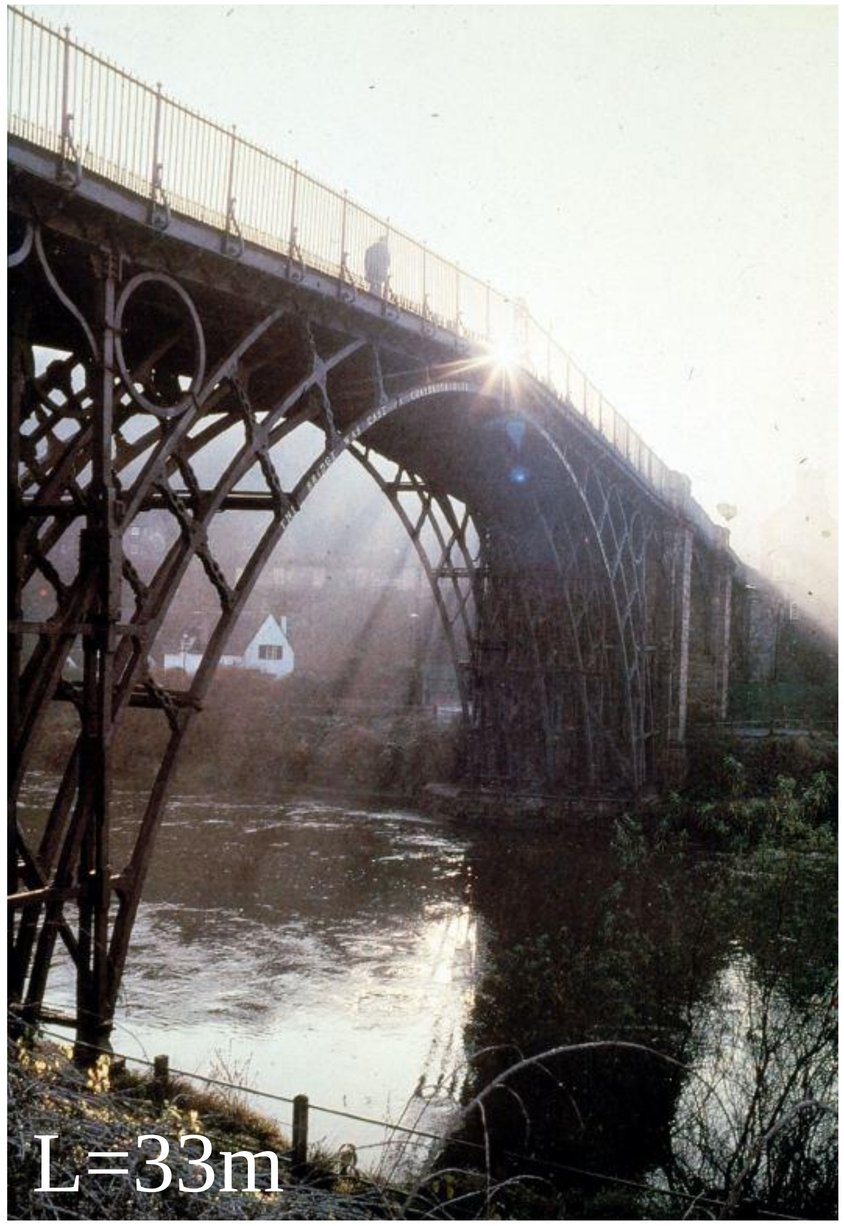
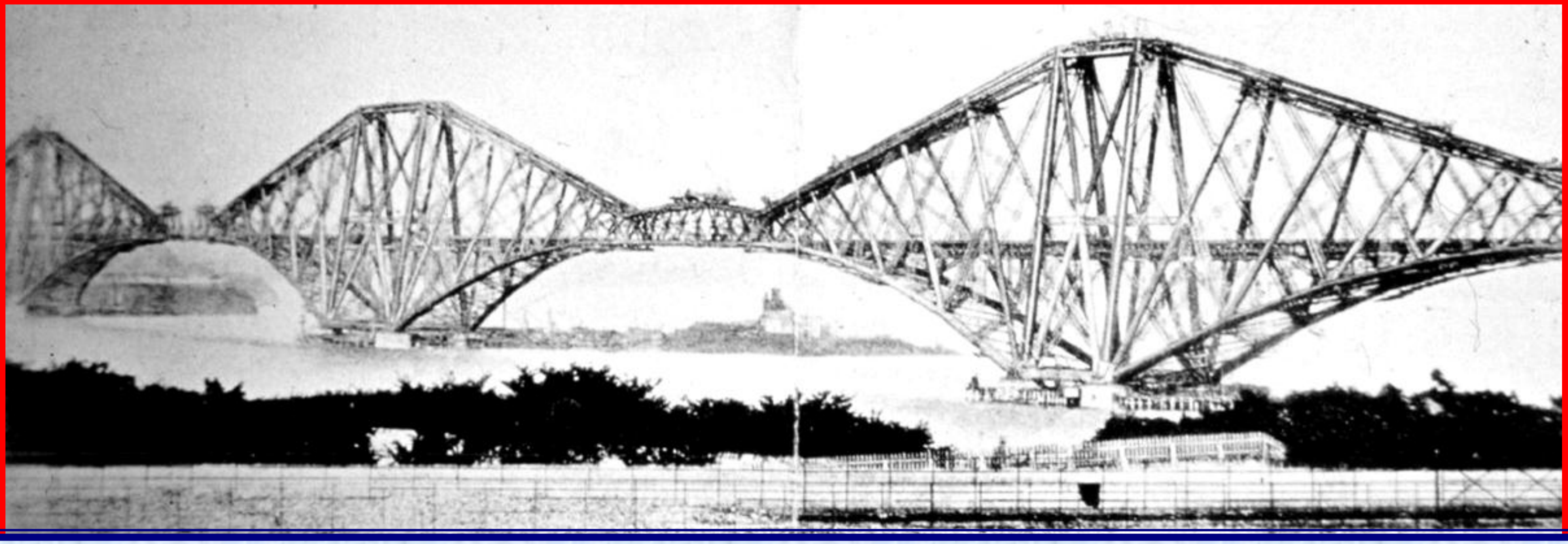
STRUCTURAL RESTORATION OF 19th CENTURY BRIDGES

THE OLDEST IRON BRIDGE (1779): COALBROOKDALE ON SEVERN RIVER (U.K.)

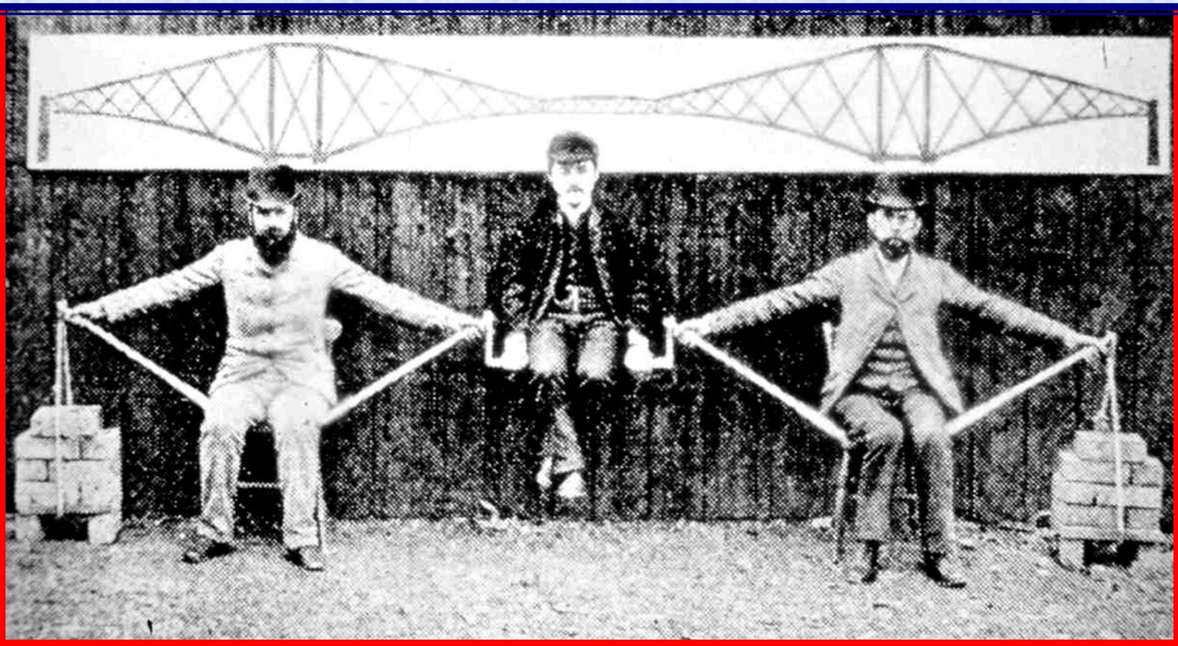




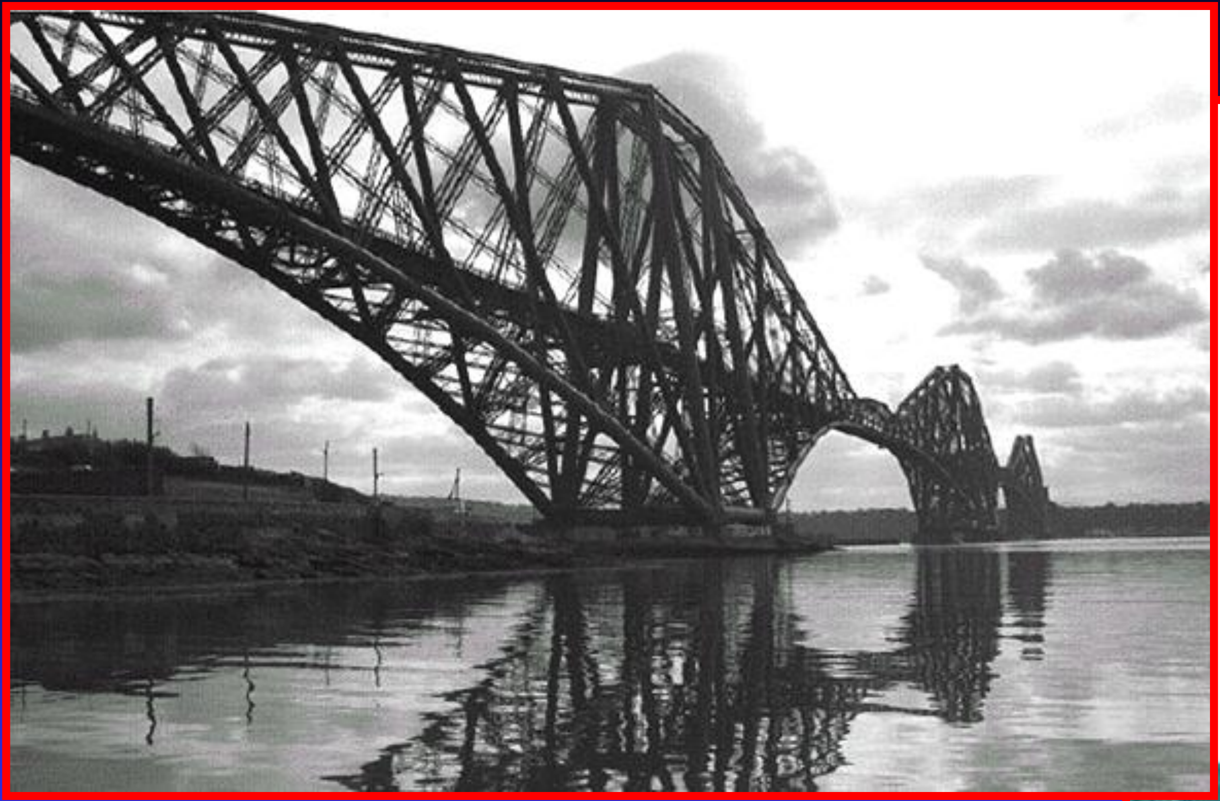
THE STRUCTURAL CHALLENGE OF STEEL BRIDGES



THE GERBER SCHEME OF THE "FIRTH OF FORTH" BRIDGE



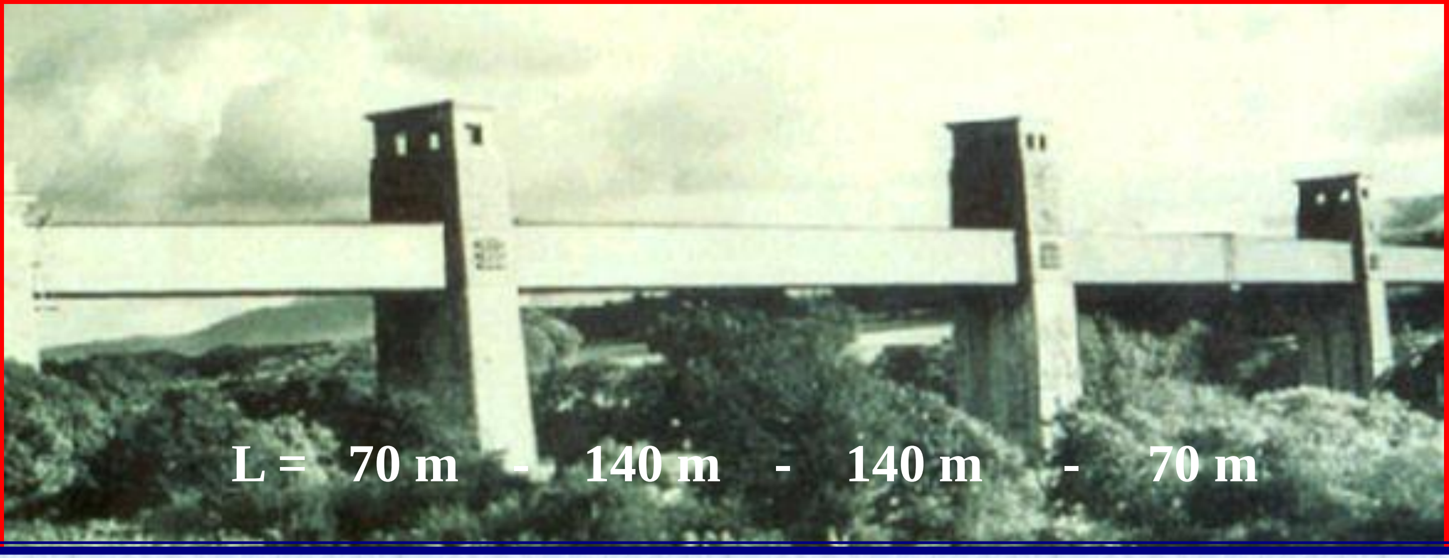
THE STRUCTURAL CHALLENGE OF STEEL BRIDGES



FIRTH OF FORTH BRIDGE (1889)

L=521 m

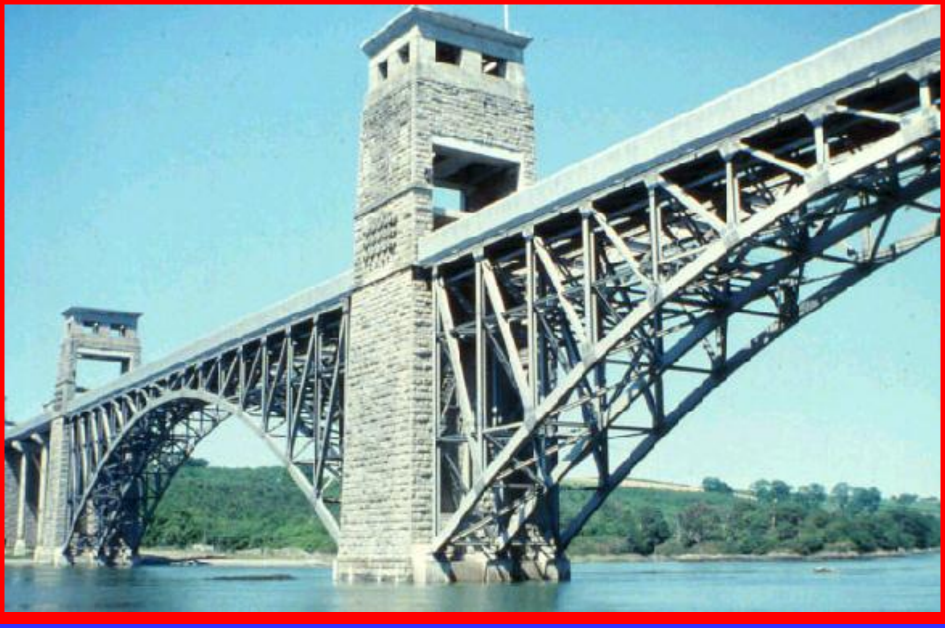
THE STRUCTURAL CHALLENGE OF STEEL BRIDGES



(1846 – 1895)

THE BRITANNIA TUBOLAR BRIDGE (R.Stephenson)

AFTER THE FIRE OF 1970



THE DEVELOPMENT OF METALLURGY

1400 a. C. - 1100 d.C. **Preistoria**	XII secolo **La ghisa**	1400 **Ricottura**

2300 anni

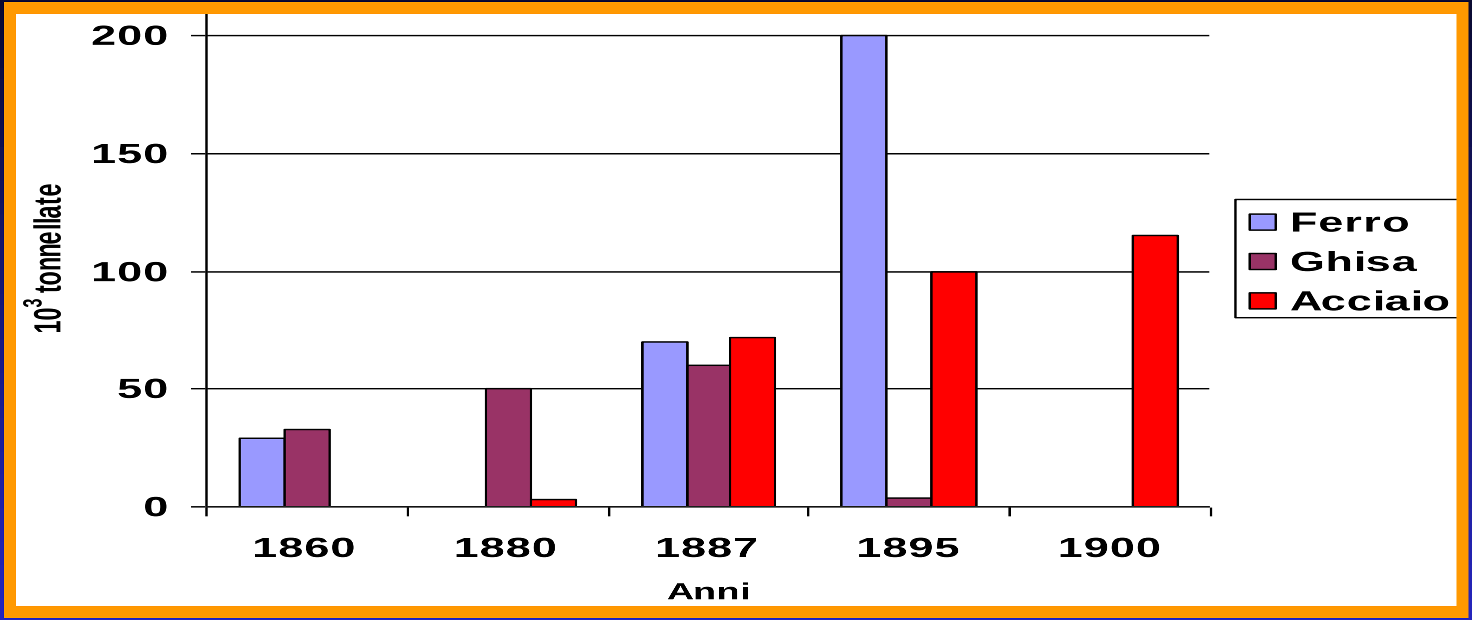
1730 **Carbon-Coke**	1740 **“Altoforno”**	1782 **Puddellaggio**

60 anni

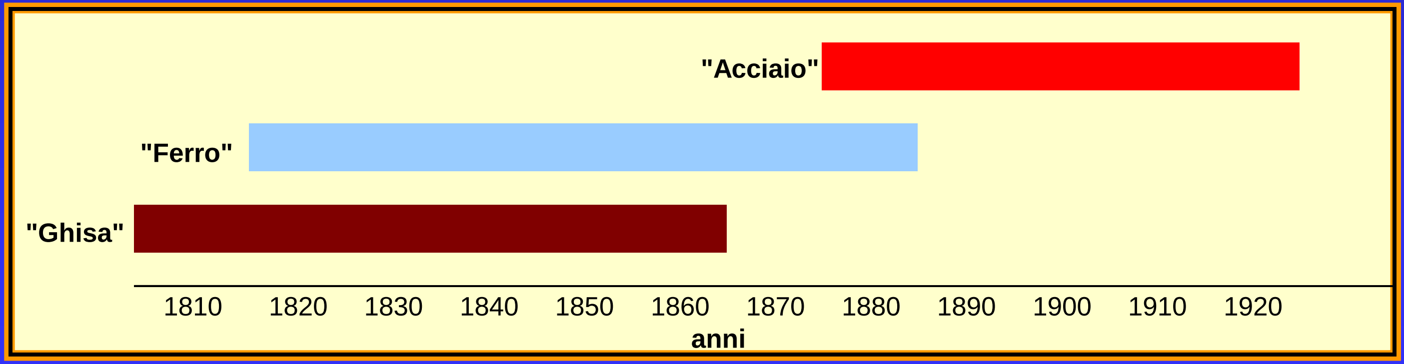
1857 **Bessemer**	1861 **Martin-Siemens**	1878-1889 **Thomas-Héroult**

30 anni

PRODUCTION OF METALLIC MATERIALS IN 19th CENTURY



Produzione annua italiana di metallo lavorato



Utilizzo dei metalli lavorati nel campo delle costruzioni civili

PROPERTIES OF METALLIC MATERIALS OF 19th CENTURY

Classificazione / Denominazione	F.P. Boubée 1880	Encicl. dell'Ingegnere 1892	L.V. Rossi 1913	G.A. Breymann 1925
Ferro dolce	fino a 0.5%	da 0.05% a 0.2%	fino a 0.05%	fino a 0.5%
Acciaio	da 0.5% a 1.5%		da 0.05% a 1.5%	da 1.5% a 2.0%
Ghisa	da 2.5% a 5.0%		da 1.5% a 6.0%	da 2.5% a 5.0%

Quadro sinottico dell classificazione dei materiali metallici in base al tenore di carbonio

Caratteristiche / Materiale	E N/mm^2	f_y N/mm^2		f_u N/mm^2		τ_u N/mm^2	γ kg/mm^3
		Trazione	*Compressione*	*Trazione*	*Compressione*		
Ghisa	98100	74	147	123	735	196	7,207
Ferro battuto	196200	137	137	392	343	343	7,788
Ferro laminato	171675	137	137	343	294	-	7,788
Filo di ferro	196200	235	-	637	-	-	7,844
Acciaio fuso	269775	593	-	981	-	735	7,83-7,92
Acciaio cementato	220725	265	-	735	-	490	7,26-780

Proprietà meccaniche dei materiali metallici secondo Breymann (1877)

PROPERTIES OF METALLIC MATERIALS OF 19th CENTURY

Materiale	Qualifica (Caratteristiche)	E N/mm^2	f_u N/mm^2 Trazione	f_u N/mm^2 Compressione	f_y N/mm^2 Trazione	f_y N/mm^2 Compressione
Ghisa	*ordinaria*	65000	123	314	25	42
	media	88000	128	353	33	59
	ottima	118000	132	491	59	73
Ferro laminato	*qualità 1*	105000 - 131000	294	245	89	83
	qualità 2	154000 - 171000	343	294	120	118
	qualità 3	170000 - 183000	373	353	155	141
	qualità 4	183000 - 193000	442	392	160	155
	qualità 5	201000 - 222000	540	442	210	222
Acciaio	*dolcissimo*	177000	442	412	240	196
	dolce	245000	540	520	209	221
	duro	304000	638	640	186	265
	durissimo	373000	785	883	157	324

Valori del modulo E e delle tensioni di snervamento e rottura secondo il Boubée (1892)

PROPERTIES OF METALLIC MATERIALS OF 19th CENTURY

Caratteristiche / Materiale	E N/mm^2	f_y N/mm^2 Trazione	f_y N/mm^2 Compressione	f_u N/mm^2 Trazione	f_u N/mm^2 Compression
Ghisa	73575 - 103000	-	-	117-177	687 - 785
Ferro saldabile	196200	127-167	127-167	324-392	226-275
Ferro omogeneo	210915	196 -235	196-235	353-412	245-294
Filo di ferro	196200	235	-	549	-
Acciaio	215820	245-491	245-291	441-981	275-981
Filo di acciaio	-	-	-	1128	-

Valori del modulo E e delle tensioni di snervamento e rottura secondo il Breymann (1925)

Alfredo Cottrau

(estratto dal “Monitore delle Strade Ferrate “ del 2 maggio 1883) :

- ………Ed in quanto alla sostituzione dell’acciaio al ferro (quistione che non sembrami ancora risolta , per la incertezza dei coefficienti di resistenza e di elasticità , dipendente dalla difficoltà , tuttora esistente , di produrre dell’acciaio di qualità costante ed omogenea) , ……………………………

PROPERTIES OF METALLIC MATERIALS OF 19th CENTURY

Propr. Mecc. / Denominazione	f_u N/mm^2	f_y N/mm^2	ε %
Ferro *Ferro agglomerato*	314	147	7
Acciaio *Ferro omogeneo*	589	245	15

Proprietà meccaniche dei materiali ferrosi
Capitolato Generale del 1887)

Quadro normativo vigente in Italia nel 1887

Tipologia strutt. / Materiale	Travi principali Briglie	Parti soggette a taglio	Parti compresse
	σ_{amm} N/mm^2	τ_{amm} N/mm^2	σ_{amm} N/mm^2
Ferro (Ferro agglomerato)	59	49	39
Acciaio (Ferro omogeneo)	98	79	59

Tensioni ammissibili nelle diverse parti strutturali
(Capitolato Generale del 1887)

PROPERTIES OF METALLIC MATERIALS OF 19th CENTURY

Quadro normativo vigente in Italia nel 1890

Propr. Mecc. / Denominazione	f_u N/mm^2	f_y N/mm^2	ε %
Ferro *Ferro agglomerato*	333	157	18
Acciaio *Ferro omogeneo*	412 - 471	196	18 - 24

Proprietà meccaniche dei materiali ferrosi (Capitolato Generale del 1890)

PROPERTIES OF METALLIC MATERIALS OF 19th CENTURY

Quadro normativo vigente in Italia nel 1893

Caratt. meccaniche / Tipologie strutturali	*Ferro saldato*			*Ferro colato*		
	R kg/mm^2	λ %	R x λ	R_{min} kg/mm^2	R_{max} kg/mm^2	$(R \times \lambda)_{min}$
Lamiere e profilati:						
in senso longitudinale	33	9	400	38	46	920
in senso trasversale	28	3	100	38	46	780
Tondini per chiodi e chiavarde	36	16	700	36	40	1100

Caratteristiche meccaniche dei material ferrosi (Regolamento del 1893)

THE ALLOWABLE STRESSES AND SAFETY FACTORS FOR METALLIC MATERIALS OF 19th CENTURY

	Compressione	Flessione/Trazione
Ferro	4	8
Ghisa	4	6
Acciaio	3	3

Coefficienti di sicurezza (Boubée, 1892)

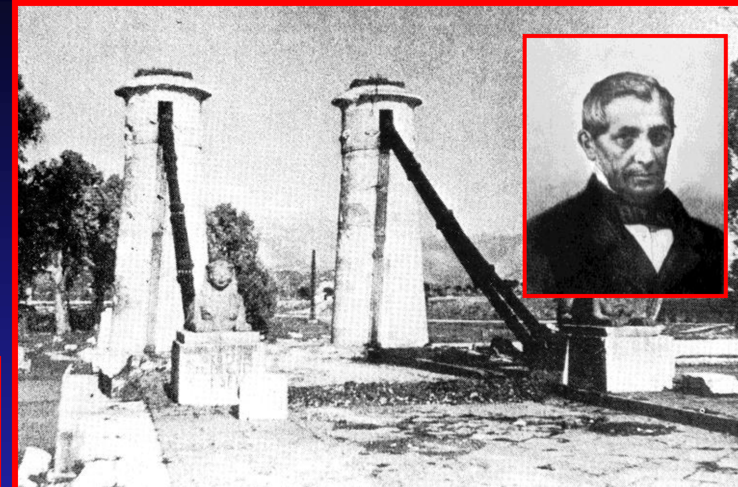
	Trazione kg/mmq	Compressione kg/mmq	Flessione kg/mmq	Schiacciamento kg/mmq	Cesoiamento kg/mmq
Ghisa	2	4	-	-	-
Ferro	6	5	6	3,5	4,5
Acciaio	12	8	12	-	8 - 10

Tensioni di esercizio raccomandate (Boubée, 1892)

THE MAIN BRIDGES OF 19th CENTURY IN ITALY

Ponte nel giardino di Villa Treves (Padova). G. Jappelli, 1827

Ponte sul Garigliano Luigi Giura, 1829



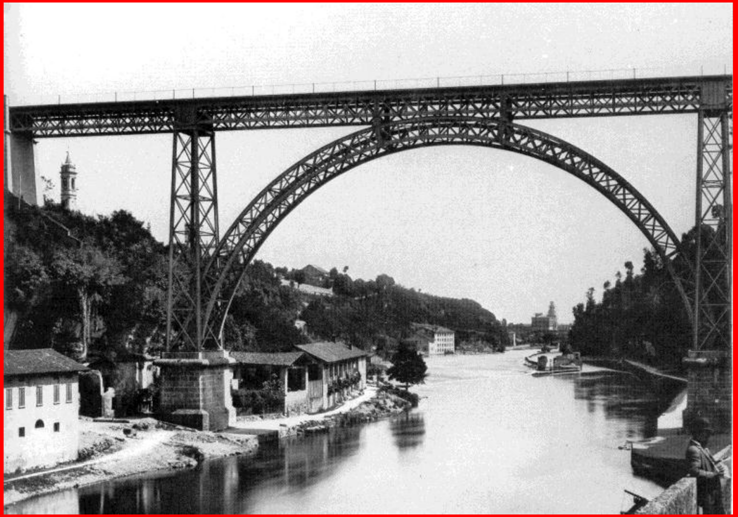
Ponte della ferrovia Pio-Latina presso Velletri. O. Yorck, 1862

Ponte dell’Industria a Roma. L. Hack, 1863

Pile del ponte Pio-Latino oggi, sovrastate dal nuovo impalcato e affiancate dalle nuove pile in c.a.

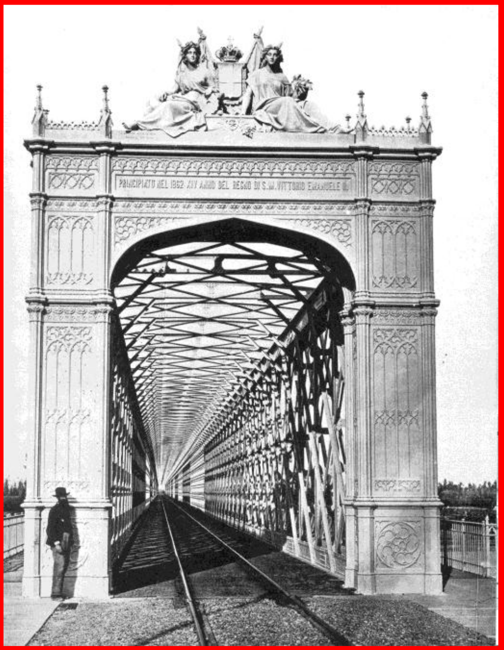
THE MAIN BRIDGES OF 19th CENTURY IN ITALY

Ponte di Piacenza. Impresa Parent, Schaken e Caillet, 1865



Ponte di Trezzo d'Adda (demolito)

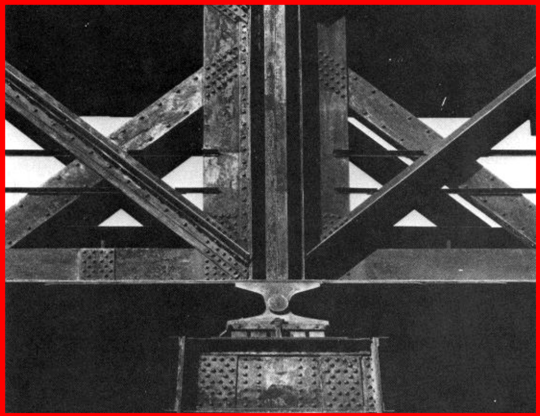
J. Rothlisberger, 1884

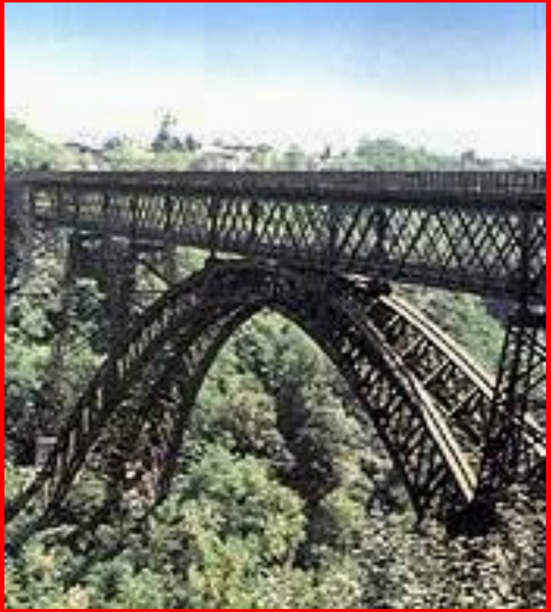


Ponte di Piacenza, portale di ingresso. A. Biella, 1865.

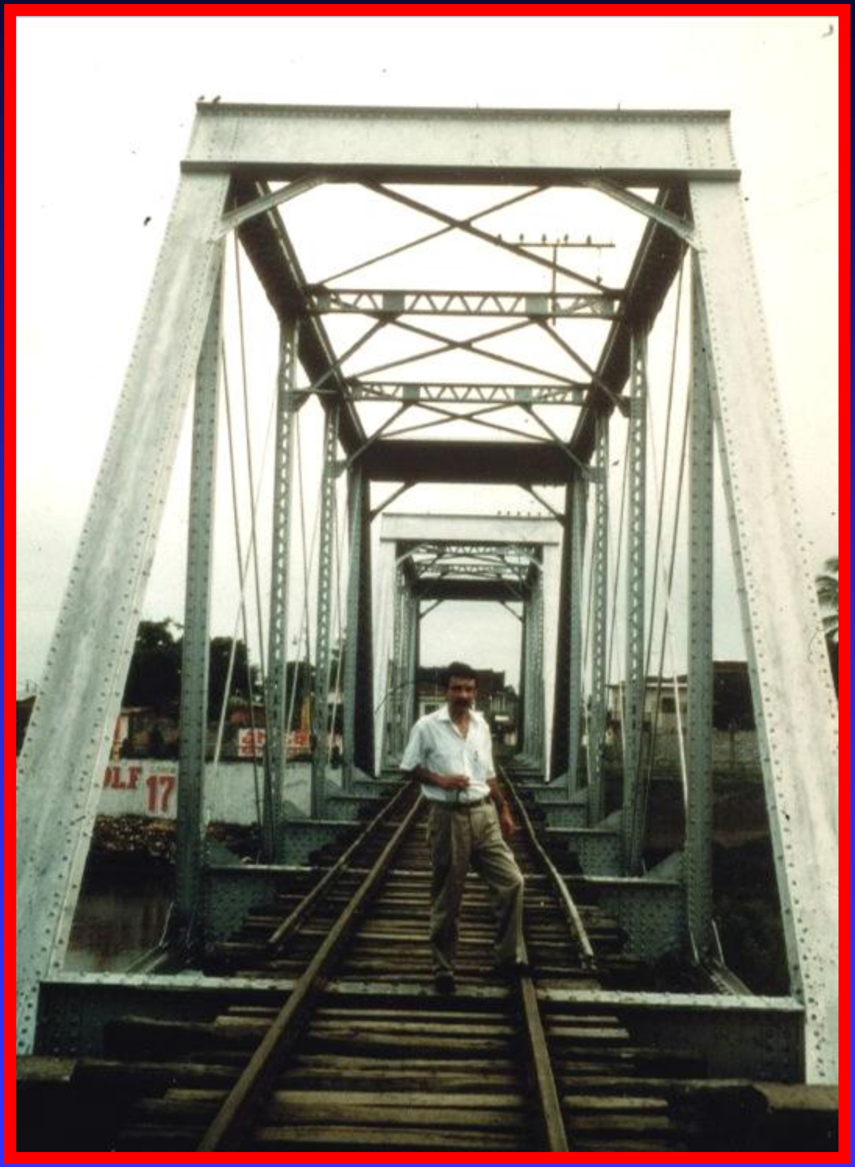
Ponte di Paderno sull'Adda.

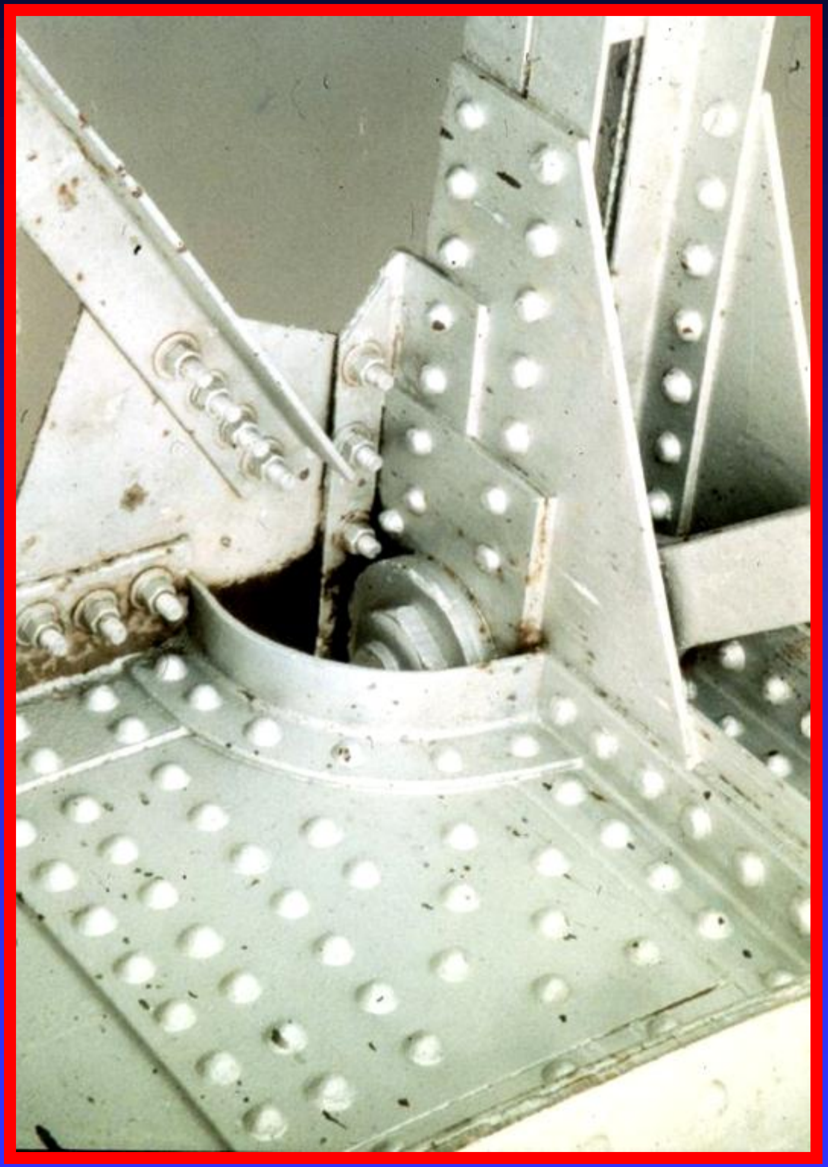
G. Rothlisberger, 1887





PROBLEMS IN STRUCTURAL RESTORATION OF BRIDGES





Railway bridge in Guayaquil (Equador)

PROBLEMS IN STRUCTURAL RESTORATION OF BRIDGES

Long Bien bridge in Hanoi (Paul Doumer , 1902)

RAILWAY BRIDGES IN U.K.

From the beginnings of practical railways in 1830, the traditional bridge materials of stone, brick and timber, were soon joined by cast iron (Smith,2004).

The unreliable properties of cast iron in tension were brought into question when the Dee bridge at Chester, designed by Robert Stephenson, failed in 1847, dropping a train and killing five people (Rolt ,1955).

RAILWAY BRIDGES IN U.K.

A three-year Royal Commission to investigate the use of iron in railway structures followed.
The principal questions to be answered were (Anon ,1849) :
"Whether the substance of metal which had been exposed for a long period to percussions and vibration,undergoes any change in the arrangements of its particles by which it becomes weakened?",
and "What are the mechanical effects of percussion, and of the passage of heavy bodies, in the deflecting and fracturing of bars and beams upon which they are made to act?"

A series of experiments on an heroic scale, conducted by James and Dalton, were made to "ascertain the effect of subjecting iron bars to reiterated stains which correspond to loads equal to some fractional part of the breaking weight."
It was concluded, "that iron bars will scarcely bear the reiterated application of one-third that of their breaking weight without injury".

Thus the phenomenon of fatigue was identified and a crude experimental notion of what we call the fatigue limit was established. But bridges continued to be made of cast iron and existing bridges were used for many years, before being replaced by wrought iron and steel constructions.

RAILWAY BRIDGES IN U.K.

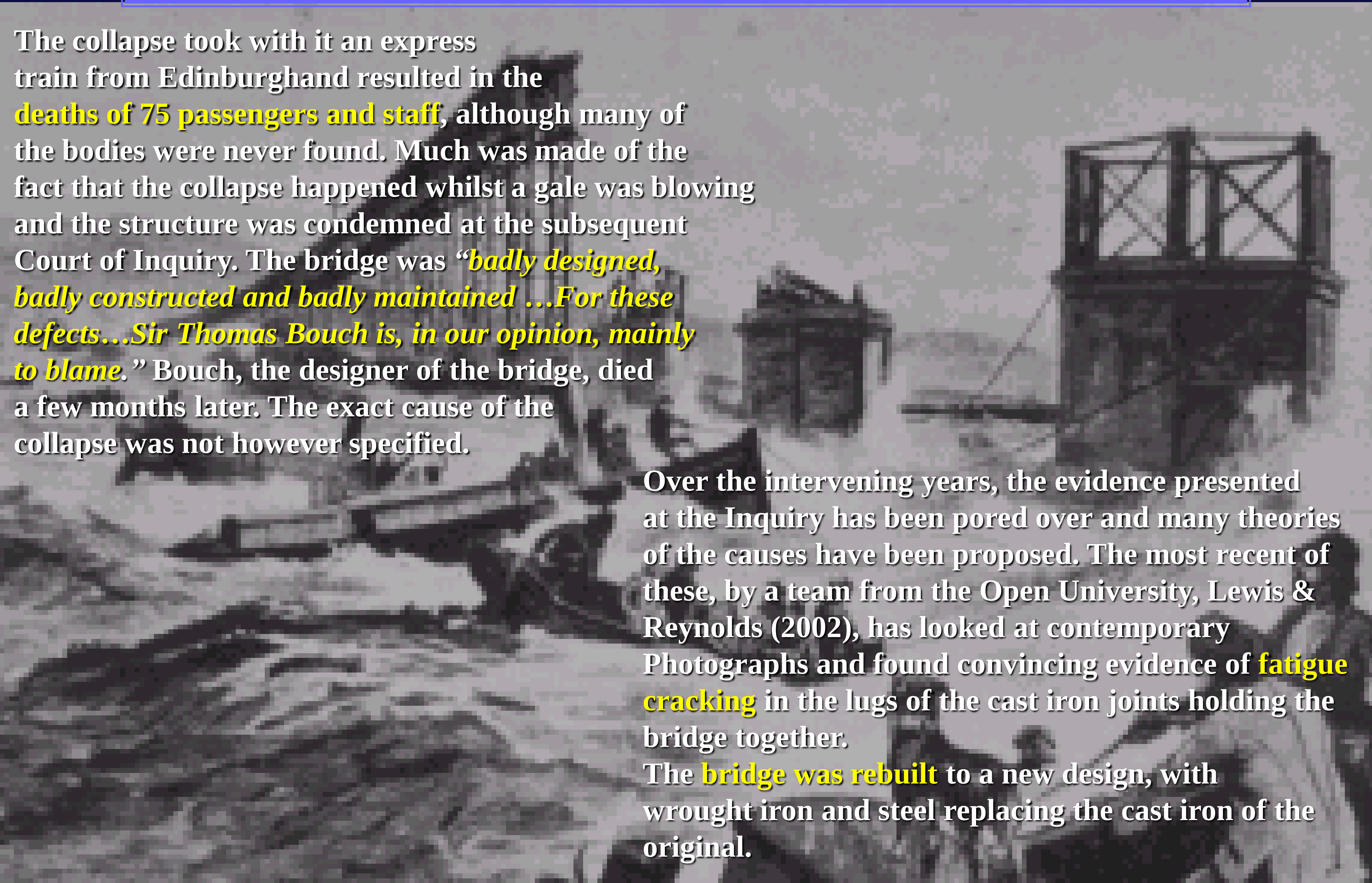
Many examples of the failure of railway bridges could be quoted.
Usually these accidents caused few deaths or injuries, despite their often spectacular appearance.
It is the case of the bridge failure at Hereford in 1858,the first known photograph of a railway accident.

RAILWAY BRIDGES IN U.K.

The greatest disaster to befall Victorian engineering was the failure of the Tay Bridge in 1879, unique amongst British railway accidents to this day in that there were no survivors.

This failure still retains the dubious distinction of being the worst structural failure to have occurred in Britain in terms of both lives lost and the size of the failed structure. On the wild and stormy night of 28 December 1879,the central part of the two mile long Tay Bridge, at the time the longest in the world, collapsed leaving a gap of well over half a mile (almost exactly one kilometer). (Rolt , 1955).

RAILWAY BRIDGES IN U.K.



The collapse took with it an express train from Edinburghand resulted in the deaths of 75 passengers and staff, although many of the bodies were never found. Much was made of the fact that the collapse happened whilst a gale was blowing and the structure was condemned at the subsequent Court of Inquiry. The bridge was *"badly designed, badly constructed and badly maintained …For these defects…Sir Thomas Bouch is, in our opinion, mainly to blame."* Bouch, the designer of the bridge, died a few months later. The exact cause of the collapse was not however specified.

Over the intervening years, the evidence presented at the Inquiry has been pored over and many theories of the causes have been proposed. The most recent of these, by a team from the Open University, Lewis & Reynolds (2002), has looked at contemporary Photographs and found convincing evidence of fatigue cracking in the lugs of the cast iron joints holding the bridge together.

The bridge was rebuilt to a new design, with wrought iron and steel replacing the cast iron of the original.

RAILWAY BRIDGES IN U.K.

In May 1891, a bridge near Norwood Junction on the London, Brighton and South Coast Railway, (LBSCR) collapsed as a train was passing over it, Rolt (1955).Fortunately, although the train was derailed, it cleared the bridge, with only the rearmost guard's van falling into the gap. The report of the Board of Trade inspector, pointed out yet again the problems with cast iron:

"The cast iron girder which failed on this occasion had been in place for about thirty-one years, and during the whole of this time had had concealed in the interior of the web and the outer part of the flange, a very serious flaw, abstracting at least one-fourth from the strength of the girder. This flaw was invisible even to careful inspection, nor was it visible when the girder was cast…"

Furthermore, he was of the opinion that even if the girder had been perfectly sound, its margin of safety was insufficient for the weight of the locomotives then using the line (it is well for us to remember the tremendous increase in size and power of locomotives in the period encompassing the thirty years before this accident).

He urged the replacement of cast by wrought iron or steel girders on bridges throughout the railway system.

The press were vociferous in backing up this call, see the cartoon appeared in Punch.

The railway companies, so parsimonious in safety expenditure in the past, found this very pressure hard to resist and the results were far reaching. The (LBSCR) replaced twenty of its bridges within a year and a further sixty thereafter. Other railways followed: for example, on the Midland Railway some 180 cast iron bridges were replaced.

At last the railways seemed to have learned, through long and sometimes bitter experience, the lessons from these accidents and thereafter built better designed and stronger structures from improved materials. In this way gross failures due to inadequate strength became a rarity in the twentieth century.

ON THE BRIDGE!

RAILWAY BRIDGES IN U.K.

Stone, brick and wooden bridges have also had problems.

There are records of stone viaducts failing during construction, or after many years satisfactory service, like the Penistone viaduct, which collapsed in 1916, many years its construction due to water scour of the pier foundation.

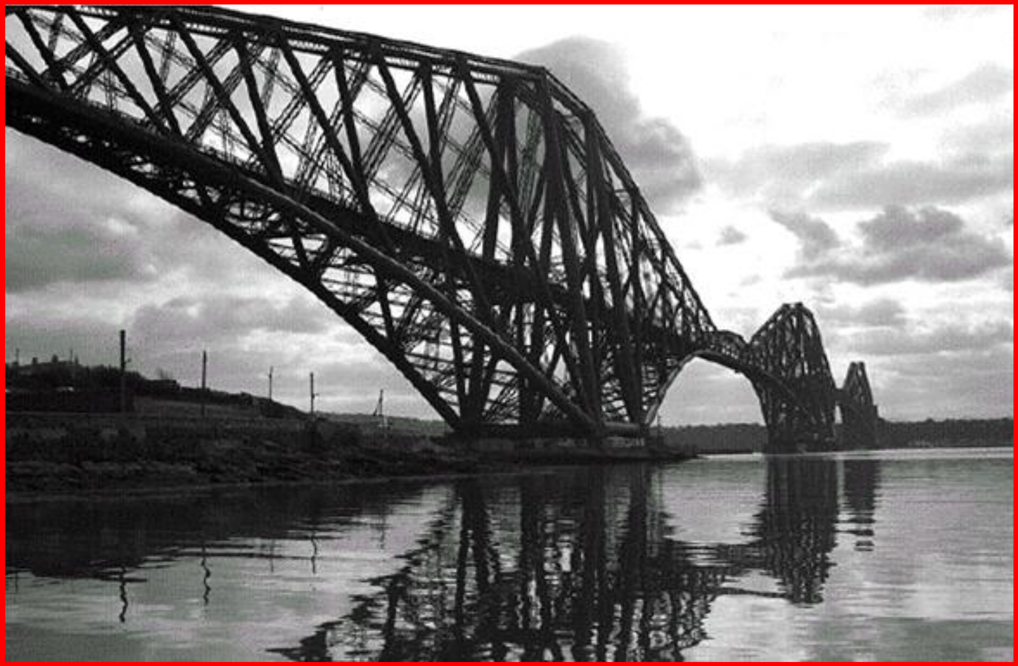
RAILWAY BRIDGES IN U.K.

Collapses were not infrequent also in case of wooden bridges and were as spectacular as the original structures,like in case of the Lonesome Gap bridge. The comments of Robert Stephenson, made much earlier (1851), are worth recalling:

"Wooden viaducts … are frequently composed of complicated wooden trussing for the purpose of obtaining the greatest amount of strength for the least consumption of material…but practice has led me to look upon it as worse than useless, for the timber is cut up into small parts and the number of joints so increased as to lead to a rapid decay in the quality of material and the firmness of the structure."

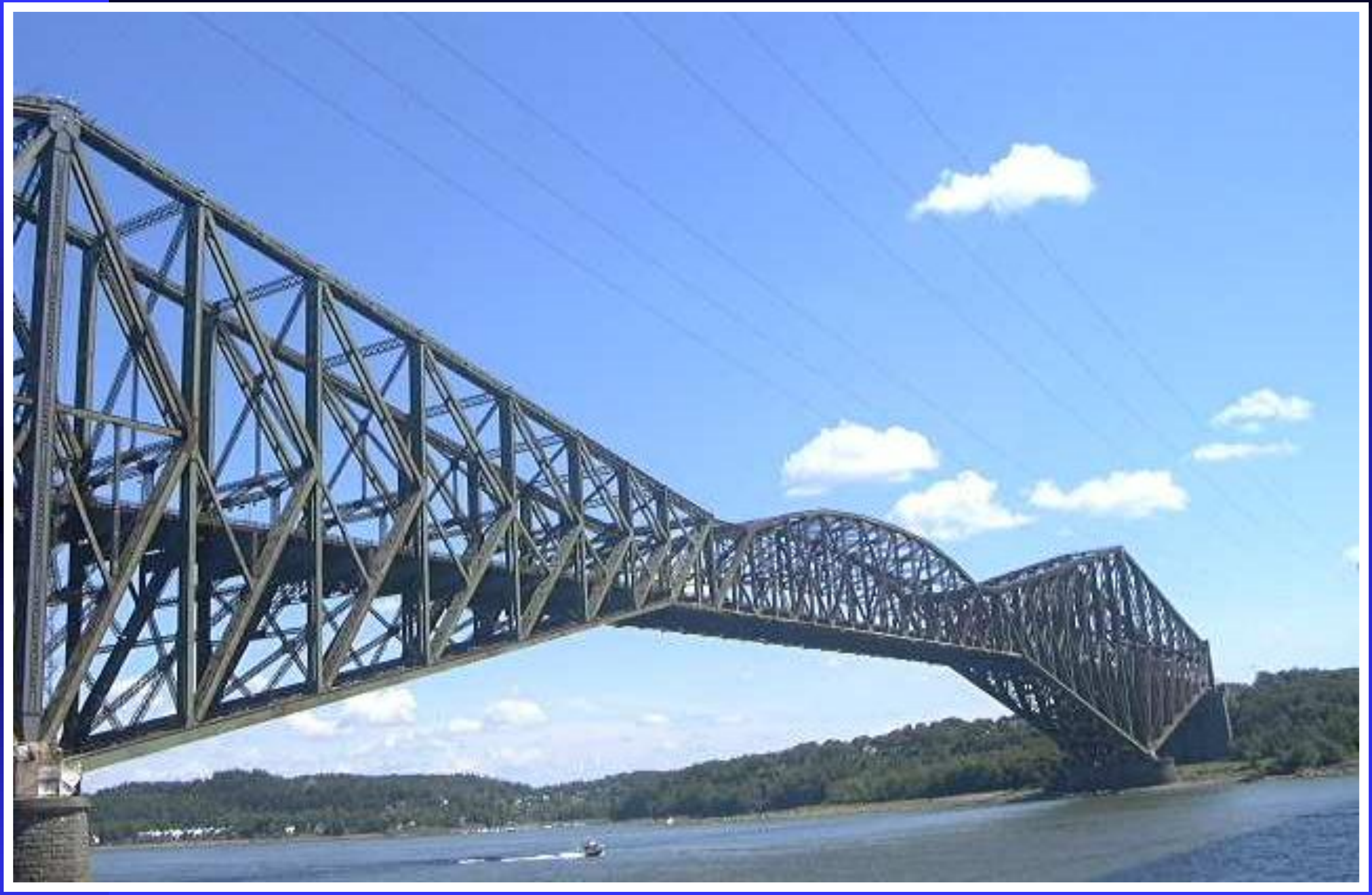
CANTILEVER BRIDGES

FIRTH OF FORTH BRIDGE (1889)



This bridge, opened in 1890, was the first major bridge in Britain to be built of steel,closely following the steel pioneering Brooklyn suspension bridge in NewYork, opened in the early 1880’s.

L=521 m



THE QUEBEC BRIDGE (CANADA, 1917 ; L = 549 m)

THE QUEBEC BRIDGE (CANADA, 1917 ; L = 549 m)

THE QUEBEC BRIDGE (CANADA, 1917 ; L = 549 m)

THE TRAGIC HISTORY OF THE ERECTION

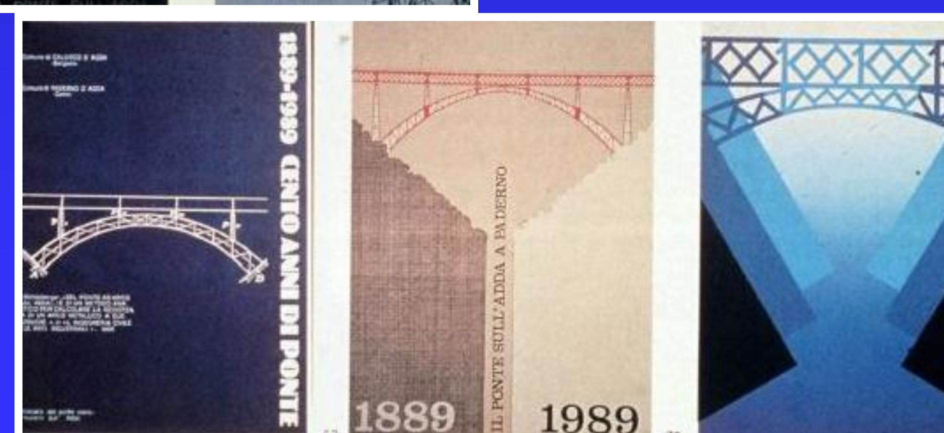
August 1907 : the bridge collapsed during erection ; 75 workers died.

The inquiry Commission stated the impossibility to erect the whole central part of the bridge with 375 m span by means of the cantilever system.

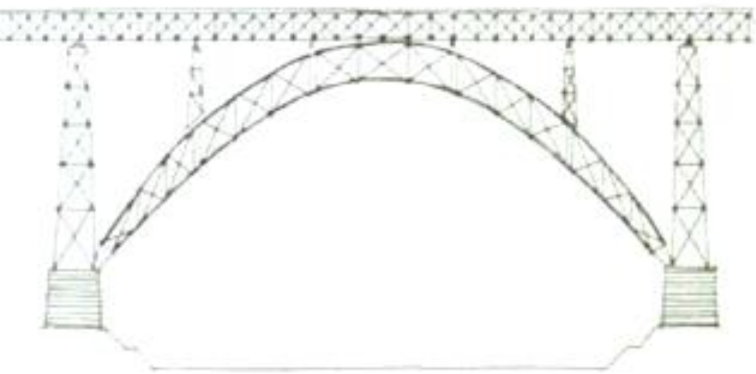
A new erection design was done based on the lifting of the whole central part of the bridge by using jacks supported on pontoons.

During the new erection , when the 2500 tons of the central part of the bridge were lifted of 4 m , the bridge collapsed into the river ; 13 workers died.

ARCH BRIDGES IN EUROPE

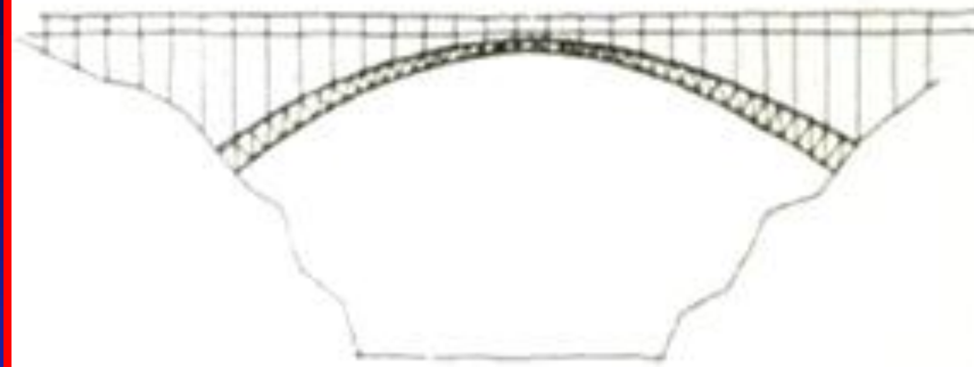


THE MAIN ARCH BRIDGES IN EUROPE

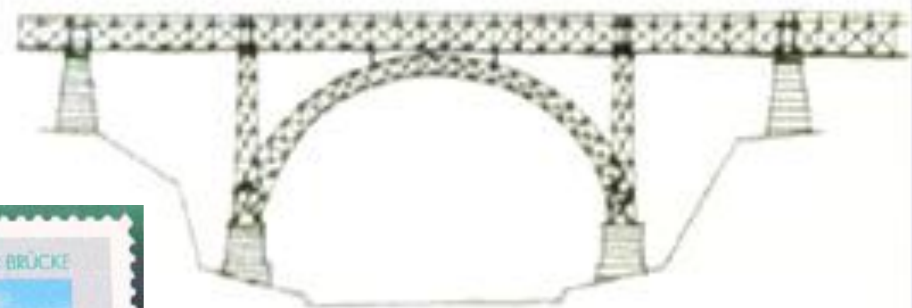


Garabit (1884) luce 165 m

Paderno d'Adda (1889) luce 151 m

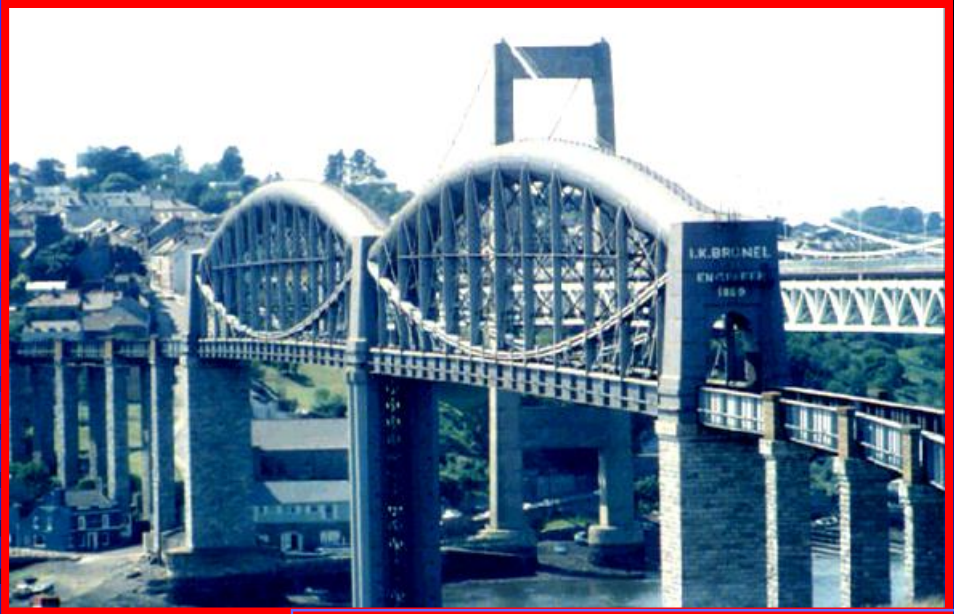


Schwarzwasser (1882) luce 114 m



zo sull'Adda (1886) luce 62,5 m

AN OLD IRON BRIDGE IN PADUA (ITALY)

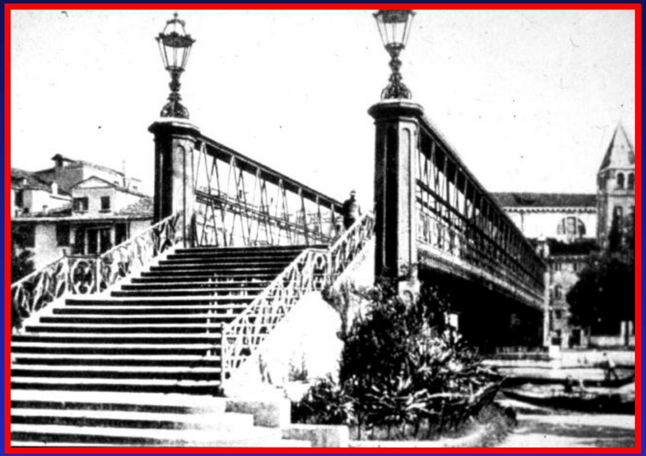


Arch-suspension combined system (I.K.Brunel)

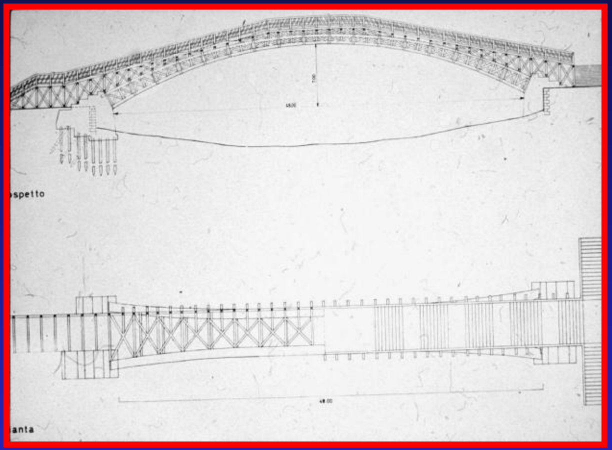
ROYAL ALBERT BRIDGE ON TAMAR RIVER (SALTASH , 1854 -1859) : in service

L = 138 + 138

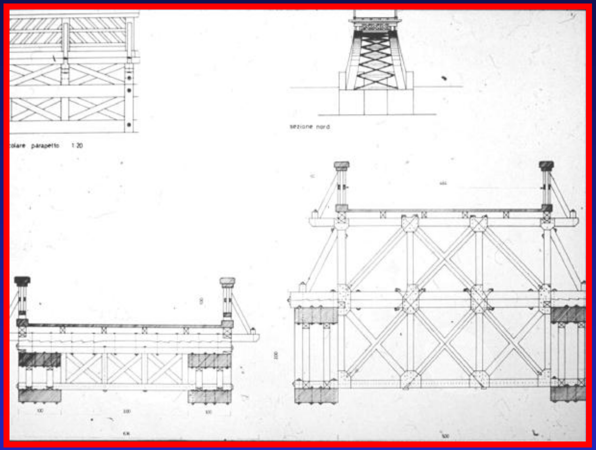
THE ACADEMIA BRIDGE IN VENICE



1.Austrian bridge (Neville,1854-1933)

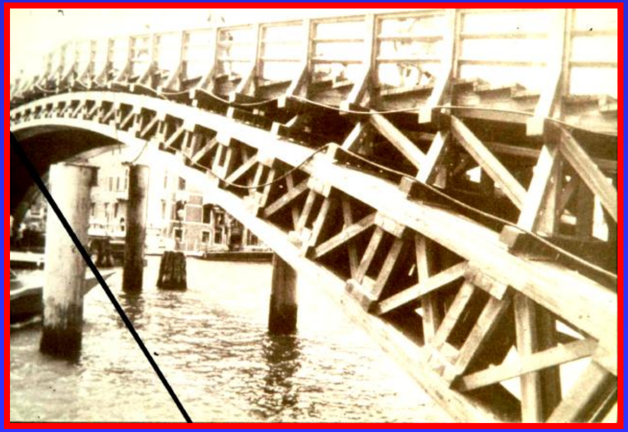


2.Provisional bridge (1933-1948)



3.Provisional bridge (1933-1948)

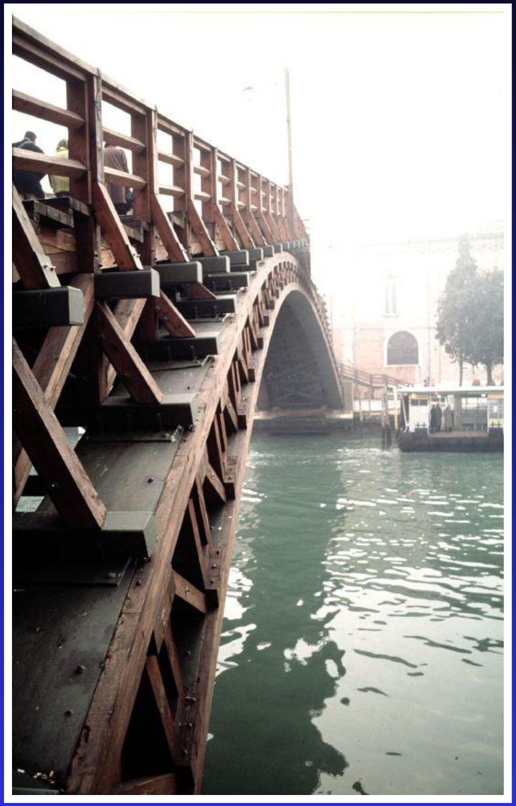
4.Provisional bridge (1933-1948)

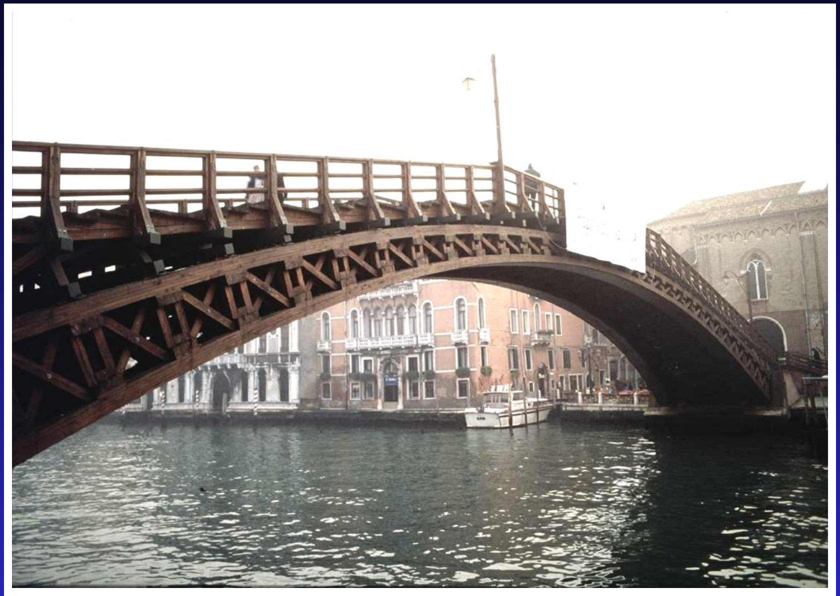


5.New provisional bridge (1948-1980)

6.Recent structural.restoration

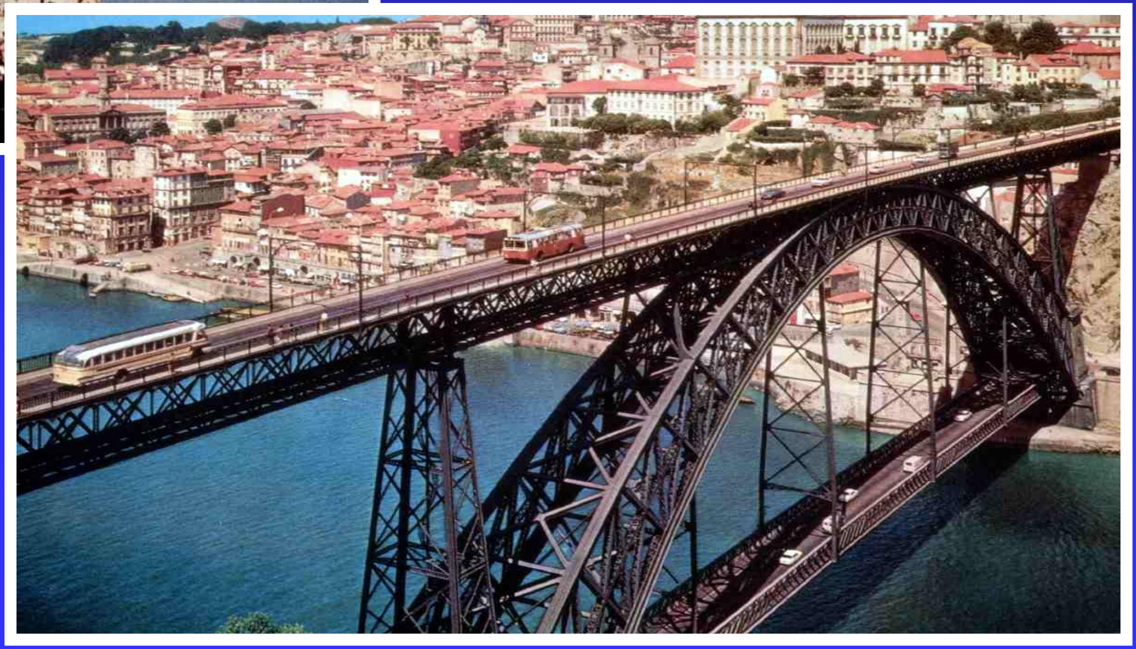
THE ACADEMIA BRIDGE IN VENICE





THE D. LUIS BRIDGE ON DOURO RIVER IN OPORTO (PORTUGAL)

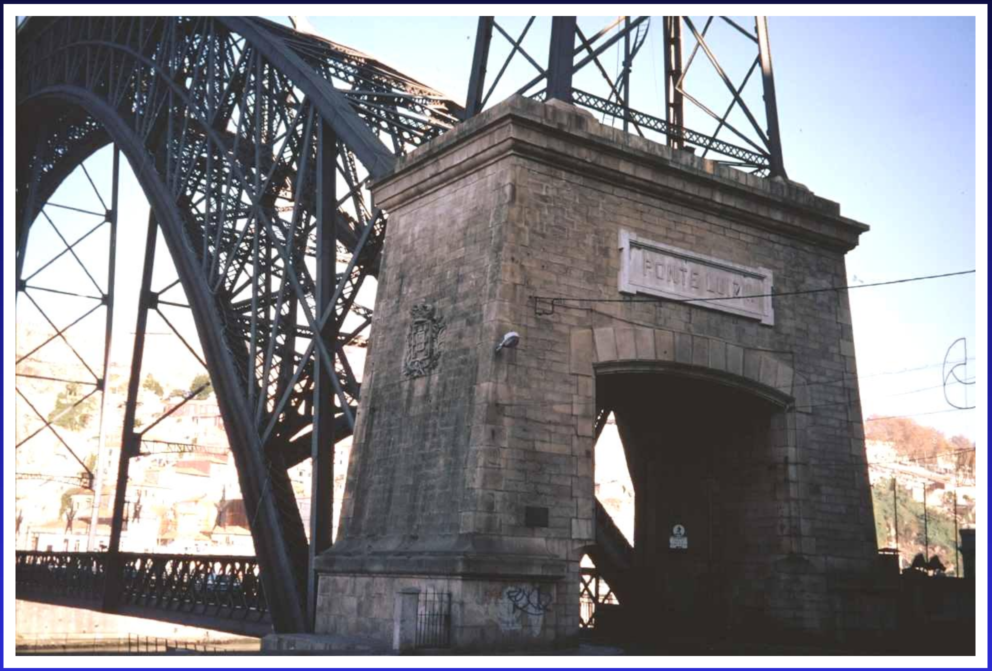
THE D. LUIS BRIDGE IN OPORTO (PORTUGAL)

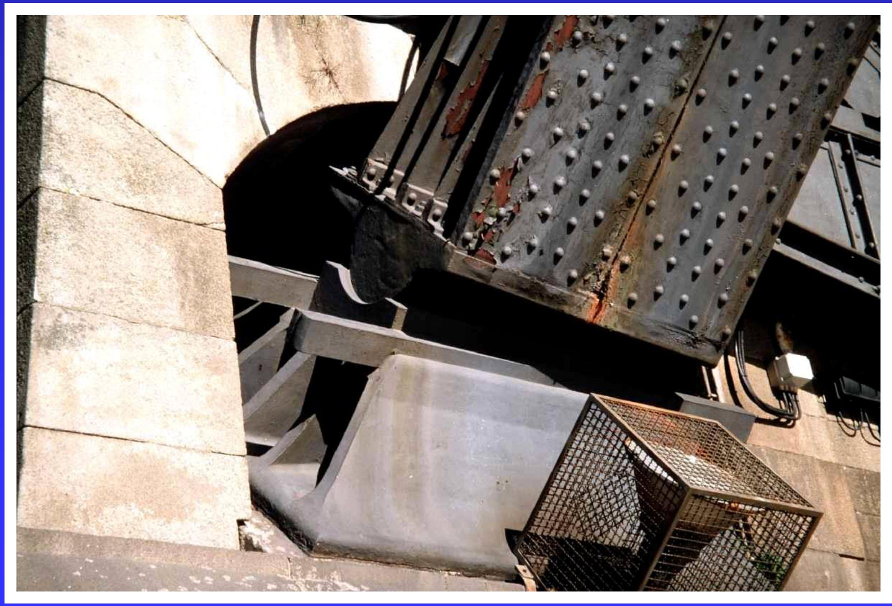


THE D. LUIS BRIDGE IN OPORTO (PORTUGAL)

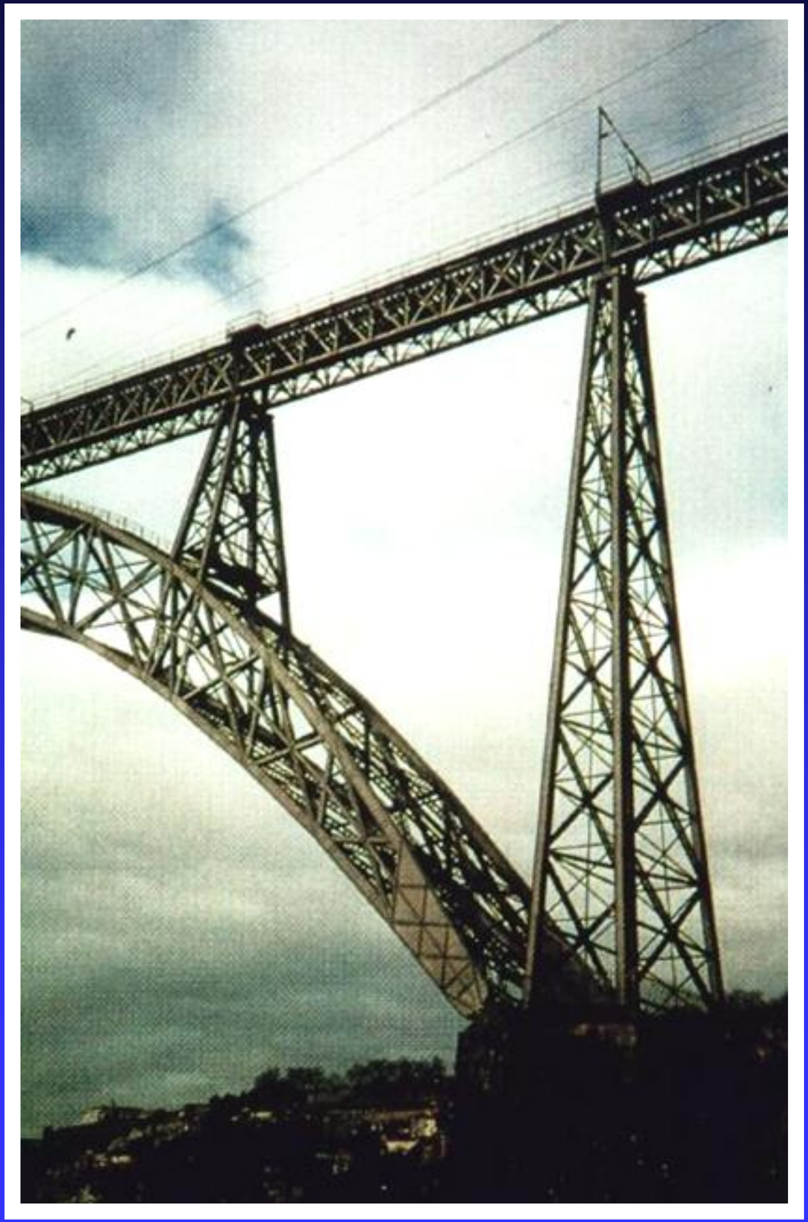
THE D. LUIS BRIDGE IN OPORTO (PORTUGAL)

THE D. LUIS BRIDGE IN OPORTO (PORTUGAL)





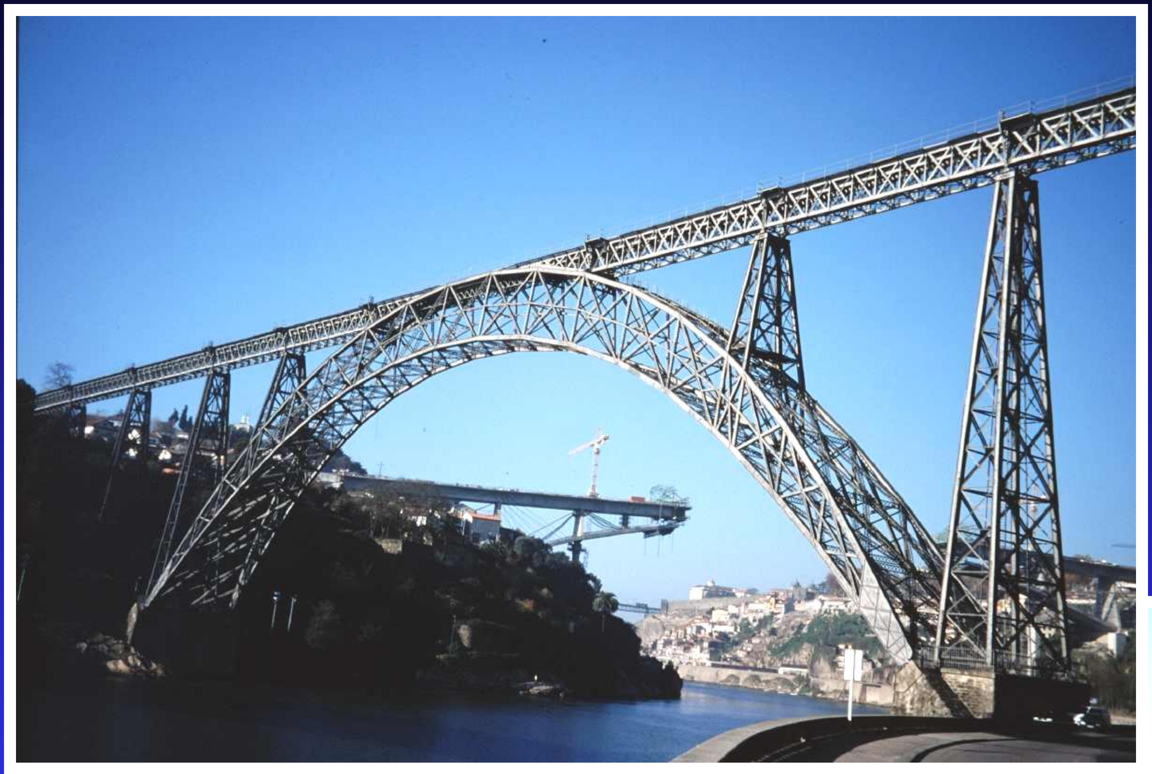
THE MARIA PIA BRIDGE IN OPORTO (PORTUGAL)

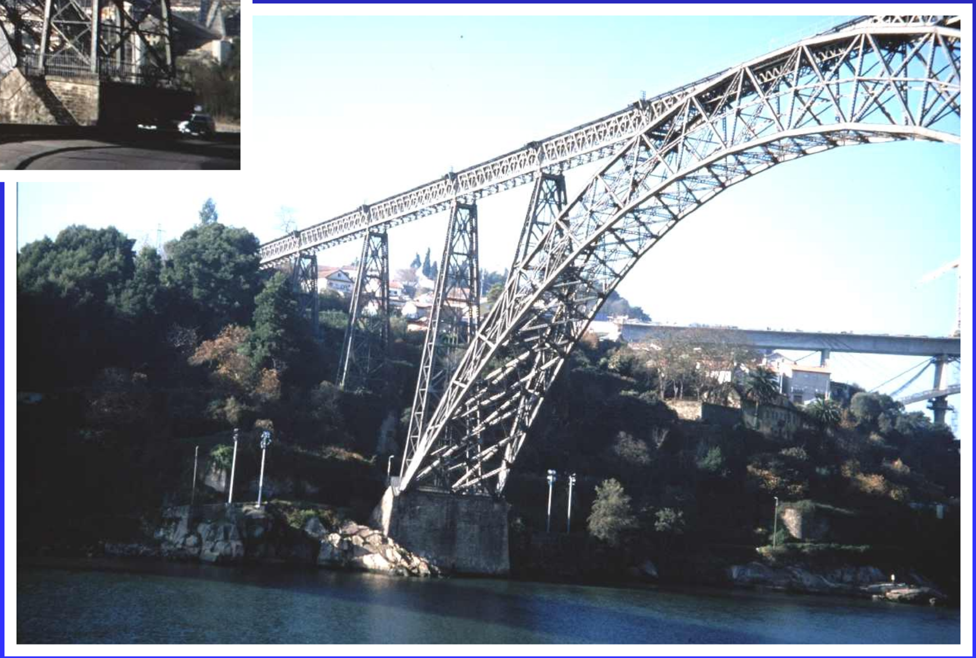


G.EIFFEL
SEYRING

(1877)

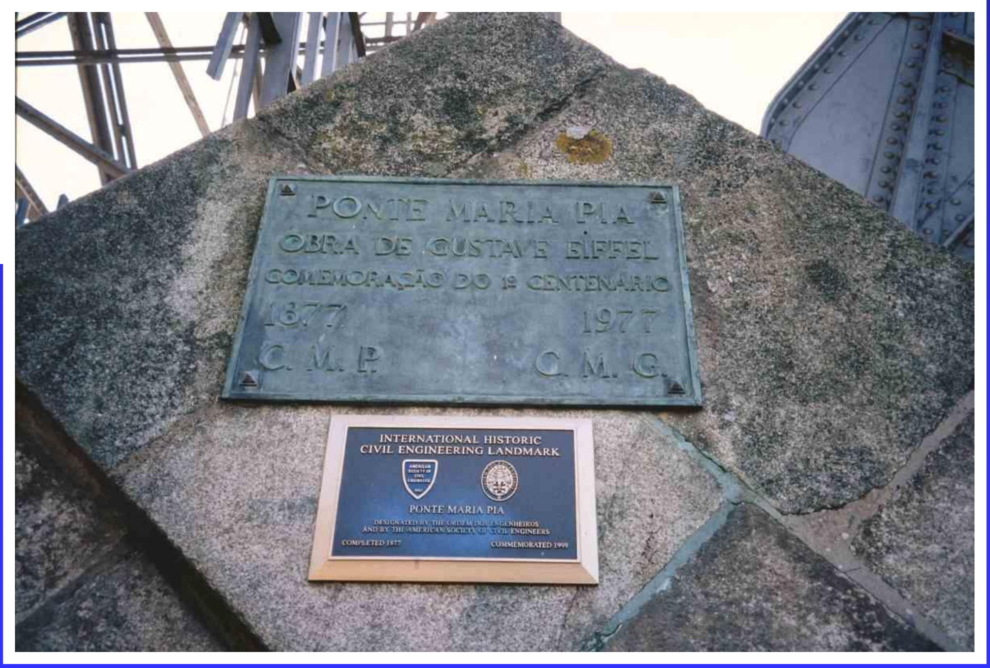
THE MARIA PIA BRIDGE IN OPORTO (PORTUGAL)



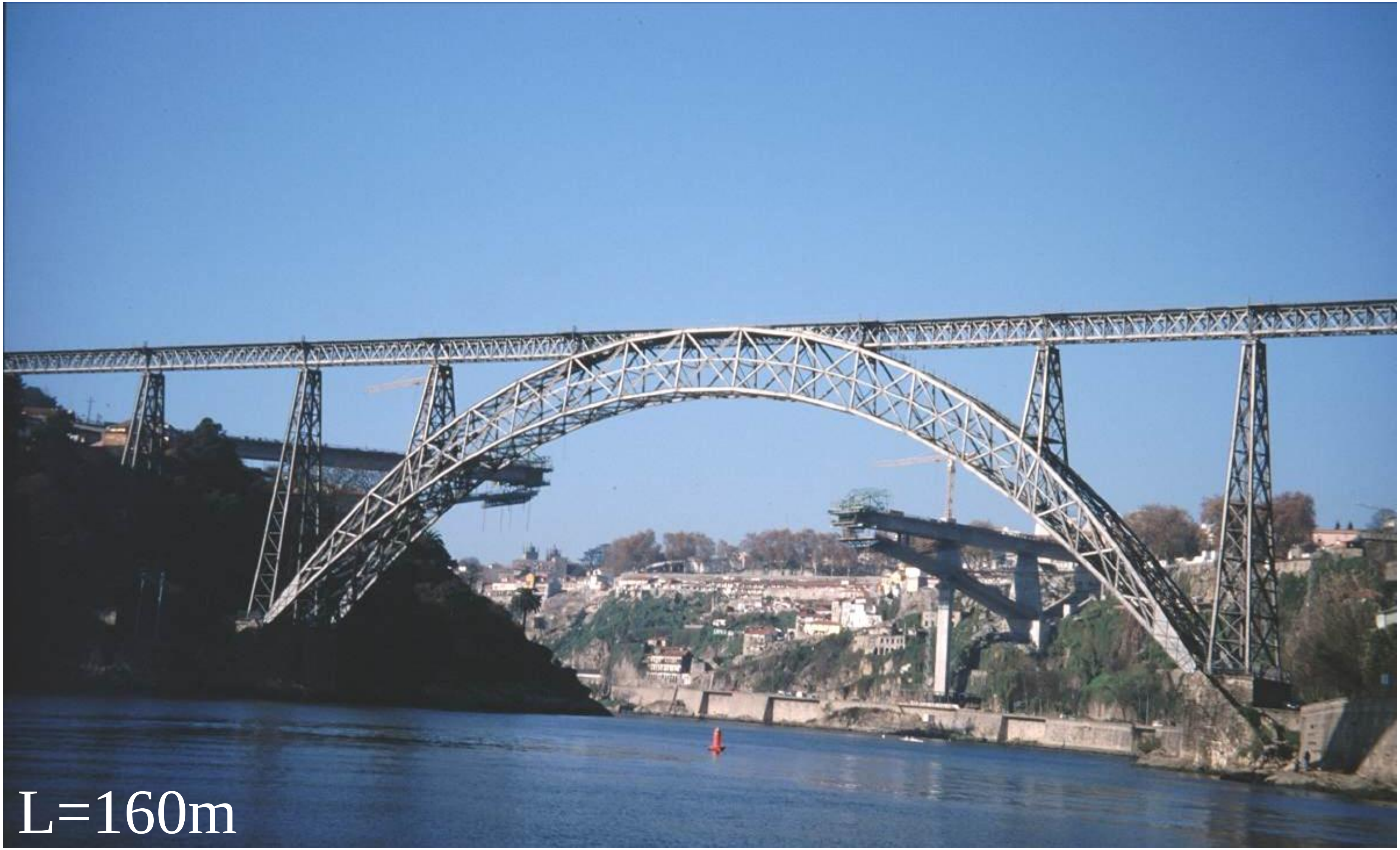


L = 160 m

THE MARIA PIA BRIDGE IN OPORTO (PORTUGAL)



THE MARIA PIA BRIDGE IN OPORTO (PORTUGAL)

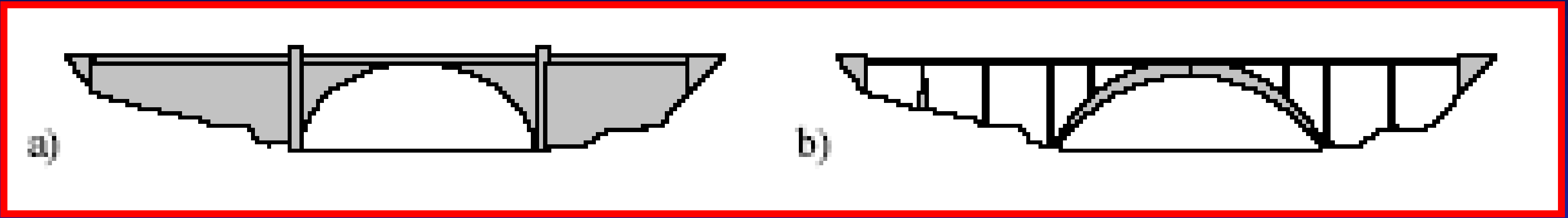


COMPARISON IN WEIGTH AMONG ARCH BRIDGES

The dead weight of the five existing bridges near the historical centre of Porto (World Heritage) are compared in the following table. The first case is remarkable, being a railway bridge which was used for more than a century until it was substituted by the S.João bridge.

Bridge - Date	Type / material	Length	Dead weight	Relative weight
D.Maria Pia - 1877	Metallic arch	400 m	1500 ton	37 kN/m
D. Luis I - 1882	Metallic arch	400 m	2900 ton	71 kN/m
Arrábida - 1966	Concrete arch	500 m	48000 ton	940 kN/m
S. João - 1991	Concrete frame	500 m	40000 ton	780 kN/m
Freixo - 1994	Concrete frame	700 m	54000 ton	760 kN/m

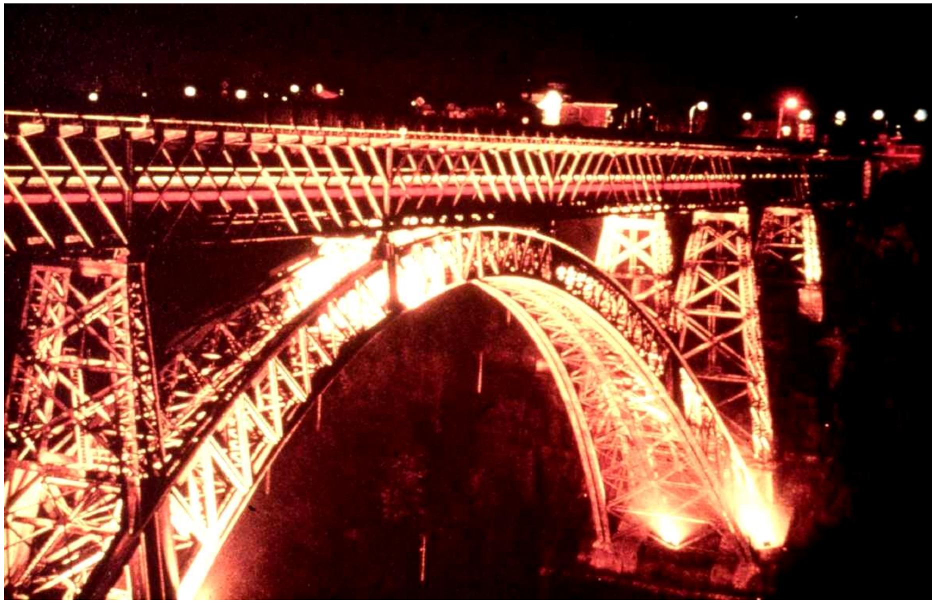
COMPARISON IN WEIGTH AMONG ARCH BRIDGES



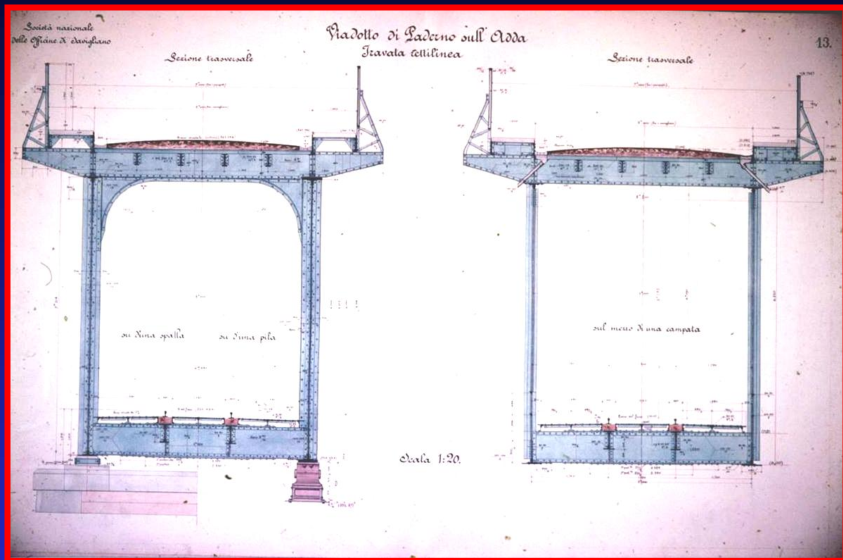
"The concern with economy of costs and resources was always a leitmotif to the discovery of new structures, and the case of the Maria Pia bridge, a century ago, seems to be a good example. The need for a railway bridge over the Douro was the reason for the first classical project, based on a opaque masonry stone arch (Figure a). Fortunately for the people of the city, Mr. Eiffel proposed a different and new solution for that time (Figure b) which has been working for more then hundred years with a unique transparency and lightweight." (Fonseca,2004)

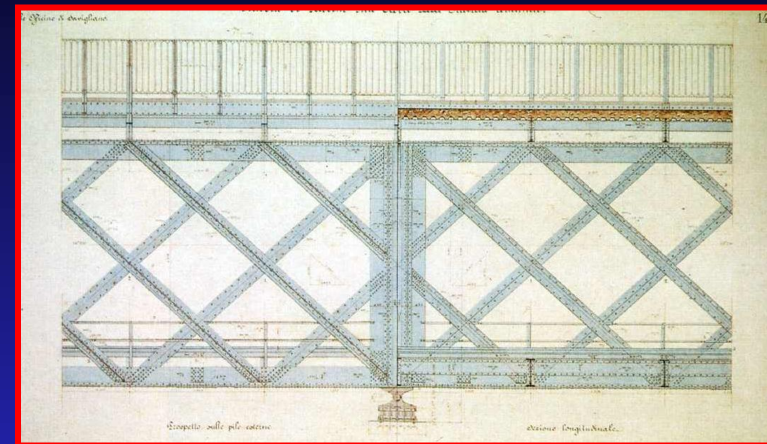
THE PADERNO BRIDGE ON THE ADDA RIVER (ITALY, 1887- 1889)

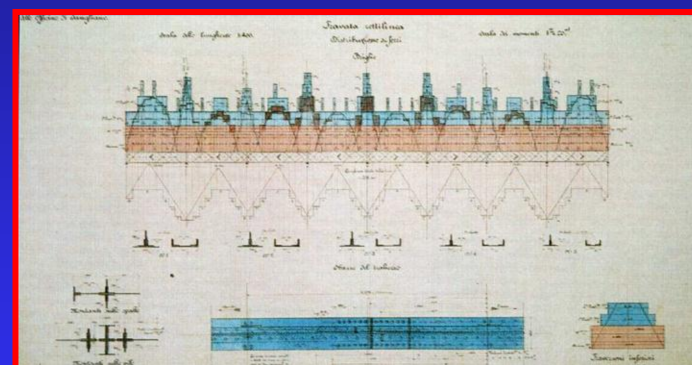
THE PADERNO BRIDGE ON THE ADDA RIVER (ITALY, 1889)



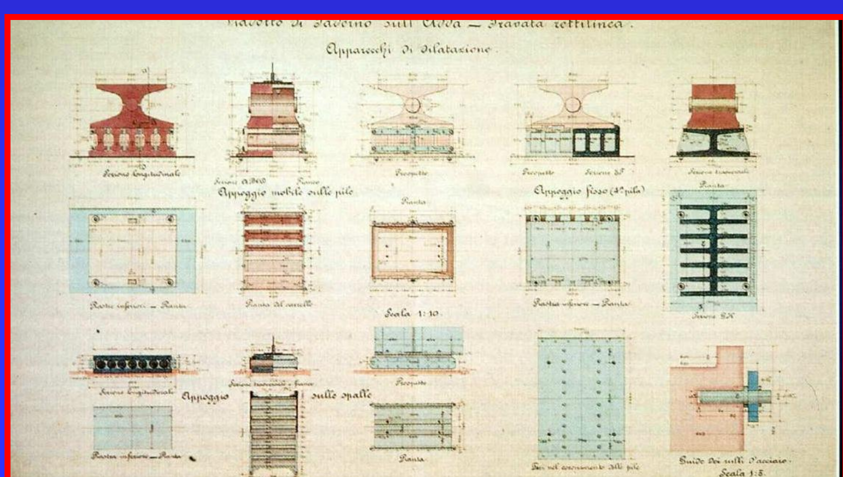
THE PADERNO BRIDGE ON THE ADDA RIVER (ITALY, 1889)

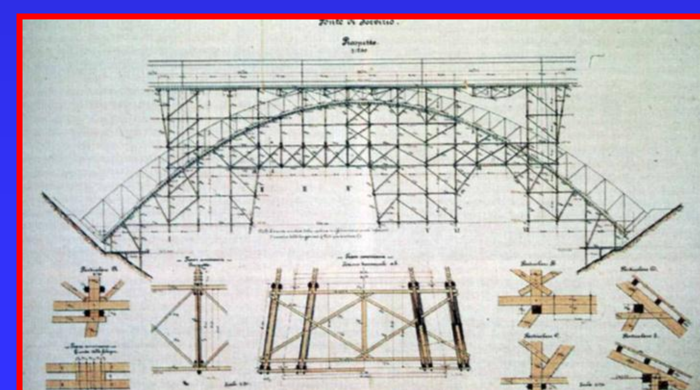






J.ROTHLISBERGER
(techn.director of SAVIGLIANO)







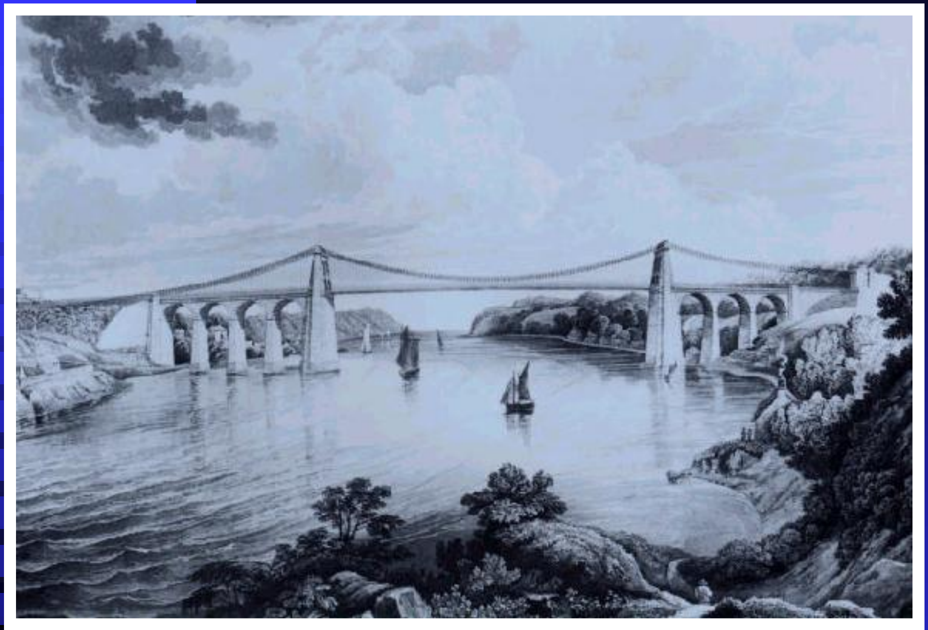

THE PADERNO BRIDGE ON THE ADDA RIVER (ITALY, 1889)

THE WHEELING BRIDGE ON THE OHIO RIVER (USA, 1850 ;L = 308 m)

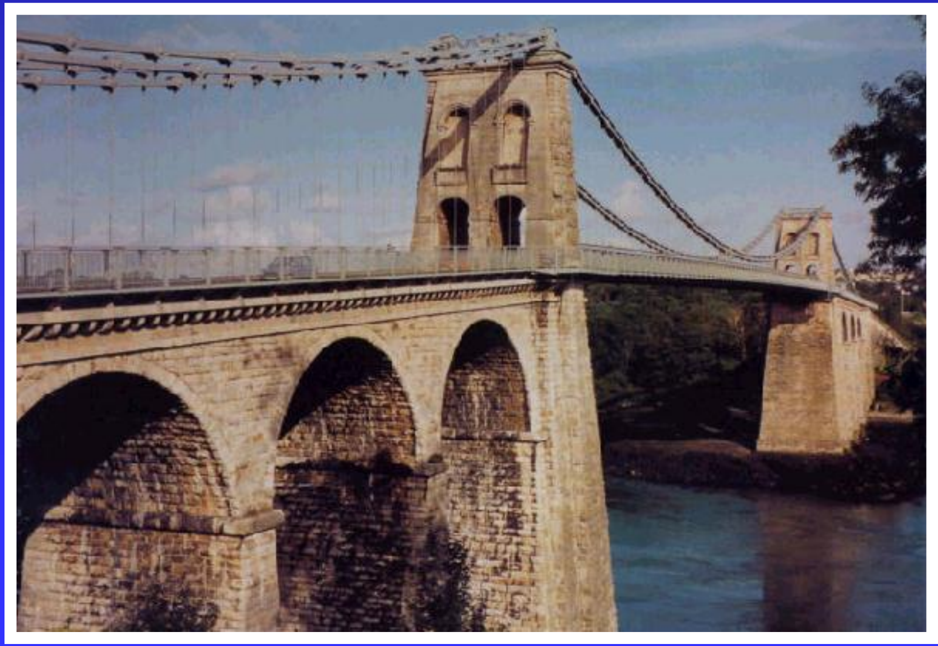
THE LEWISTON-QUEENSTONE BRIDGE (USA, 1851 ;L = 318 m)

THE SUSPENSION BRIDGES IN EUROPE

THE MENAI STRAITS BRIDGE (1819 - 1826)



Thomas Telford



L=78 + 177 + 78 m

THE CLIFTON SUSPENSION BRIDGE ON THE AVON RIVER (1833-1859)

L=214 m

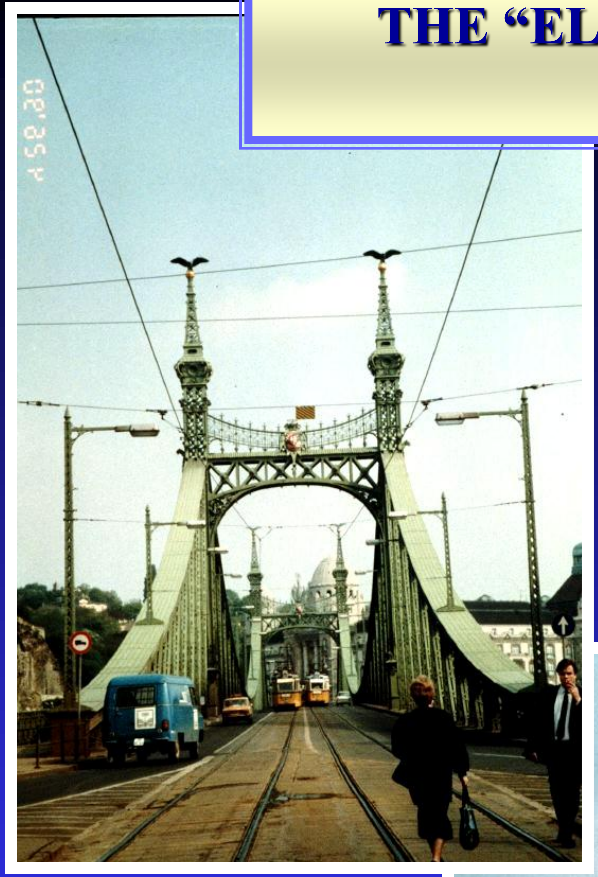
I.K.BRUNEL & HAWKSHAW

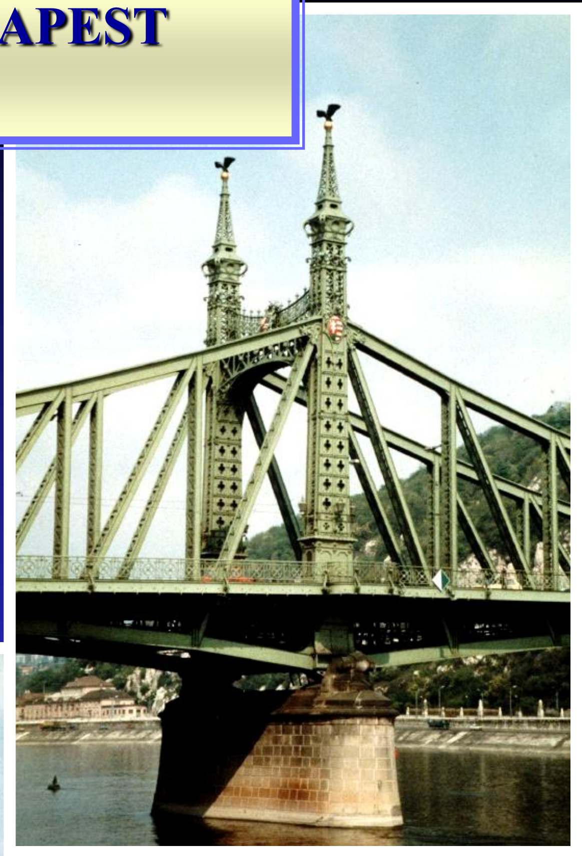
THE CINCINNATI-COVINGTON BRIDGE (USA,1856 - 1867 ;L = 322 m)

THE BROOKLYN BRIDGE (N.Y.,USA,1869 - 1883 ;L =284+486+284 m)

THE MANHATANN BRIDGE (N.Y.,USA,1909 ;designed by Leon Moisseiff)

THE “ELISABETH BRIDGE” IN BUDAPEST (HUNGARY)

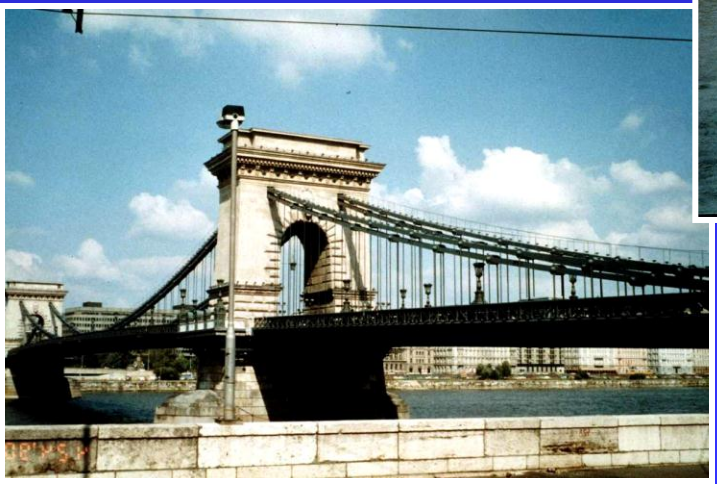




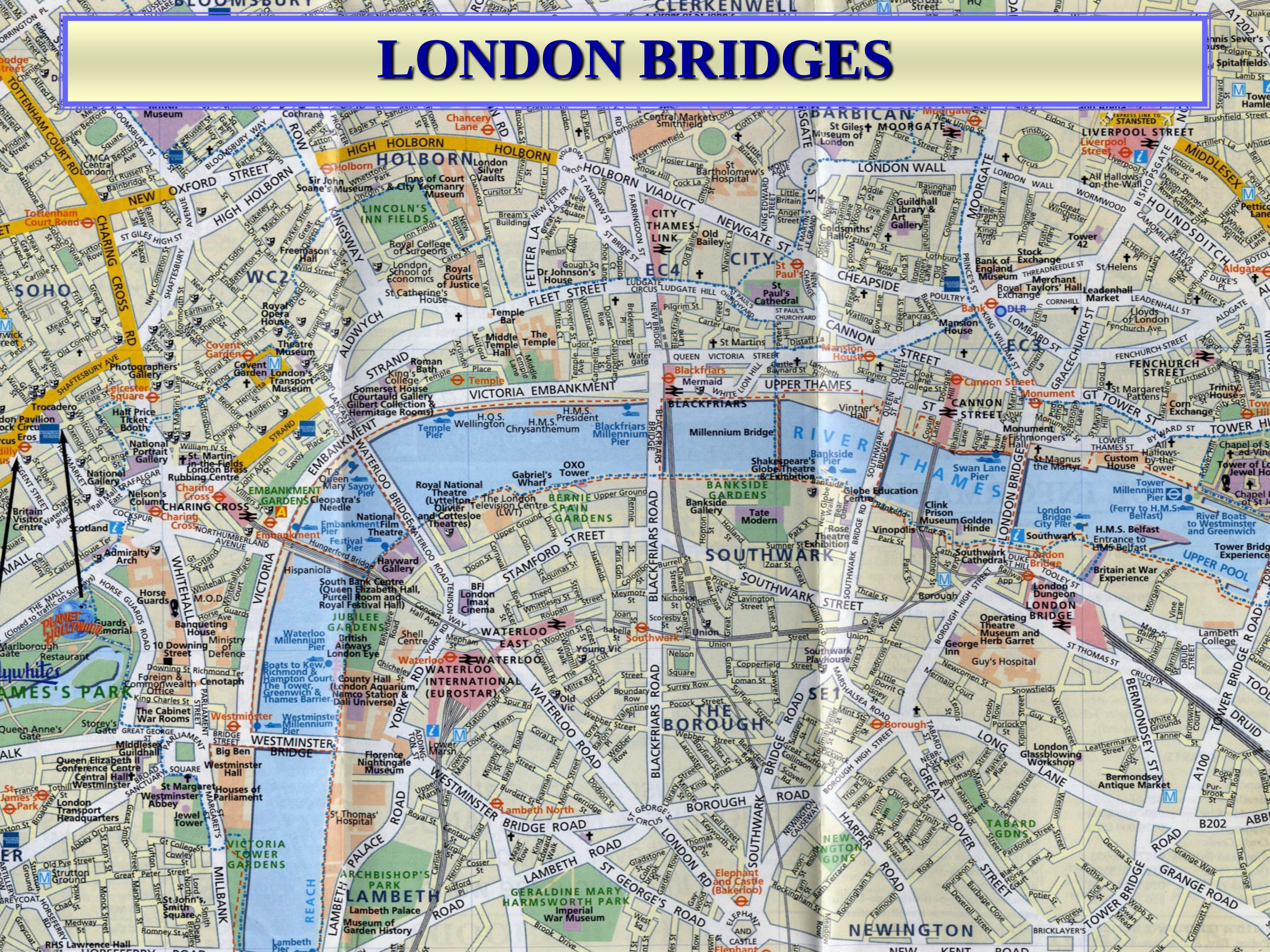
THE “CHAIN BRIDGE” IN BUDAPEST (HUNGARY,1839 - 1845)

CLARK

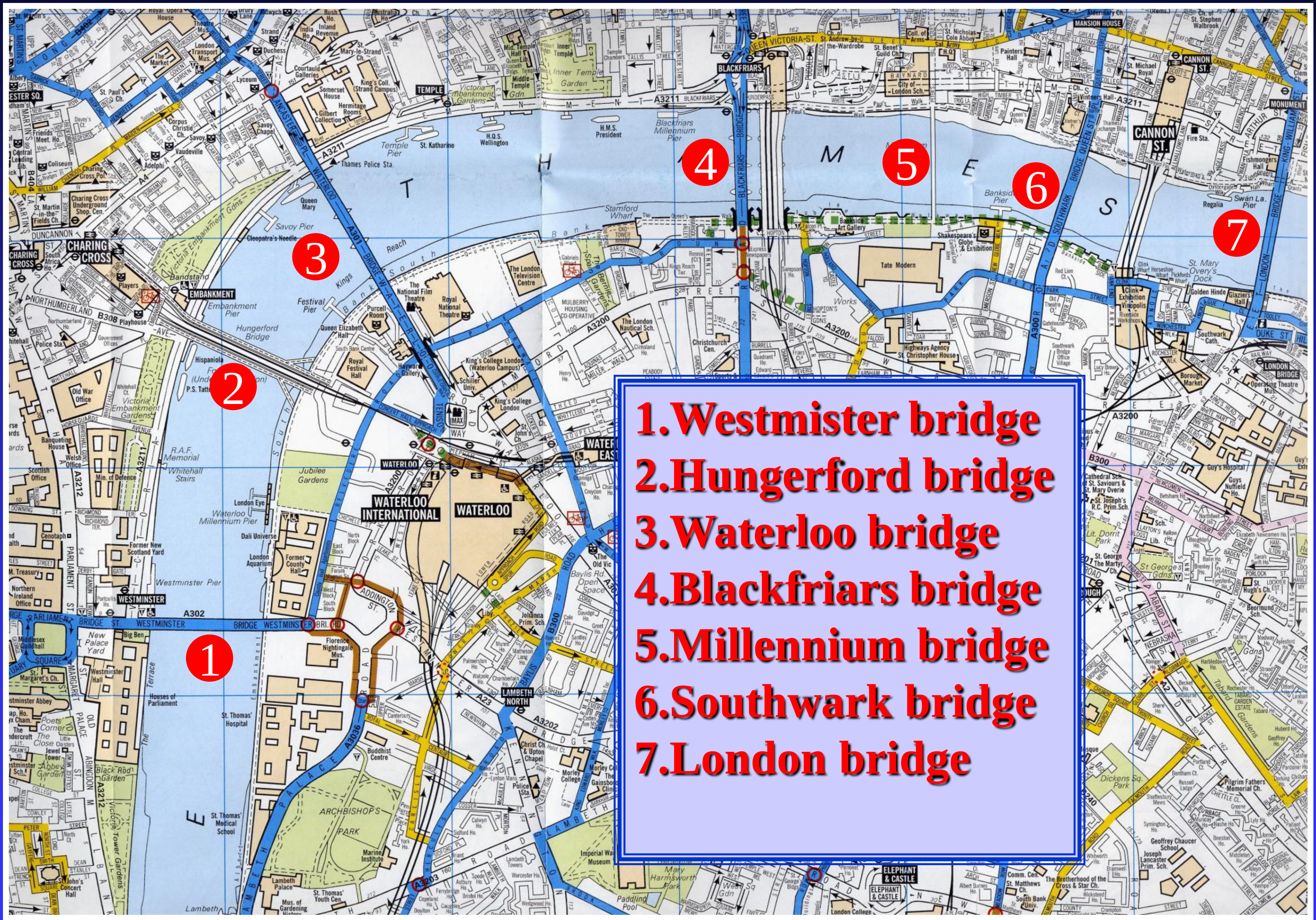
L = 203 m



LONDON BRIDGES



LONDON BRIDGES



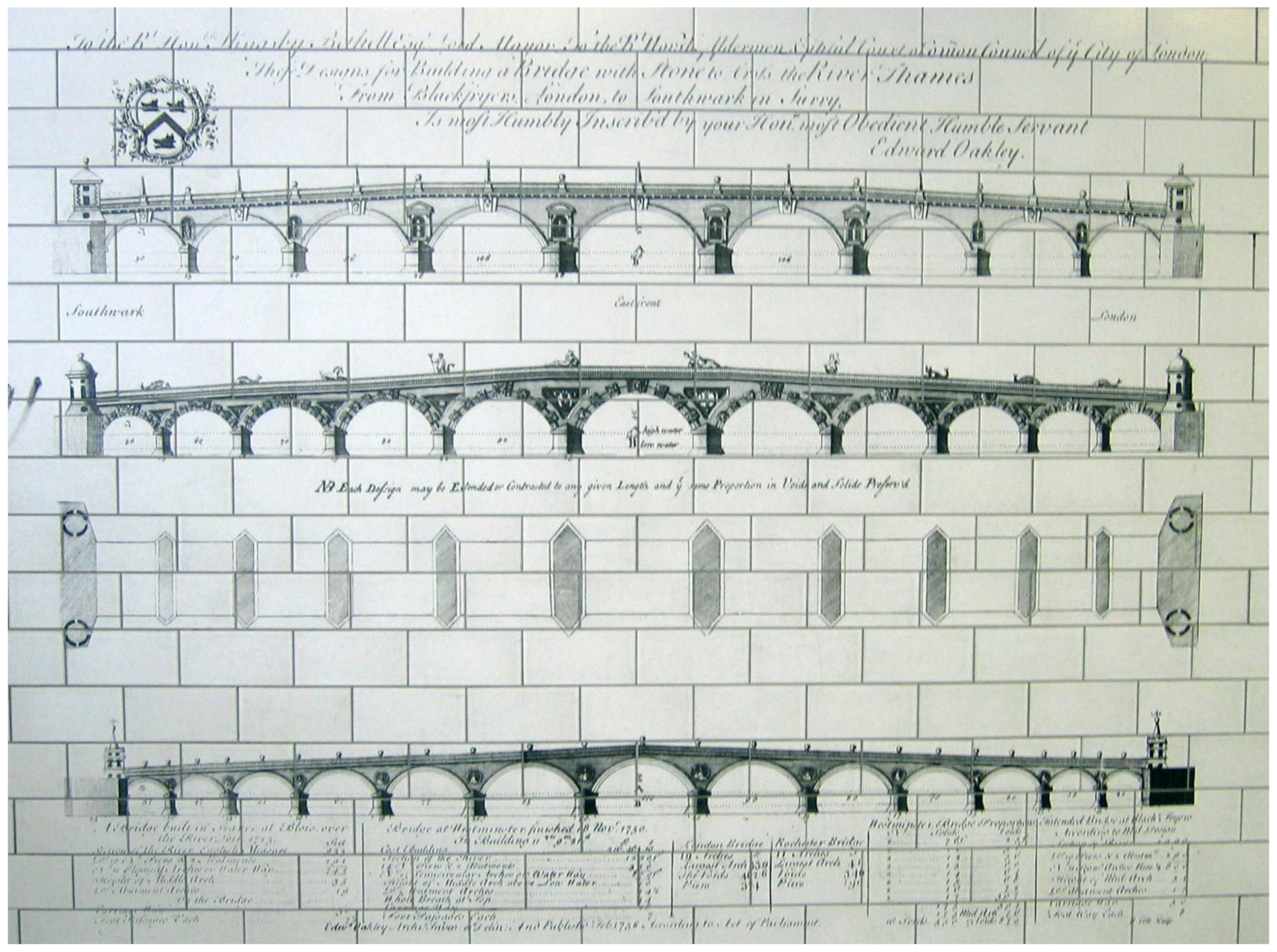
1. Westmister bridge
2. Hungerford bridge
3. Waterloo bridge
4. Blackfriars bridge
5. Millennium bridge
6. Southwark bridge
7. London bridge

LONDON BRIDGES : 2. Hungerford footbridges

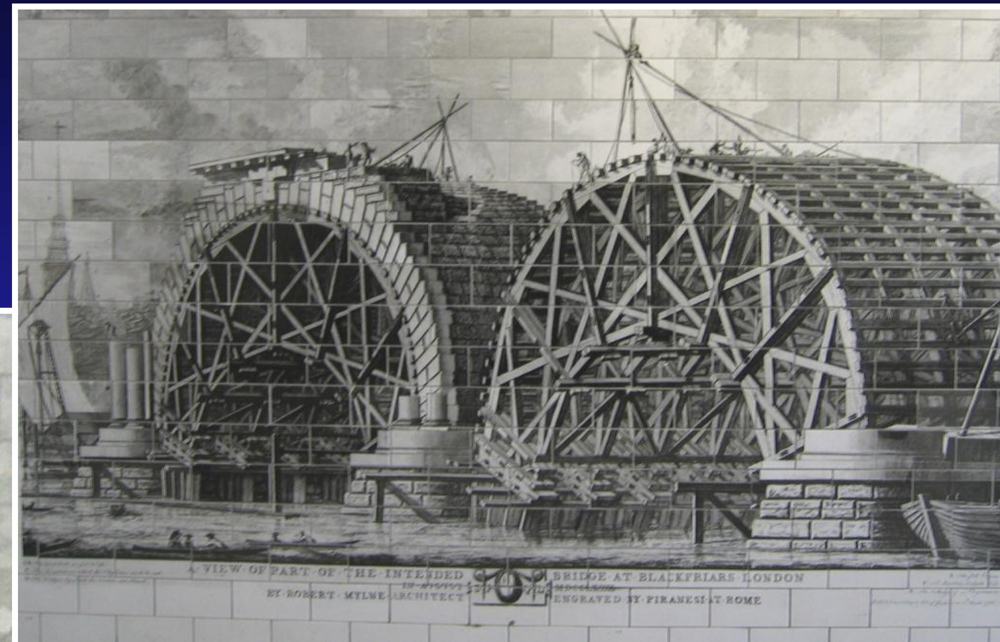
LONDON BRIDGES : 4. Blackfriars bridge

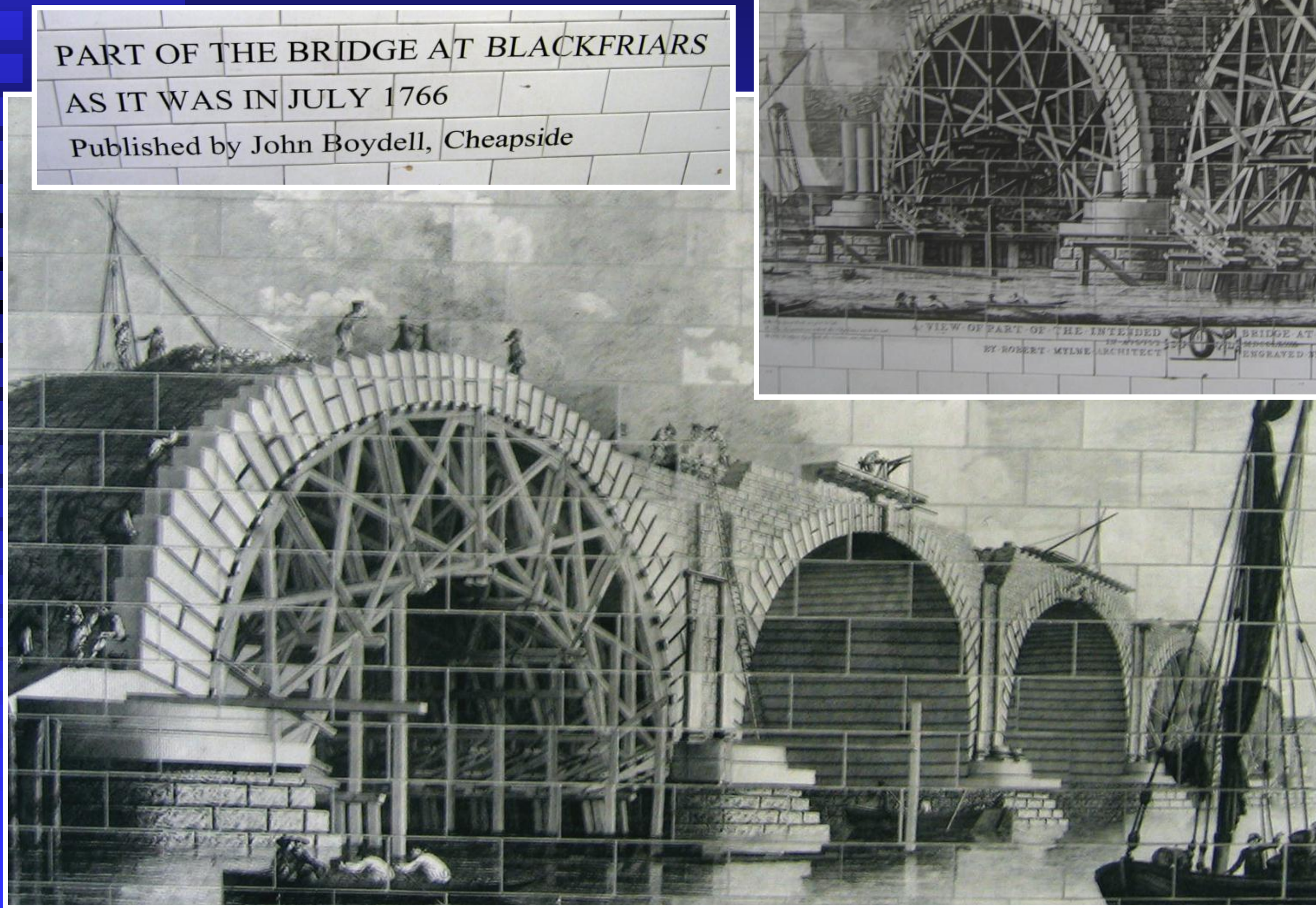
LONDON BRIDGES : 4. Blackfriars bridge

LONDON BRIDGES : 4. Blackfriars bridge

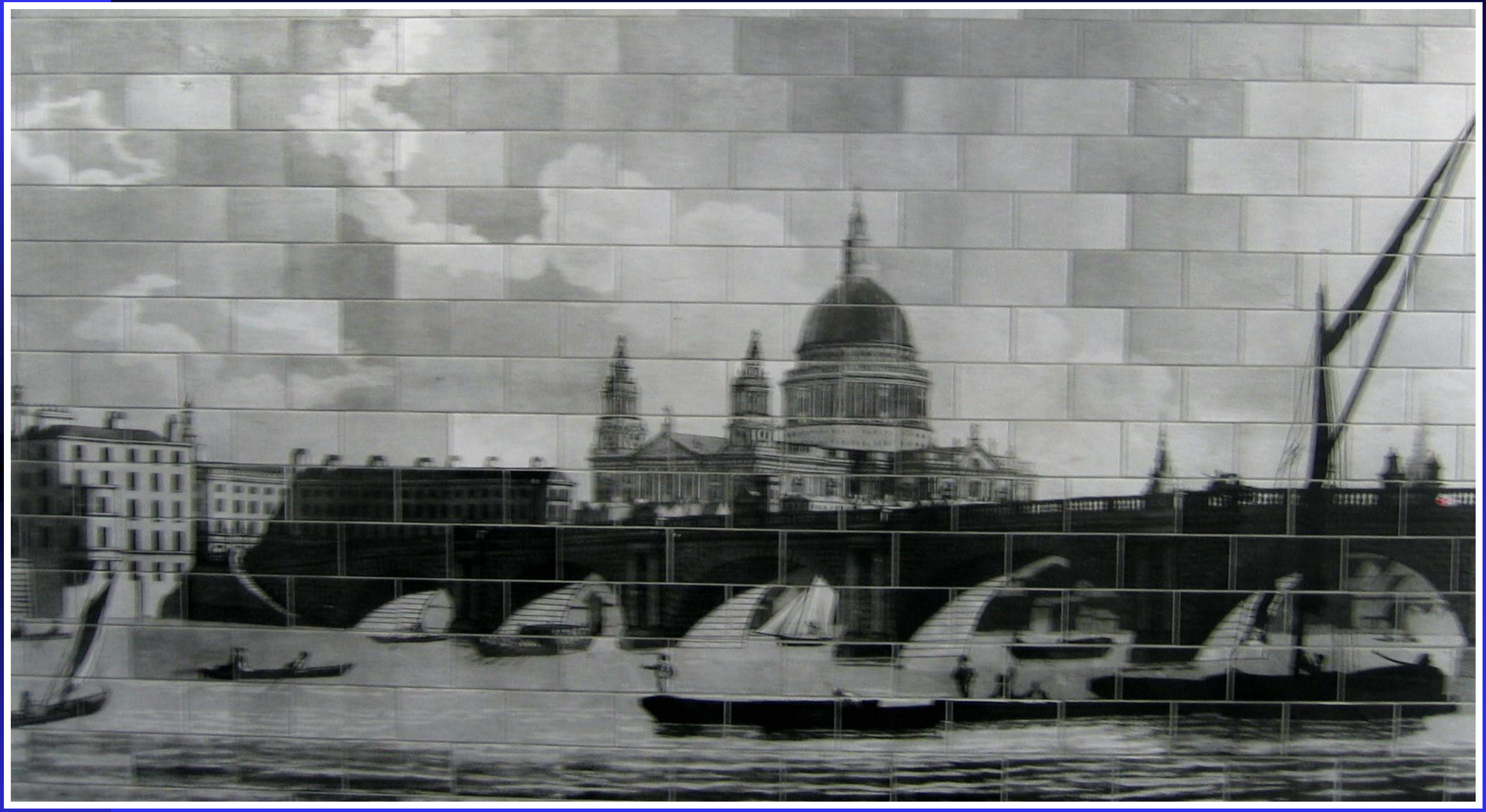


LONDON BRIDGES : 4. Blackfriars bridge





LONDON BRIDGES : 4. Blackfriars bridge



LONDON BRIDGES : 4. Blackfriars bridge

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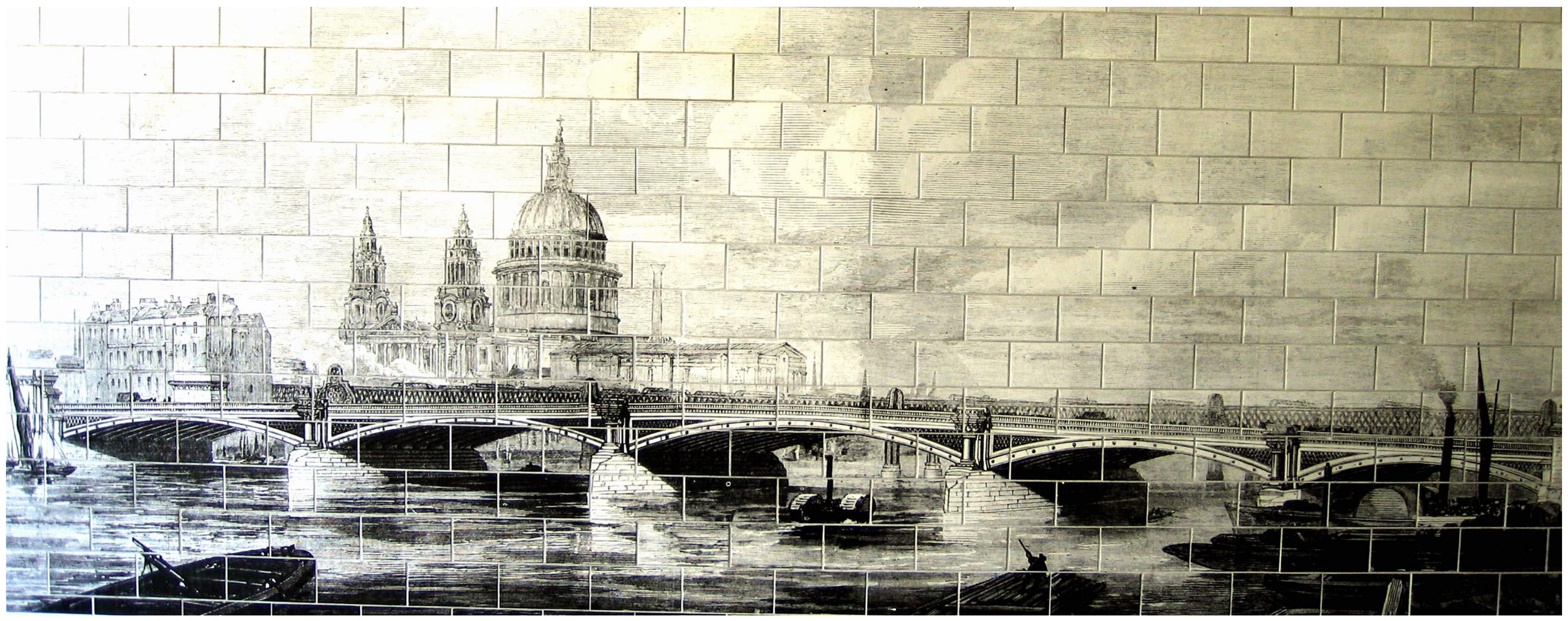
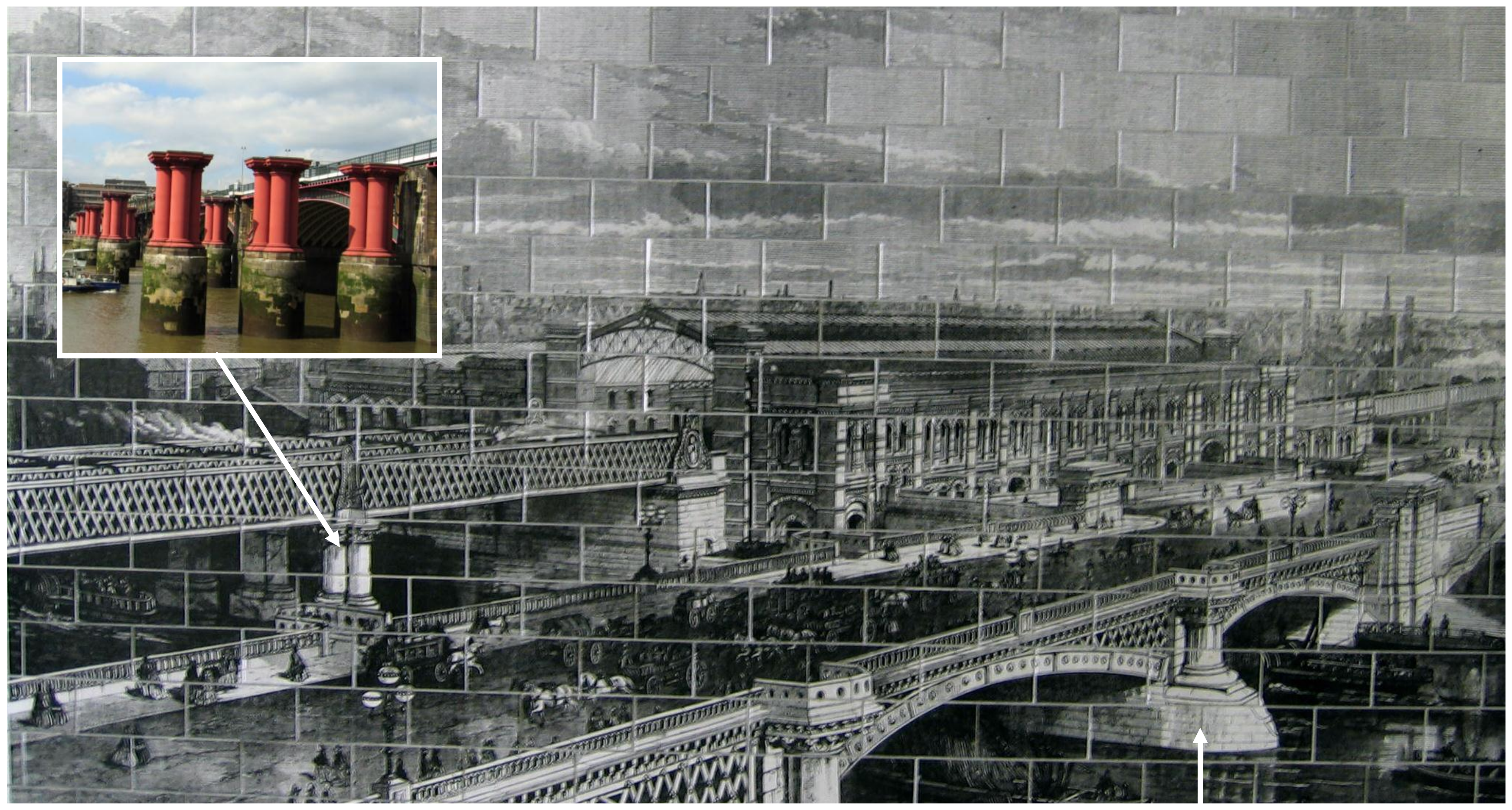


LONDON BRIDGES : 4. Blackfriars bridge

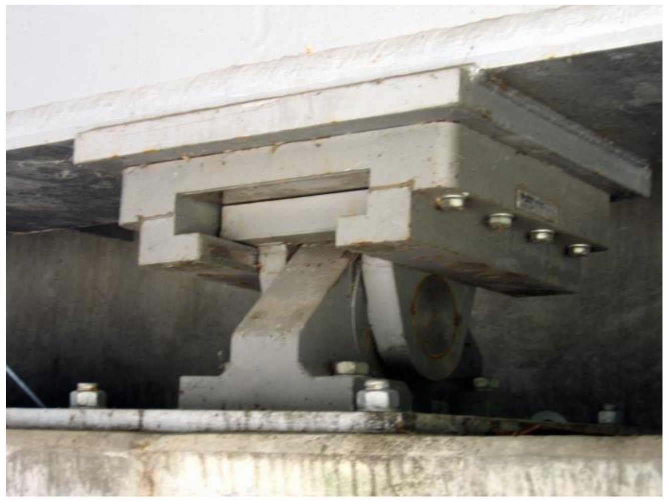


THE LONDON, CHATHAM AND DOVER RAILWAY STATION AT BLACKFRIARS
Illustrated London News 26th December 1863

LONDON BRIDGES : 4. Blackfriars bridge

LONDON BRIDGES : 5. Millennium footbribge

LONDON BRIDGES : 5. Millennium footbribge



LONDON BRIDGES : 5. Millennium footbribge

LONDON BRIDGES : 5. Millennium footbribge

LONDON BRIDGES : 6. Southwark bridge

(1815-1819) John Rennie

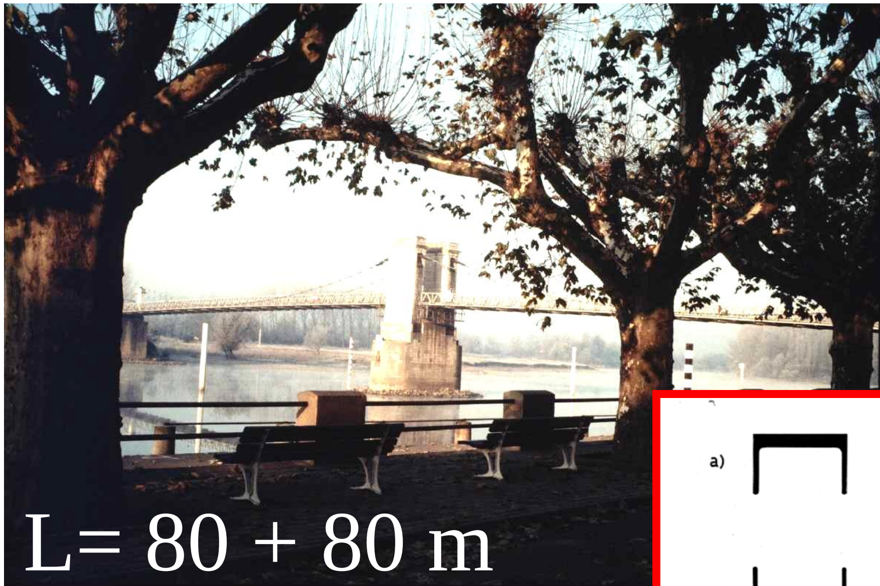
THE TOWER BRIDGE IN LONDON (U.K.)

THE TOWER BRIDGE IN LONDON (U.K.)

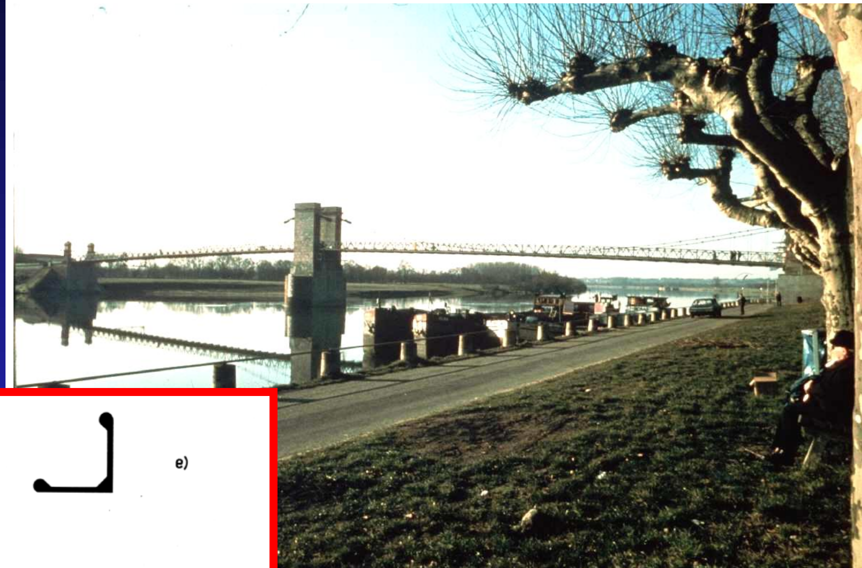
H.Jones, J.W.Barry & Wolfe

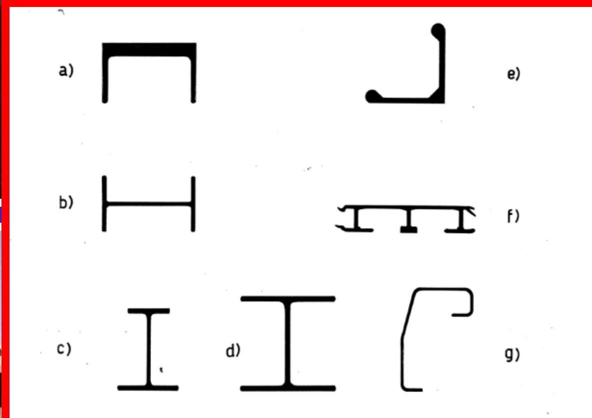
STRUCTURAL RESTORATION OF SUSPENSION BRIDGES BY MEANS OF ALUMINIUM ALLOYS

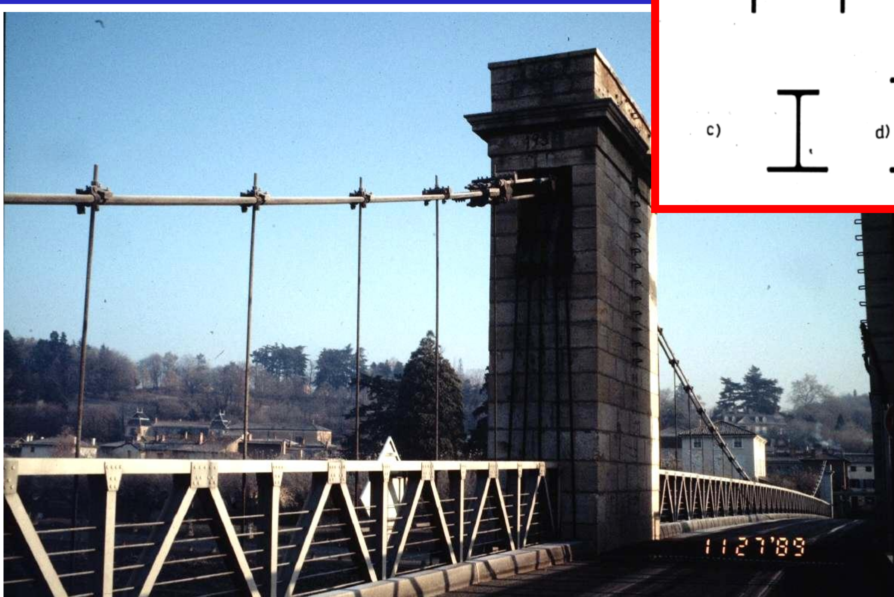
THE MONTEMERLE BRIDGE ON THE SOANE RIVER (1834 , FRANCE)



L= 80 + 80 m

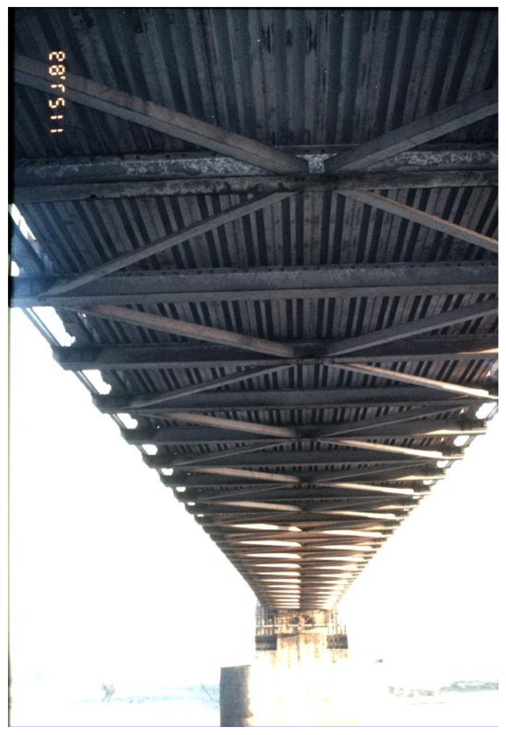


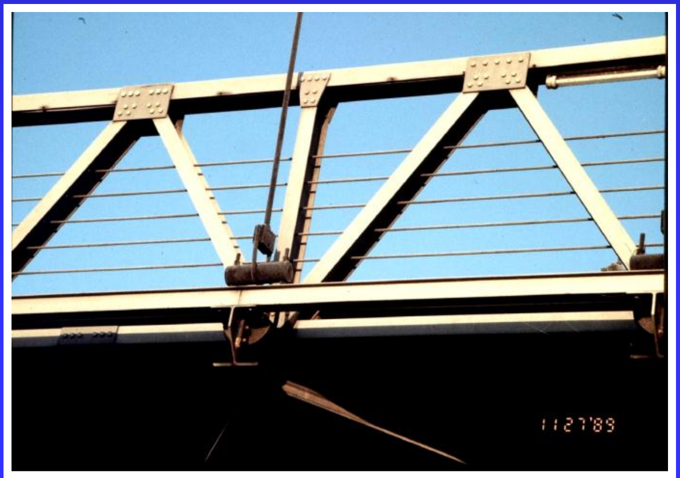




THE MONTEMERLE BRIDGE ON THE SOANE RIVER (FRANCE)

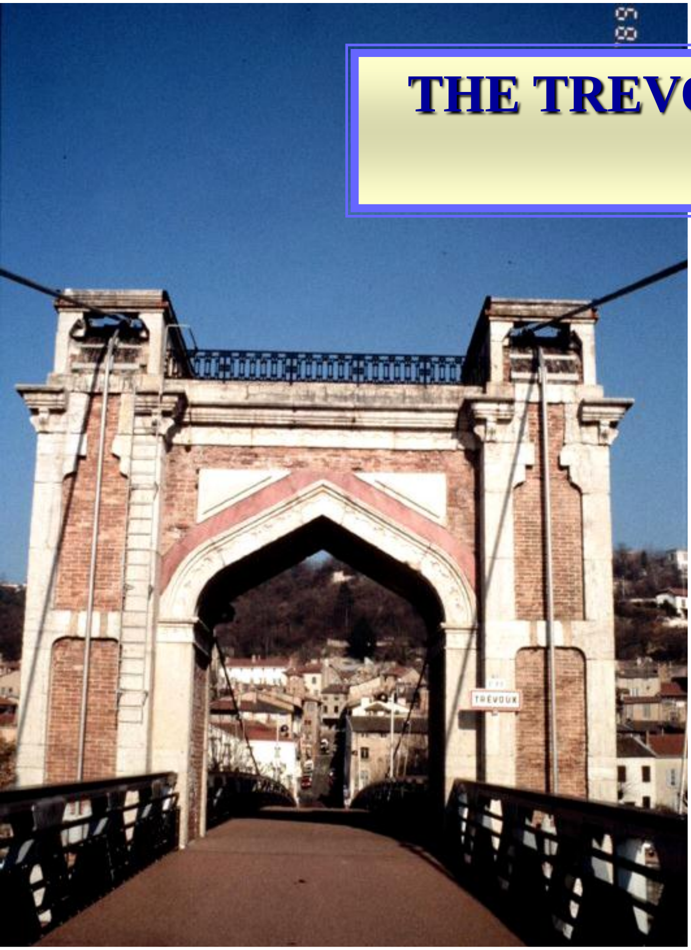
THE MONTEMERLE BRIDGE ON THE SOANE RIVER (FRANCE)

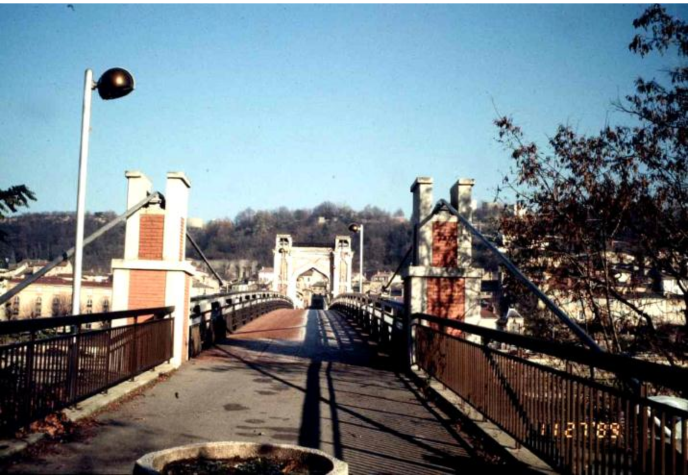




THE TREVOUX BRIDGE ON THE SAONE RIVER (FRANCE)

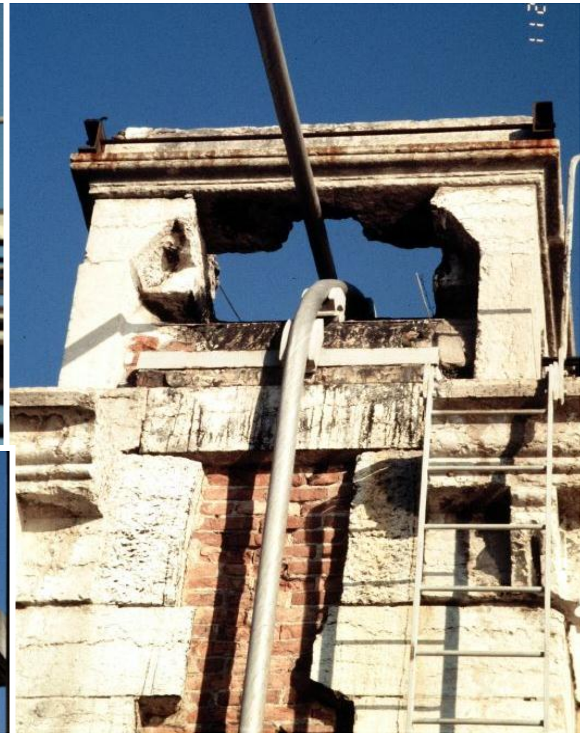
THE TREVOUX BRIDGE ON THE SAONE RIVER (FRANCE)

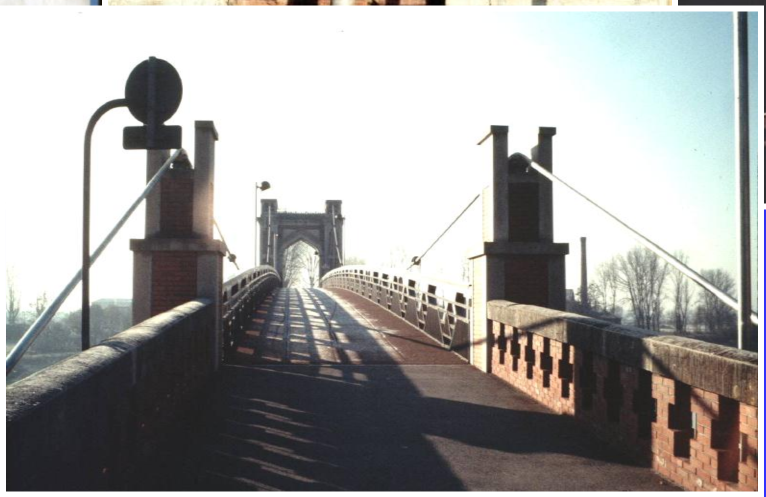




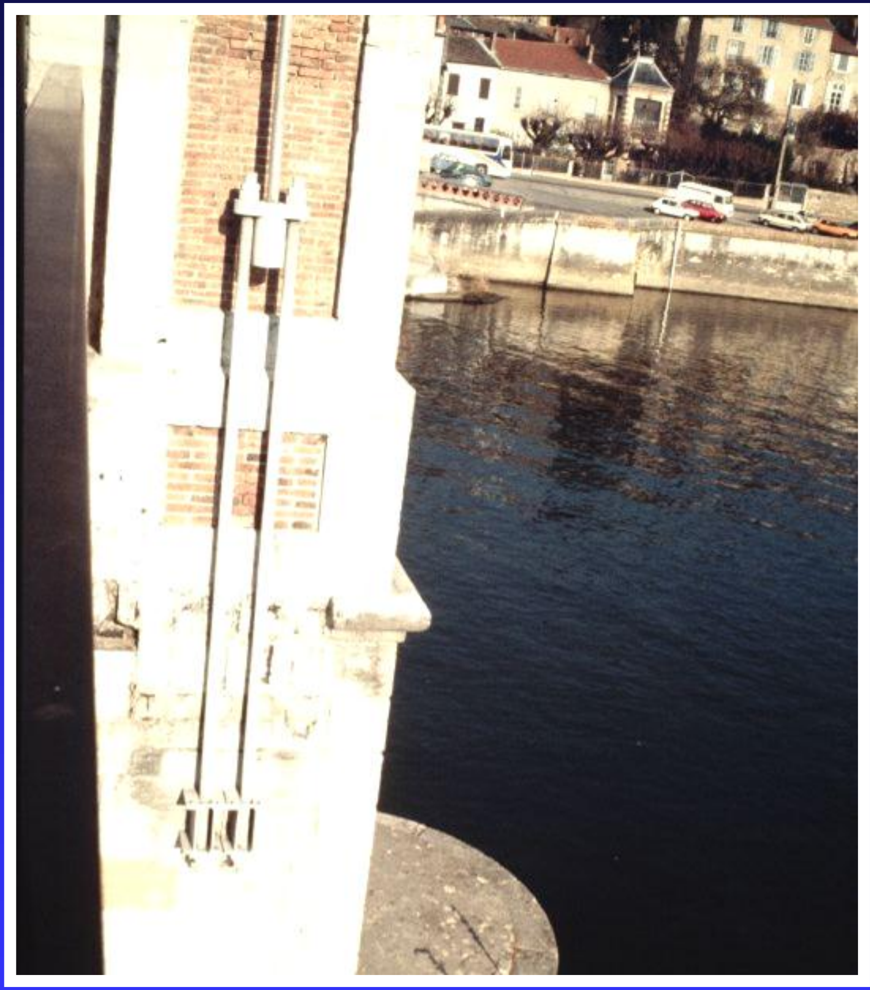
L= 80 + 80 m

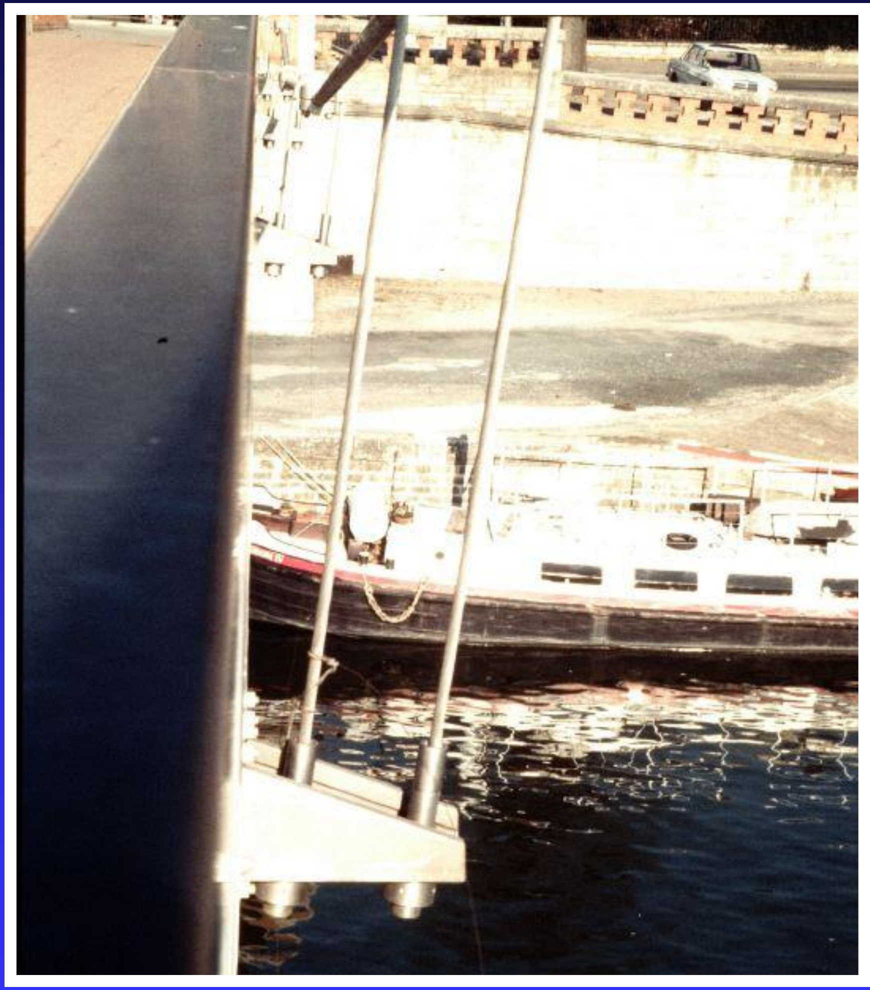
THE TREVOUX BRIDGE ON THE SAONE RIVER (FRANCE)





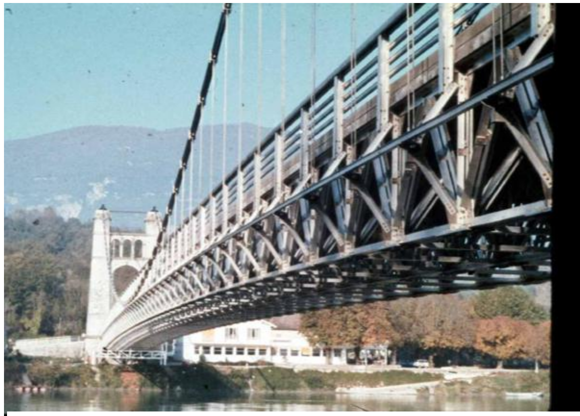
THE TREVOUX BRIDGE ON THE SAONE RIVER (FRANCE)

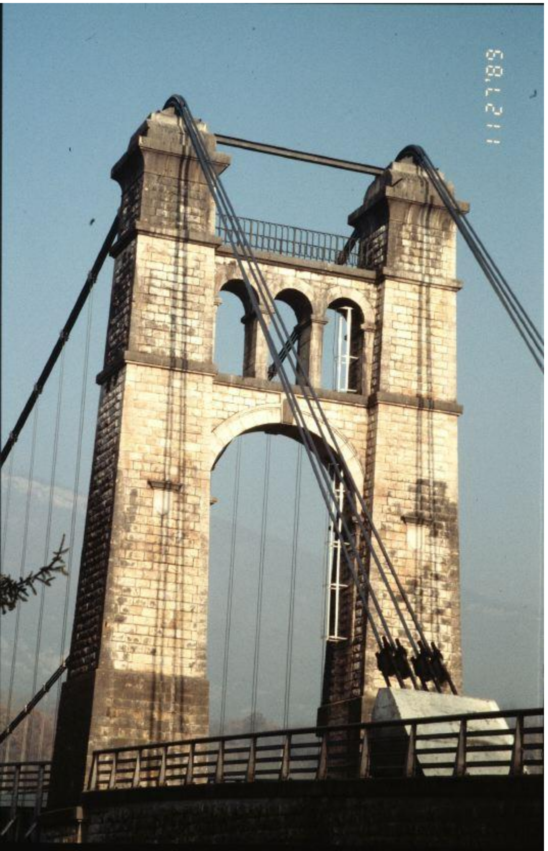


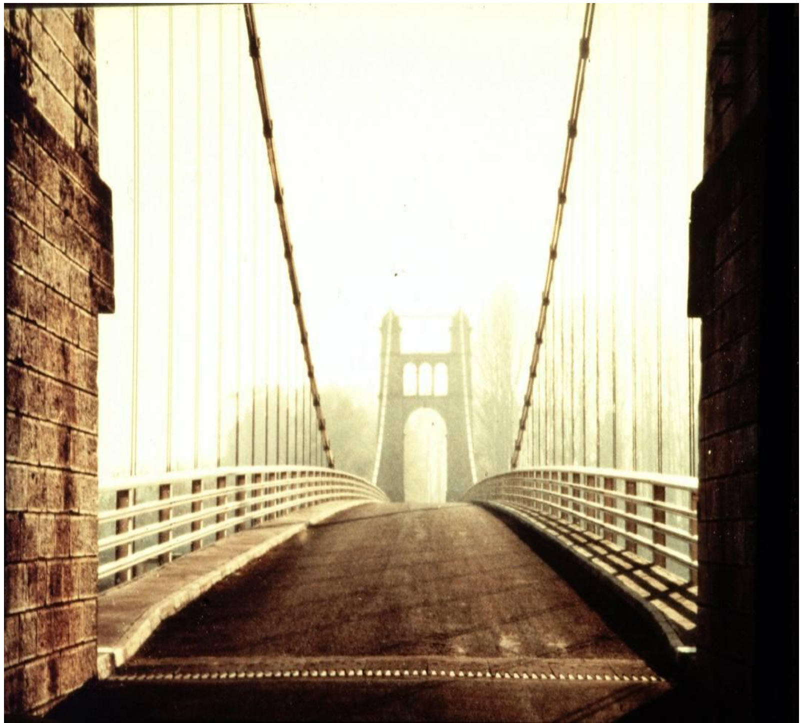


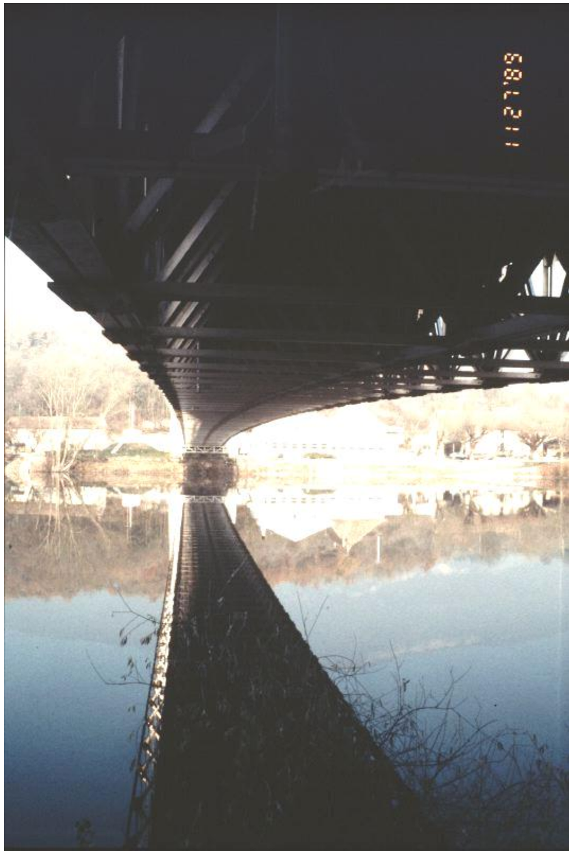
THE GROSLÈE BRIDGE ON THE RÔNE RIVER (1912 , FRANCE)

THE GROSLÈE BRIDGE ON THE RÔNE RIVER (FRANCE)

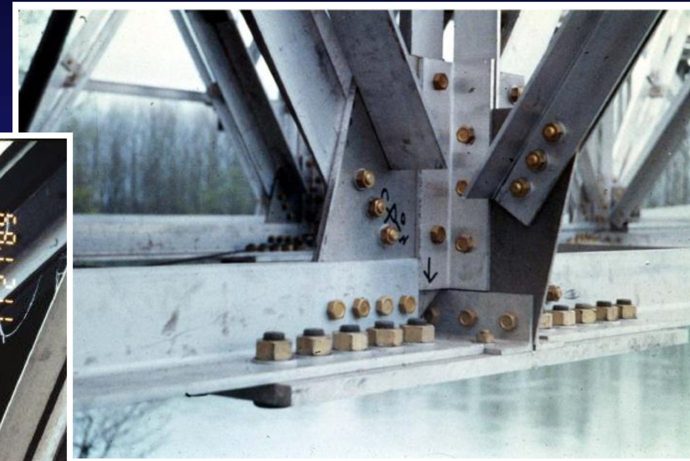


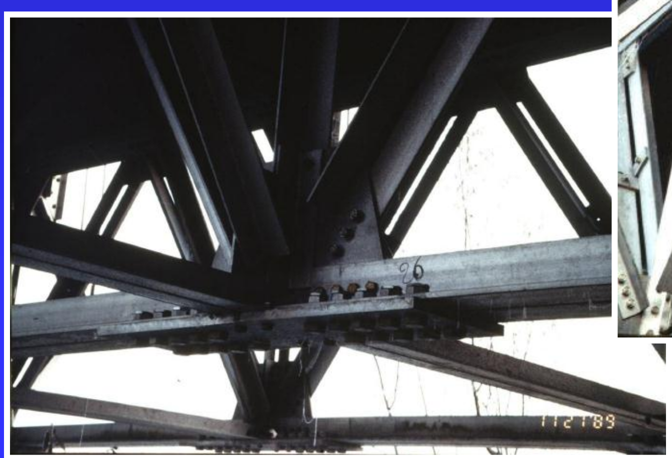




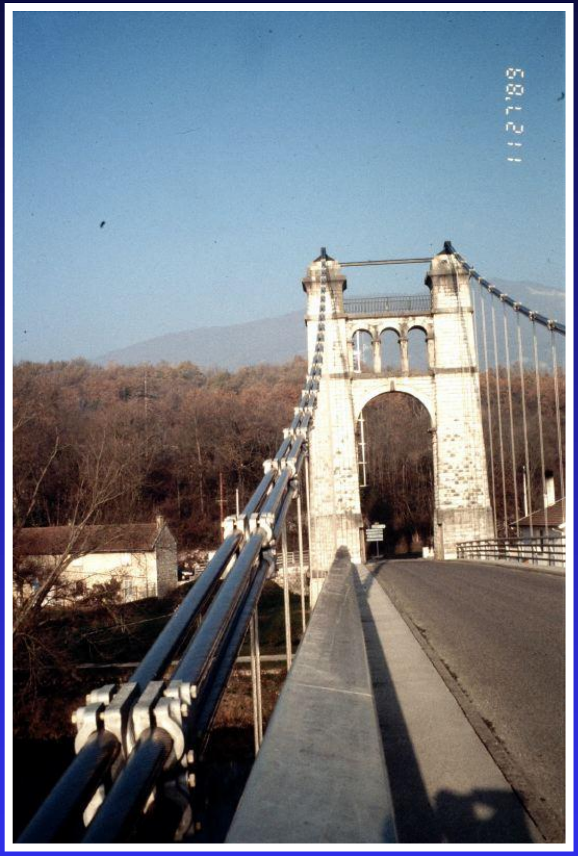


THE GROSLÈE BRIDGE ON THE RÔNE RIVER (FRANCE)





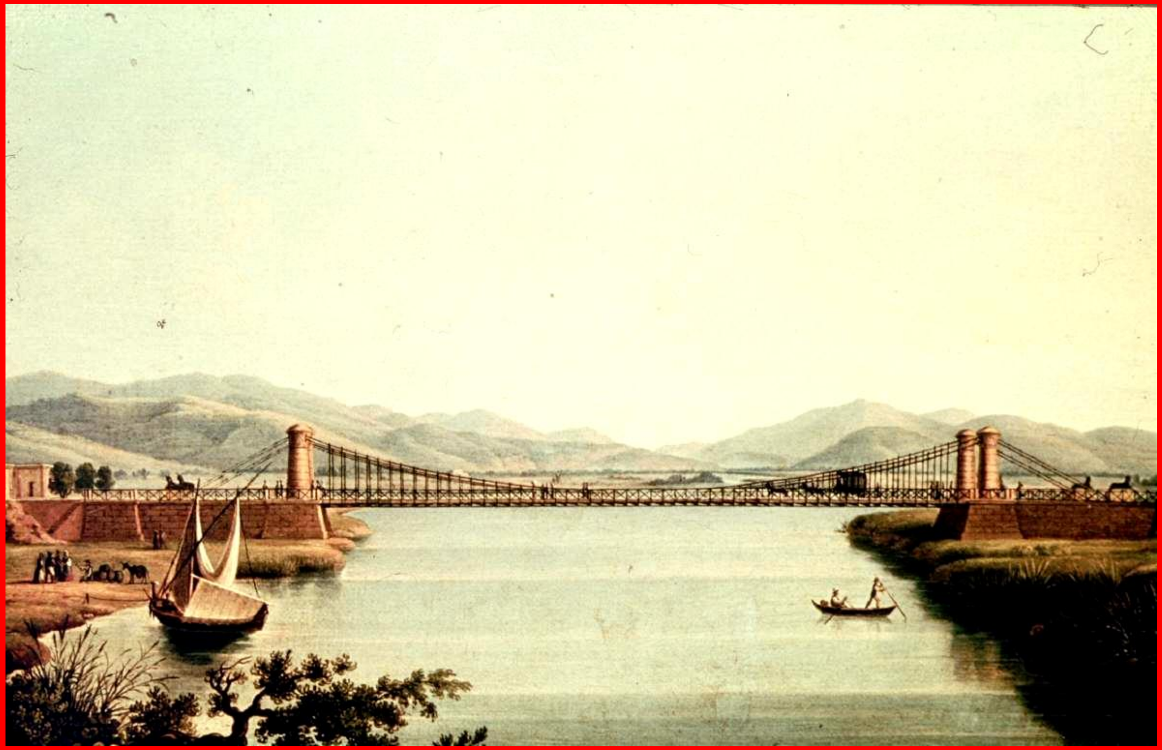
THE GROSLÈE BRIDGE ON THE RÔNE RIVER (FRANCE)



STRUCTURAL RESTORATION OF THE “REAL FERDINANDO” BRIDGE :
the first iron suspension bridge in Italy

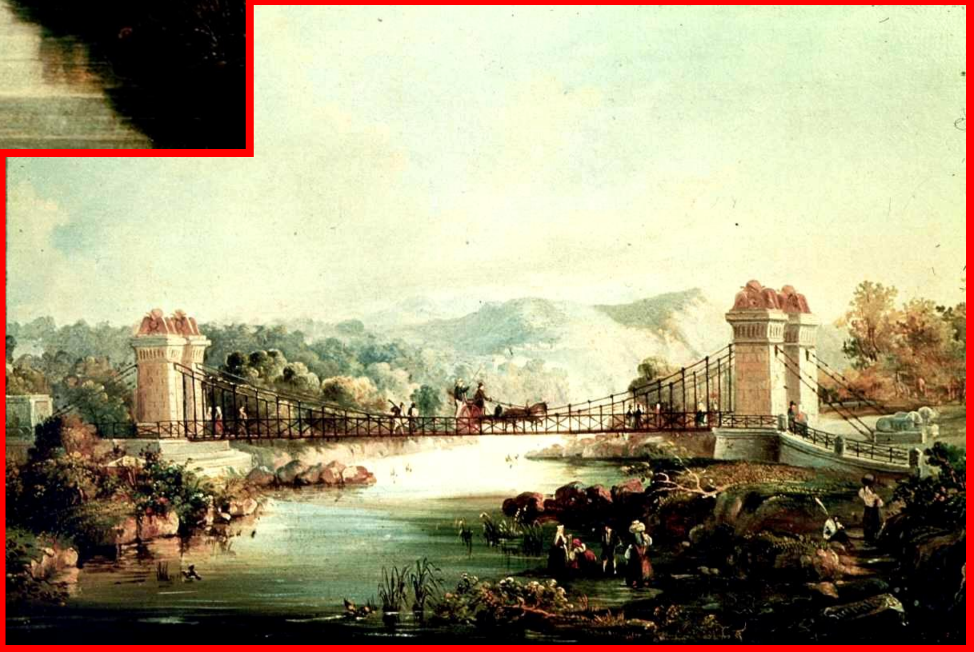
THE "REAL FERDINANDO" BRIDGE ON THE GARIGLIANO RIVER (ITALY)

Designer : Luigi Giura



The "Real Ferdinando "Bridge on the Garigliano river (1832)

The "Maria Cristina" Bridge on the Calore river (1835)



Design data (geometry)

- L = 85 m
- Distance between suspension chains 5,83 m
- Vertical ties every 1.37 m
- Two longitudinal iron beams with rectangular cross-section
- Transversal wooden beams every 1,73 m
- Two couples of piers made of calcar stone
- Chain ancorage at 24 m from piers and 6 m depth
- Chains made of pinned iron plated elements

Design data (loads and stresses)

- Dead load : 260 kg/mq
- Live load : 240 kg/mq
- Maximum axial force in chains : 500 t
- Maximum stress in iron chains : 15 kg/mmq
- Strength of stone : 600 kg/cmq

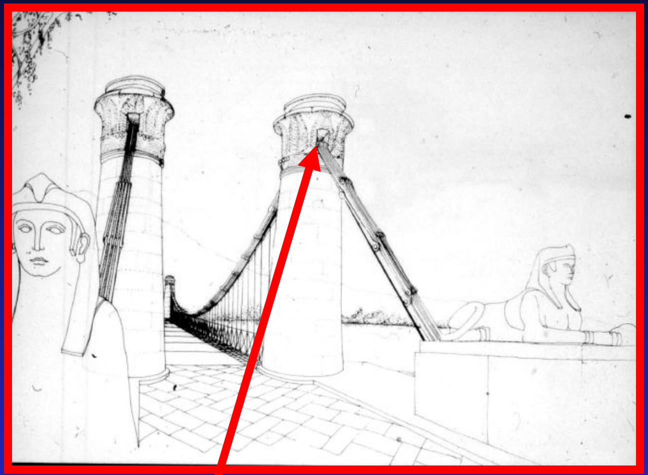
THE “REAL FERDINANDO” BRIDGE
ON THE GARIGLIANO RIVER (ITALY)

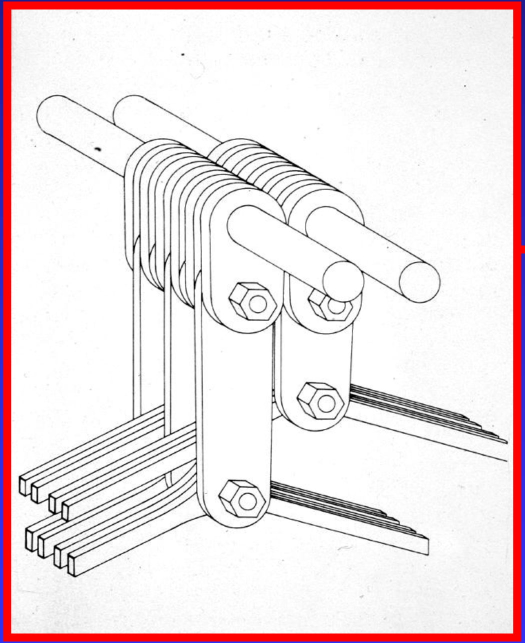
Erection data (1828 – 1832)

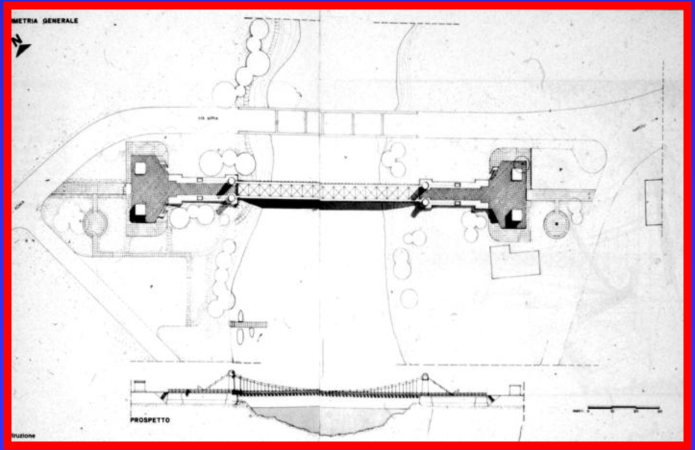
- Work period : four years
- Iron : 70 000 kg
- Cost : 75 000 ducats
- Loading test : 2 groups of lancers
  16 artillery carriages
- Proof engineer : king Ferdinand II (!)

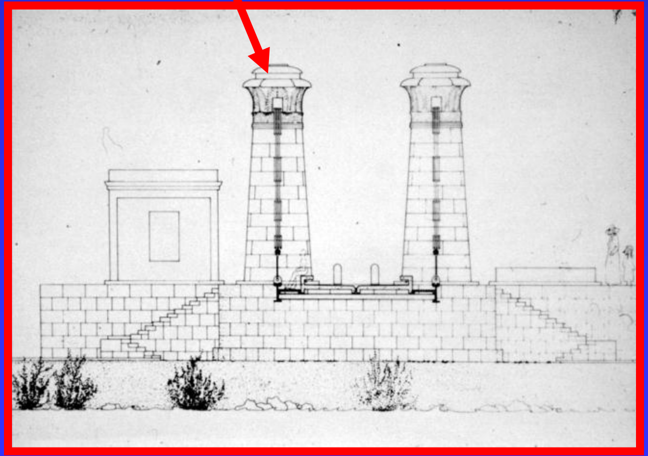
THE “REAL FERDINANDO” BRIDGE ON THE GARIGLIANO RIVER (ITALY)

Special device
for connecting
the chains to the piers









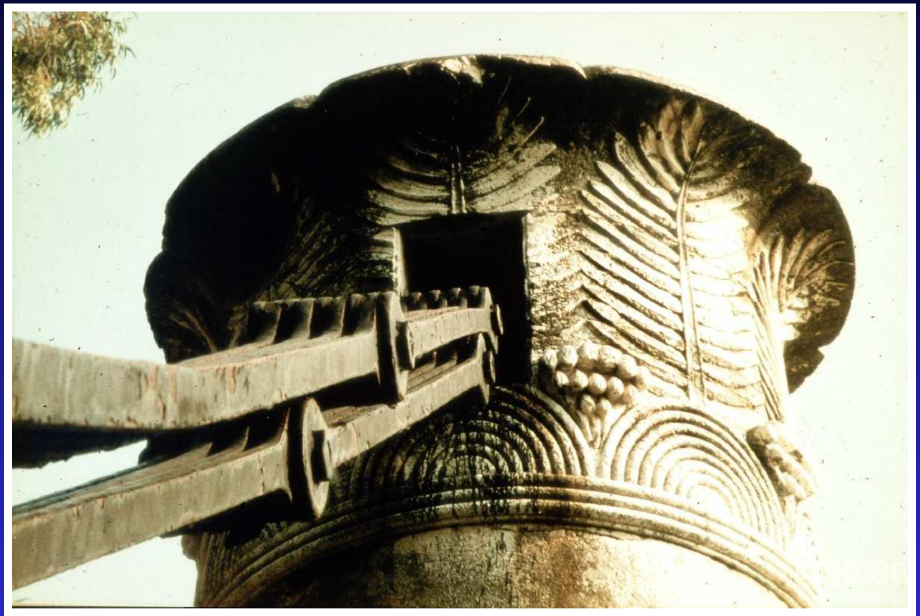
THE"REAL FERDINANDO" BRIDGE
ON THE GARIGLIANO RIVER (ITALY)

THE "REAL FERDINANDO" BRIDGE ON THE GARIGLIANO RIVER (ITALY)

1944 - 1990

The piers

THE "REAL FERDINANDO" BRIDGE ON THE GARIGLIANO RIVER (ITALY)



The top of the pier

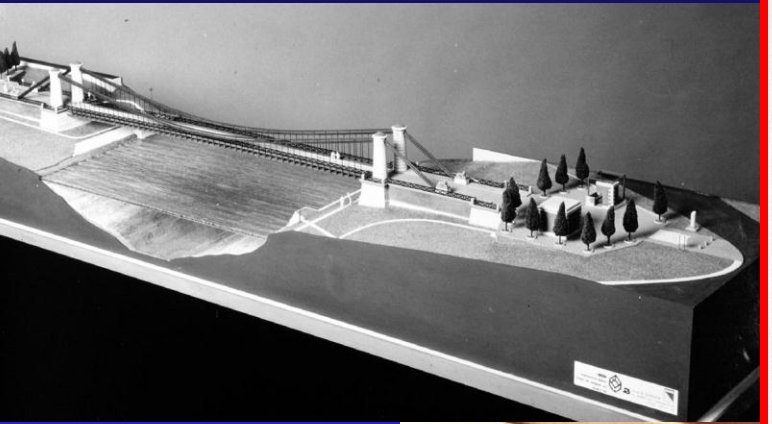
The chain

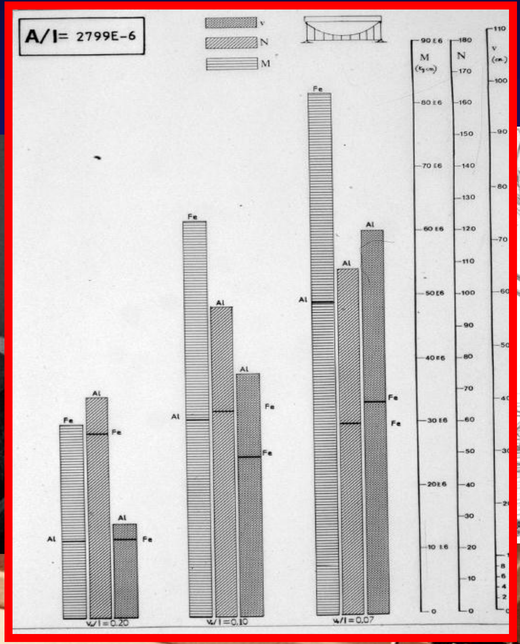
THE "REAL FERDINANDO" BRIDGE ON THE GARIGLIANO RIVER (ITALY)

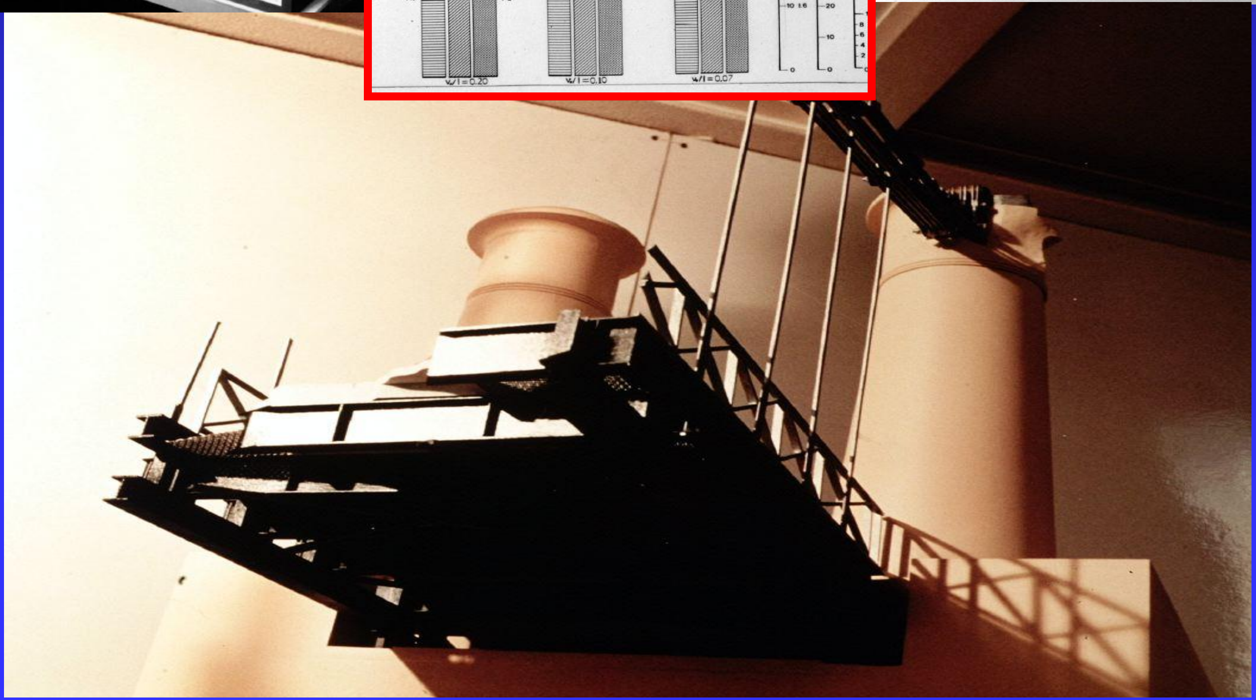
The sphinx

THE “REAL FERDINANDO” BRIDGE
ON THE GARIGLIANO RIVER (ITALY)

The design of restoration







Results of the numerical analysis

- **The structural scheme gives a good performance under uniformelly distributed vertical loads only**
- **Due to the “*mechanism*” feature of the structural scheme , it is too flexible under non symmetrical loading conditions**
- **The lack of bracing systems makes it unable to resist horizontal actions (wind , earthquake) without large deflections**
- **The design live load (240 kg/mq) is too low even for pedestrian use**

THE “REAL FERDINANDO” BRIDGE
ON THE GARIGLIANO RIVER (ITALY)

Basis criteria for the structural restoration design

- **Conservation of the original shape :**

consolidation of piers ;
keep the same shape of chains (two groups per sides) ;
keep the same spanning among the vertical ties ,
corresponding to the mash of the rails ;
keep the same structural scheme of the deck.

- **Increase the flexural stiffness both vertical and horizontal:**

main longitudinal Vierendeel beams , whose mash corresponds to the vertical ties ;
rigid transversal beams ;
horizontal cross bracings with a mash of 5.83x(3x1,37) m.

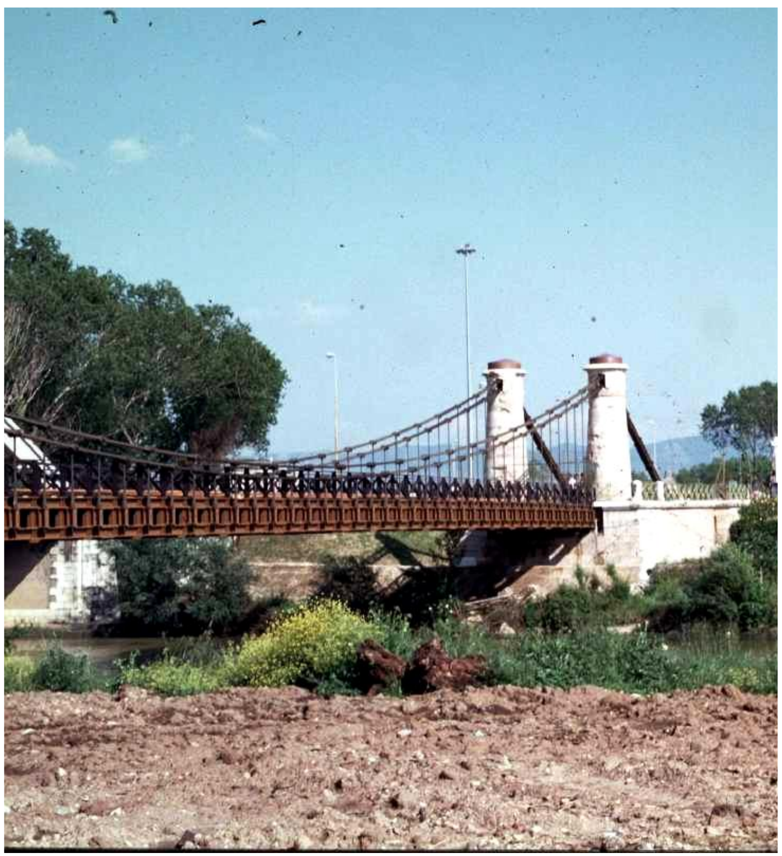
- **Use of modern technologies and materials :**

high strength steel for cables ;
use of aluminium alloys instead of steel for deck.

THE "REAL FERDINANDO" BRIDGE ON THE GARIGLIANO RIVER (ITALY)

THE "REAL FERDINANDO" BRIDGE
ON THE GARIGLIANO RIVER (ITALY)

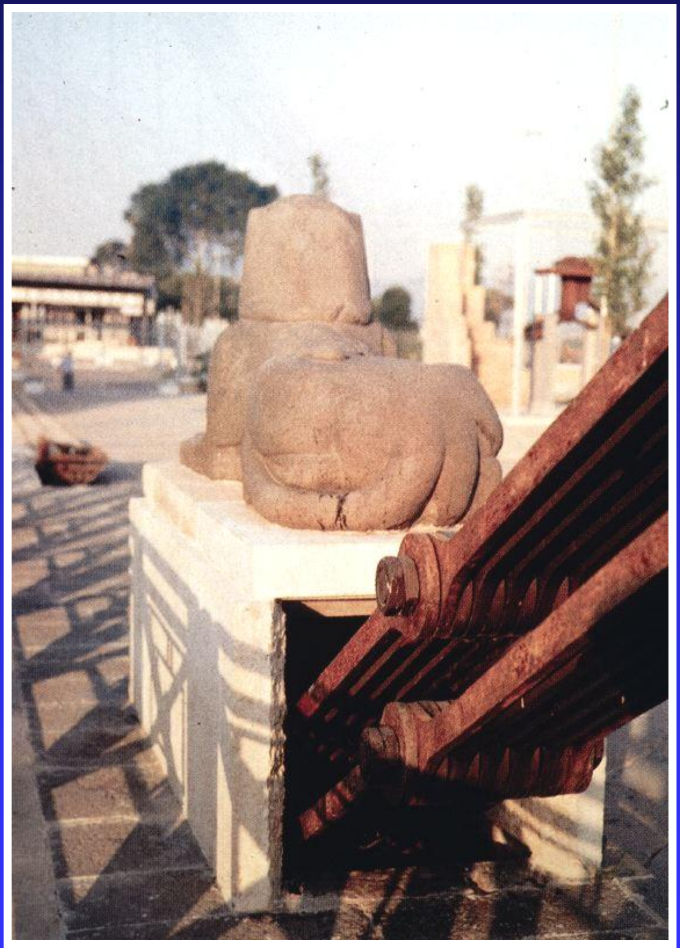
The structures of the deck

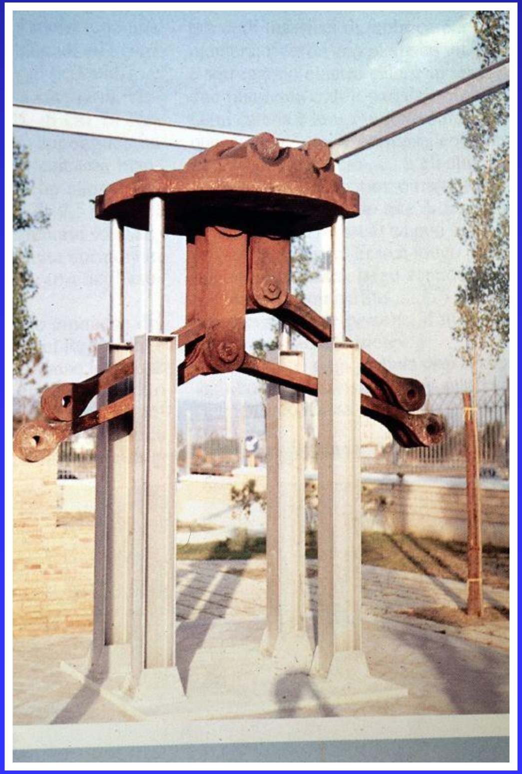




THE REAL FERDINANDO BRIDGE
ON THE GARIGLIANO RIVER (ITALY)

Lateral supports
and horizontal bracings

THE REAL FERDINANDO BRIDGE
ON THE GARIGLIANO RIVER (ITALY)





THE "REAL FERDINANDO" BRIDGE
ON THE GARIGLIANO RIVER (ITALY)

Alfredo Cottrau

estratto dal Monitore delle Strade Ferrate (Torino,3 maggio 1883) :

"Può gettarsi un ponte sullo Stretto di Messina ?"

- **"…..Secondo me,la vera scienza dell'ingegnere non deve consistere nel progettare e nell'eseguire opere colossali,ma bensì nel *raggiungere un dato scopo con la maggiore facilità e con la minore spesa possibile."***

(continua)

Alfredo Cottrau

estratto dal Monitore delle Strade Ferrate (Torino,3 maggio 1883) :

"Può gettarsi un ponte sullo Stretto di Messina ?"

- **"Il volgo va in estasi innanzi ad un elefante , una balena od una giraffa , mentre il naturalista ed il filosofo ammirano ben più la potenza del Creatore negli animali minuscoli o microscopici ; ed a mo' d'esempio , trovano più perfetta e sorprendente la *pulce* e la *formica* , che sviluppano , a parità di peso , una forza 40 a 50 volte superiore a quella dei più grossi quadrupedi."**

THE END

See you in …….2010