POLITECNICO DI MILANO

THE WORLD'S GATHERING PLACE FOR ADVANCING CONCRETE

aci CONCRETE CONVENTION

The bridges in Italy: state of the art, case studies, research in progress and rational approaches to select intervention priorities.

Marco di Prisco and Giulio Zani
Department of Civil and Environmental Engineering
Politecnico di Milano

Collapses in Italy in the last 9 years (man made hazards)

Carasco, October 22th, 2013

Lecco, October 29th, 2016

Ancona, March 9th 2017

Fossano, April 18th 2017

Bologna August, 6th 2018

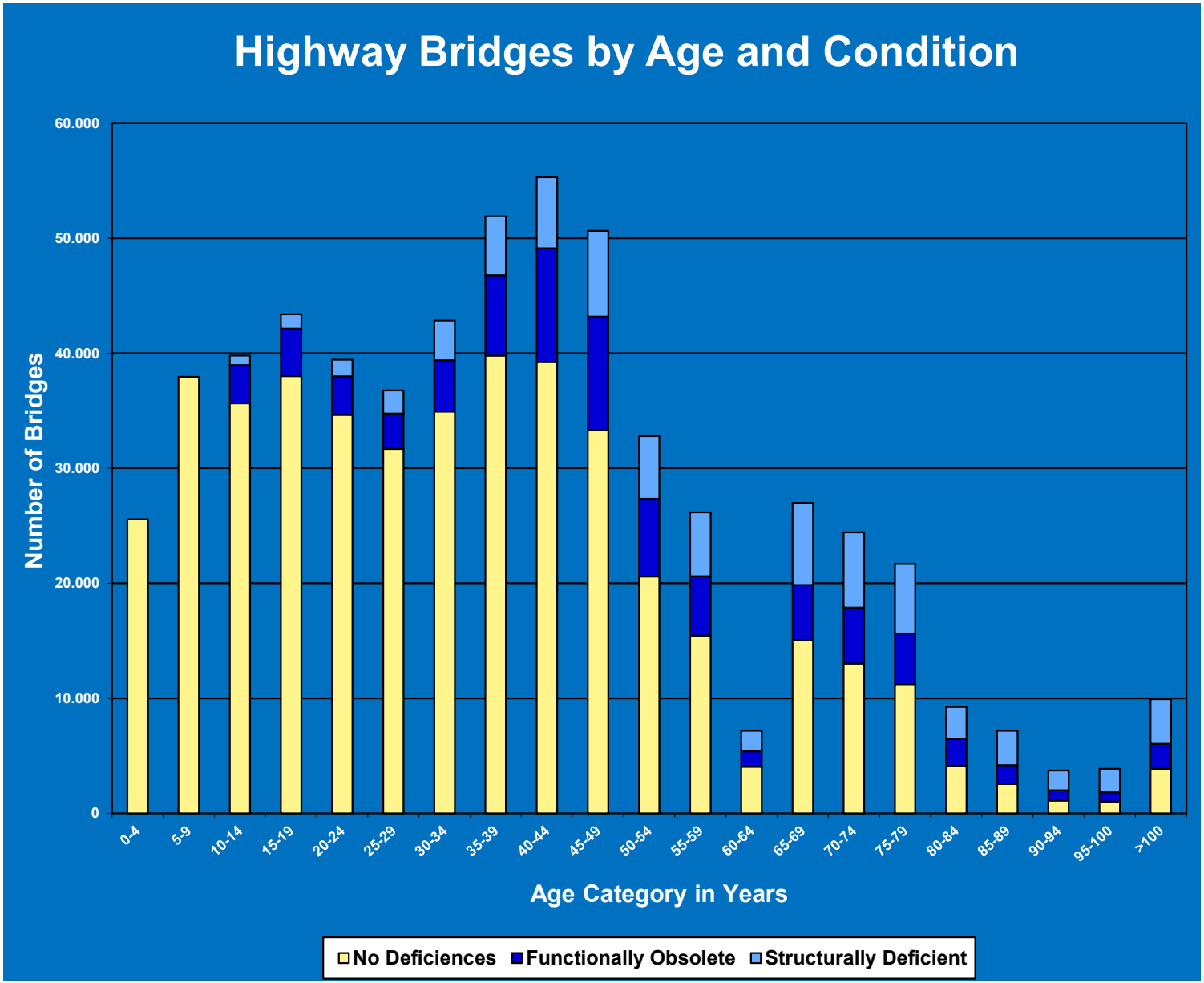
Genova August, 14th 2018

Albiano April, 9th 2020

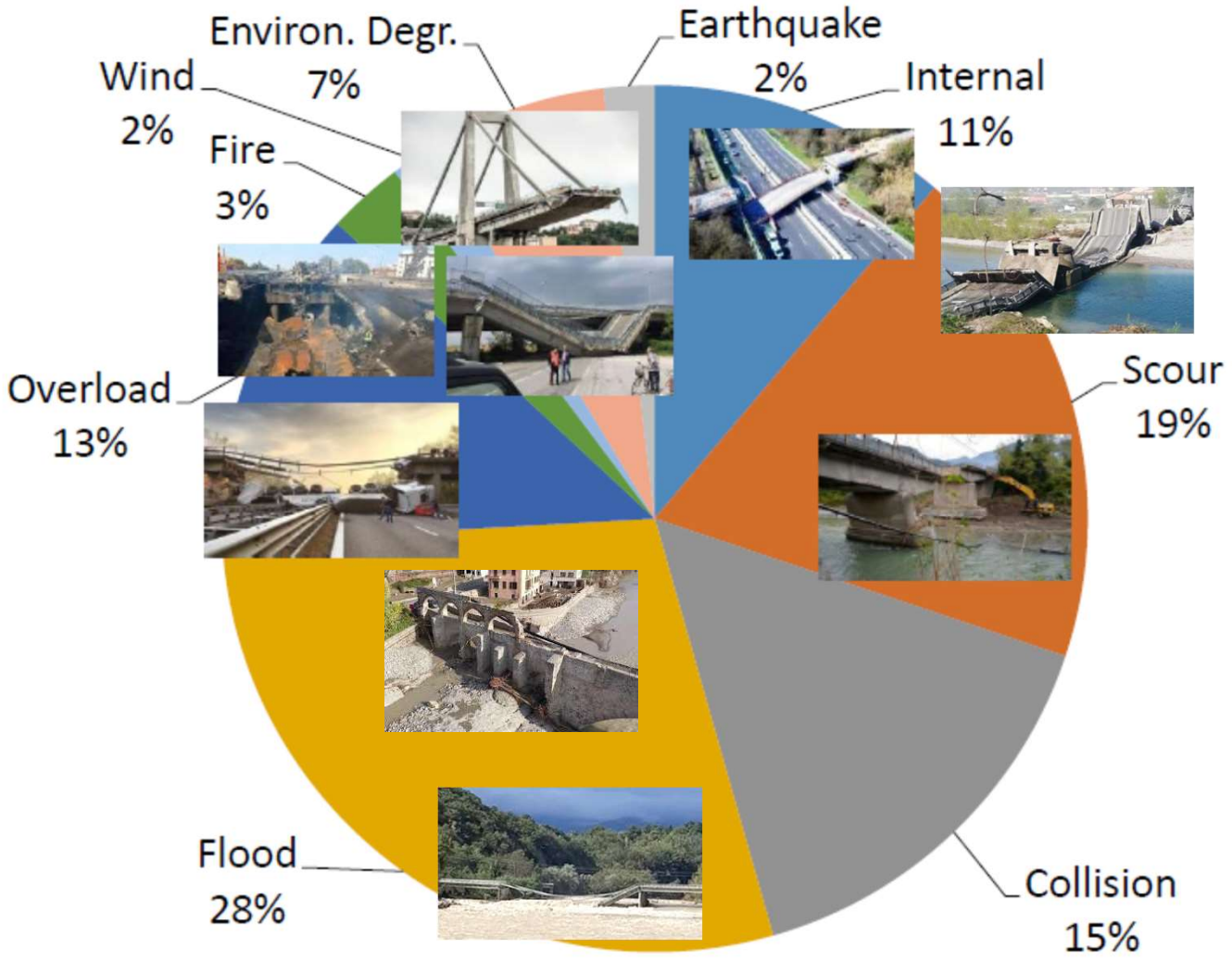
Romagnano October, 3th 2020

Bagnasco, October 3th 2020

courtesy by W.P. Yen



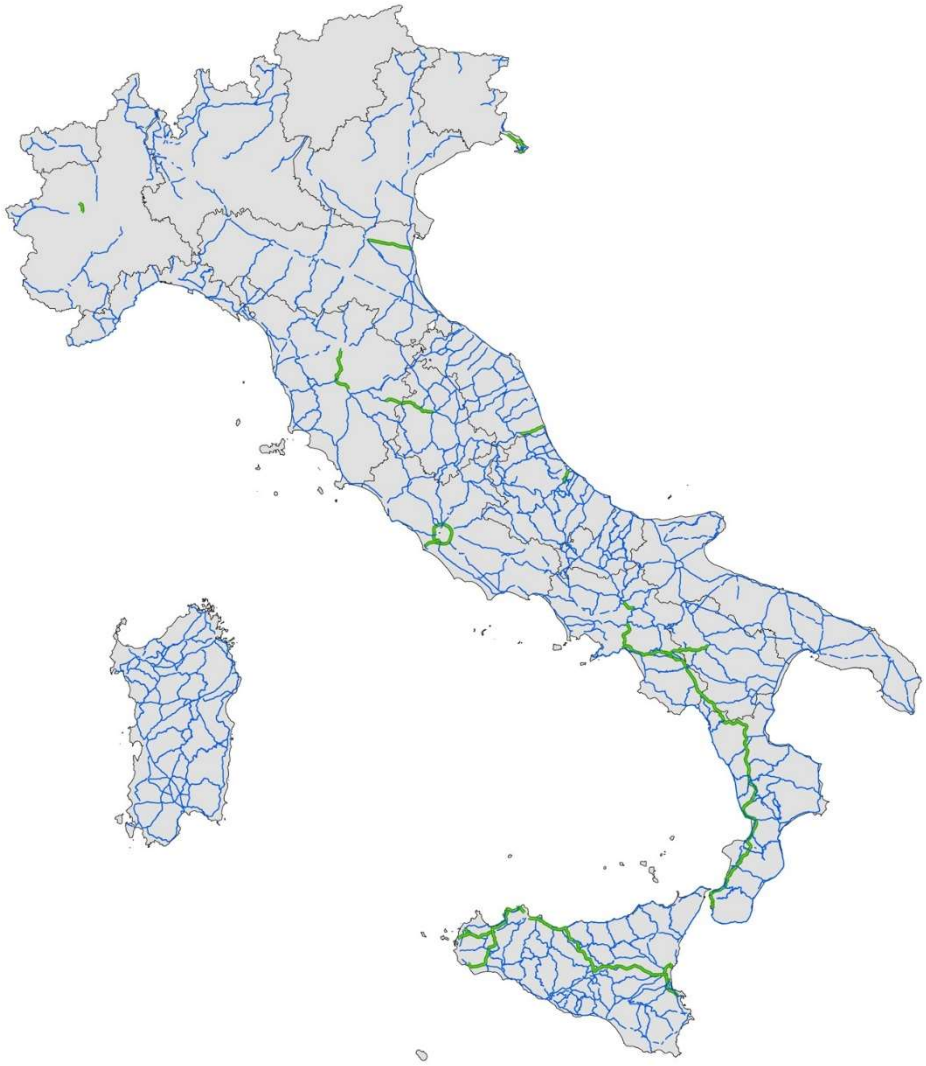
Bridge Failures 1980 ~ 2012 (Total 1.062 failures over 600.000 highway bridges)



The risk can be mitigated only if the collapse causes are suitably taken into account!

Railway (RFI)

Roadway (ANAS)



«bridge» : minimum span 6m

Railway

first line:	1839
total net length:	21,000 km
high speed:	1467 km
agencies:	23
main agency:	**RFI**
RFI net	17000 km
RFI control:	83%
viaducts:	1,575
bridges:	8,085
employers:	25,540

1 bridge / 3 km

Roadway

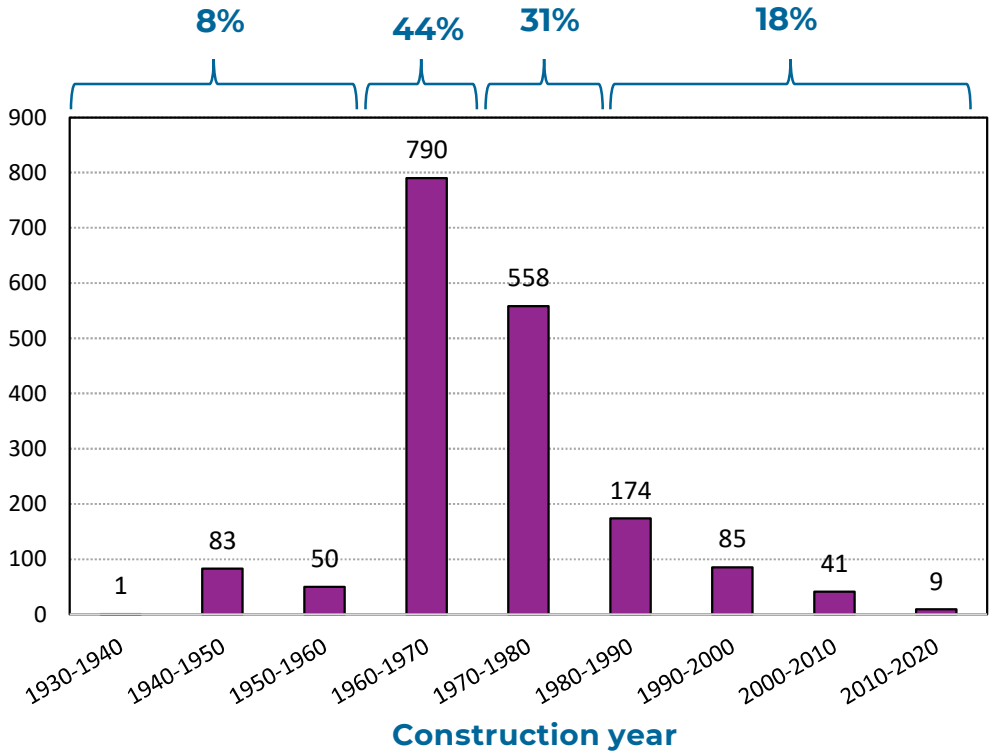
first paved road:	1900
total net length:	837,493 km
highway length:	7,472 km
highway agencies:	32
main agency:	**ANAS**
ANAS net:	30,000 km
Anas control:	3.5%
ANAS highways:	900km
highway bridges:	14,603
employers:	6,027

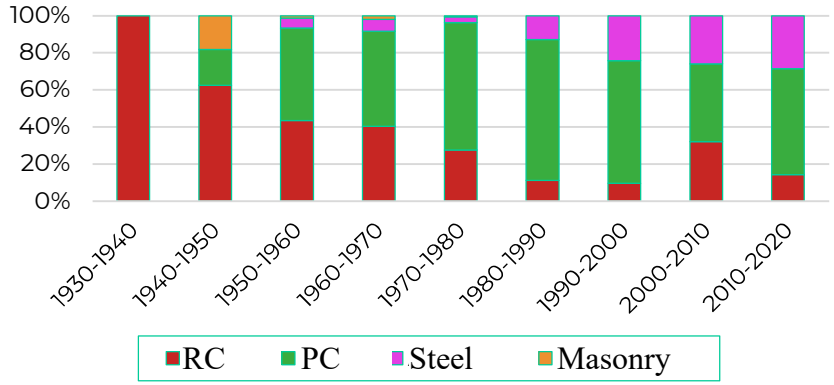
Anas: 1 bridge / 2 km

N.B. According to ANAS, around 1425 overpasses on highways do not have a recognized owner

Autostrade per l'Italia

courtesy by MOVYON



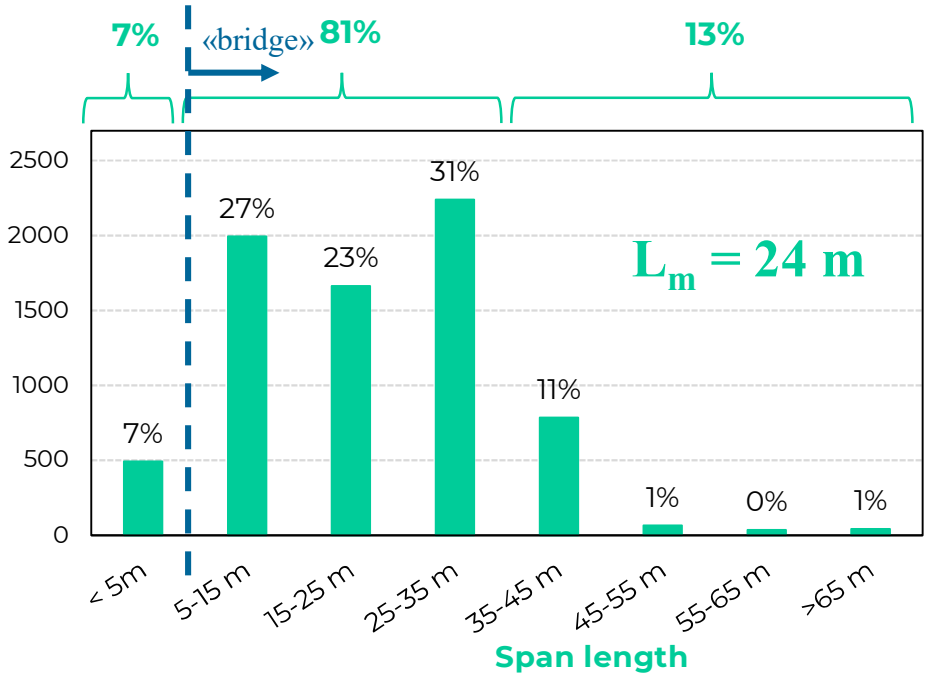


2.855 km highways

1943 bridges/viaducts

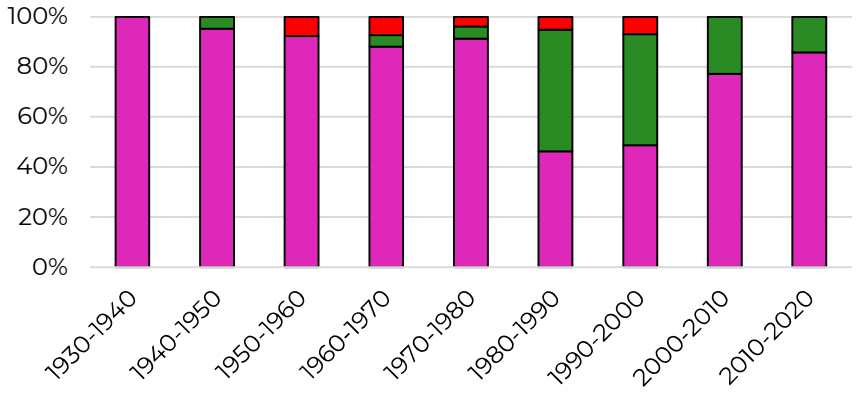
1798 overpasses

1 bridge/1,5 km



courtesy by MOVYON

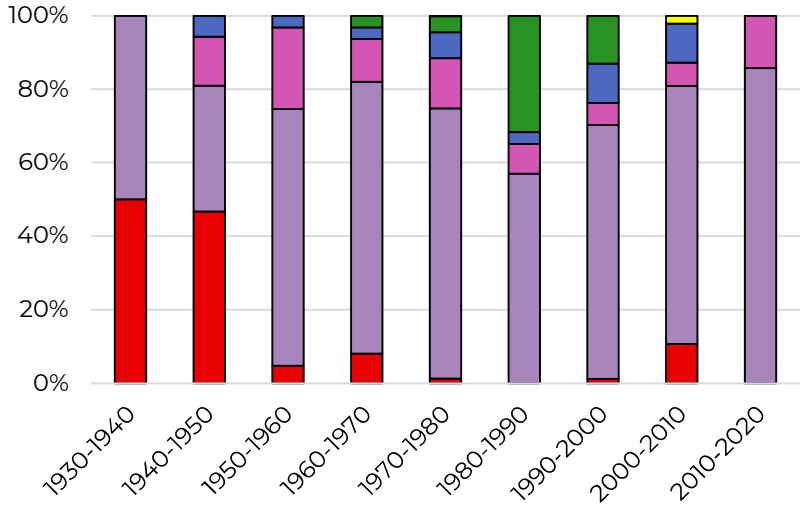
Autostrade per l'Italia



DAPPED-END

SIMPLY SUPPORTED

CONTINUOUS BEAM



STATIC SCHEME

ARCH

FRAME

COUPLED BEAMS

CAISSON

THICK SLAB

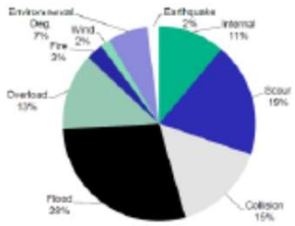
TYPOLOGY

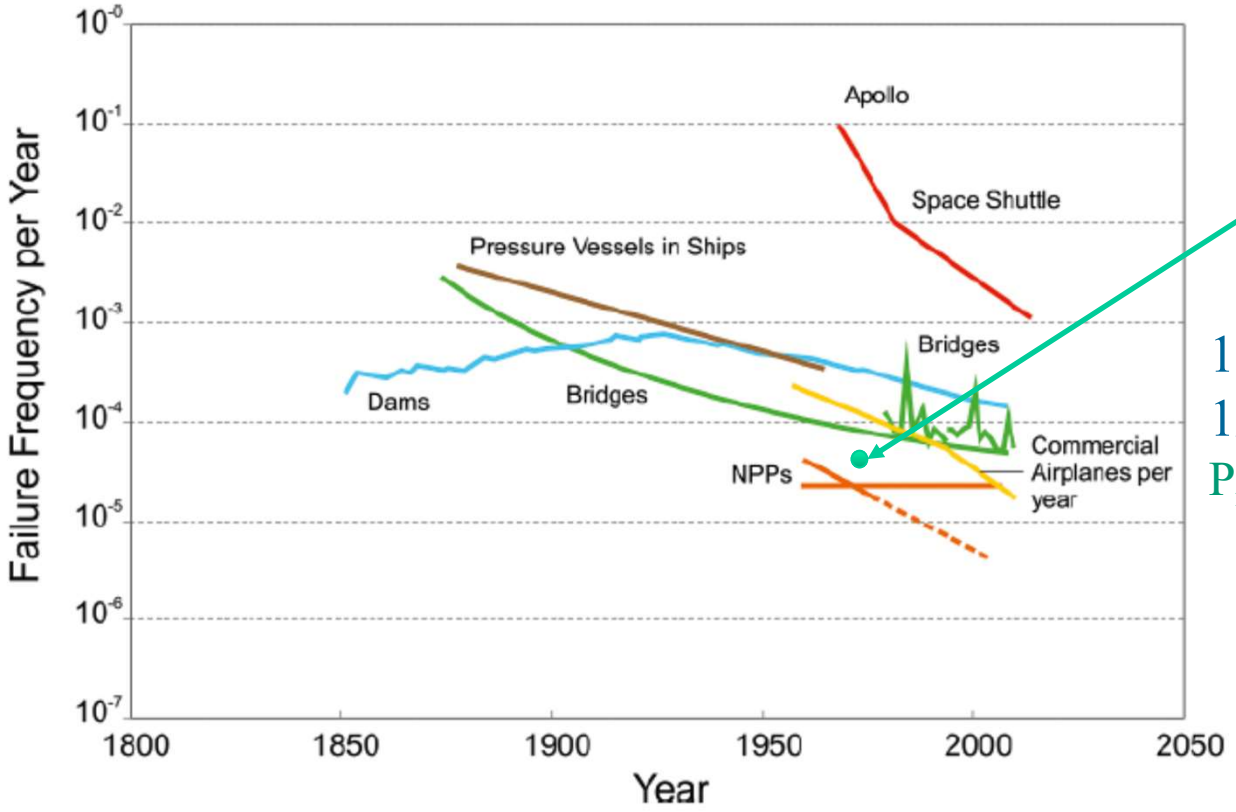
Risk associated to different constructions

fib Symposium Melbourne, 2018

1'062 Failures / 600'000 bridges in US
1980-2012, $5 \cdot 10^{-5}$/year

P_r in 50 years = $2.7 * 10^{-3}$





Failure frequencies per year given for different technologies

Italy

1 bridge failure/year

$1/400000 = 2.5 * 10^{-6}$

P_r in 50 years = $1.25 * 10^{-4}$

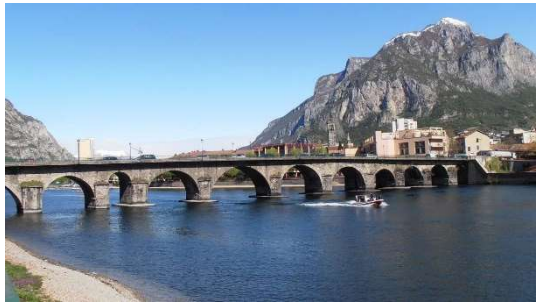
400k€/(km*year)

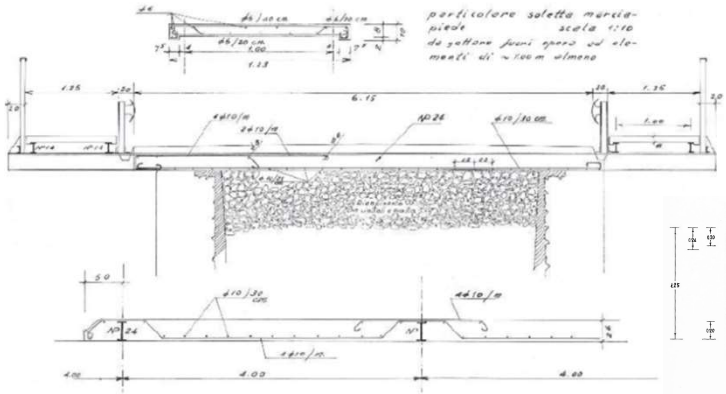
courtesy by A. Muttoni

Case studies

Which Service Life for a bridge and which criteria for their maintenance?

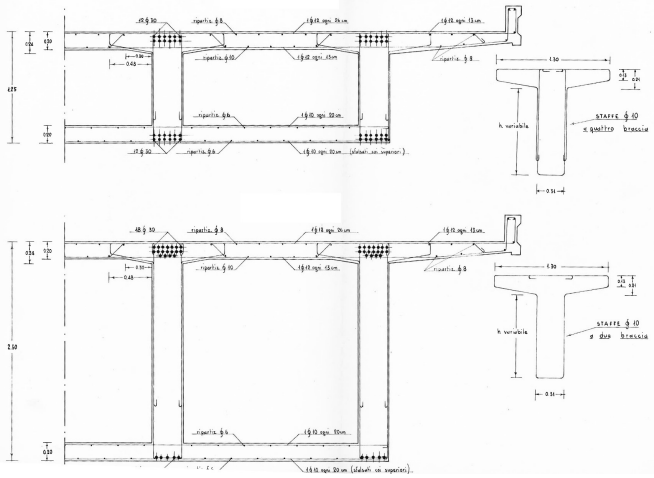
Azzone Visconti, 1336-1338 (131m, 11 spans)



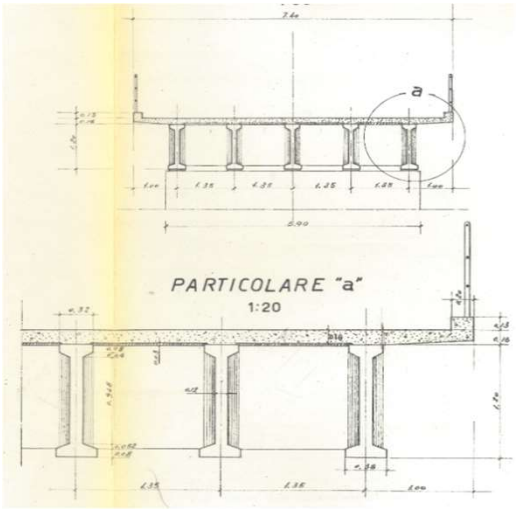


Mella, 1950s (42 m, 3 spans)

post-tensioned cast on site

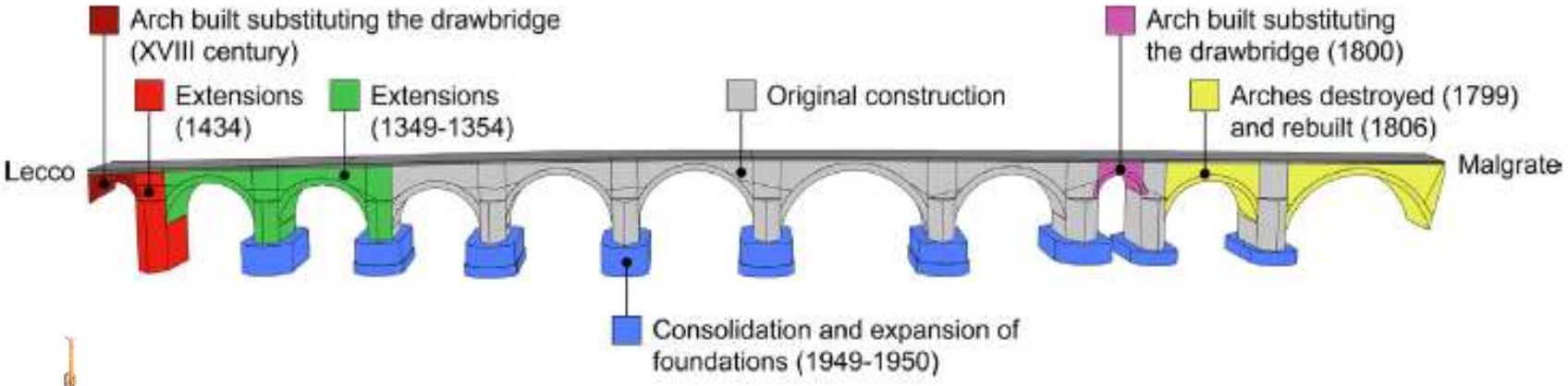


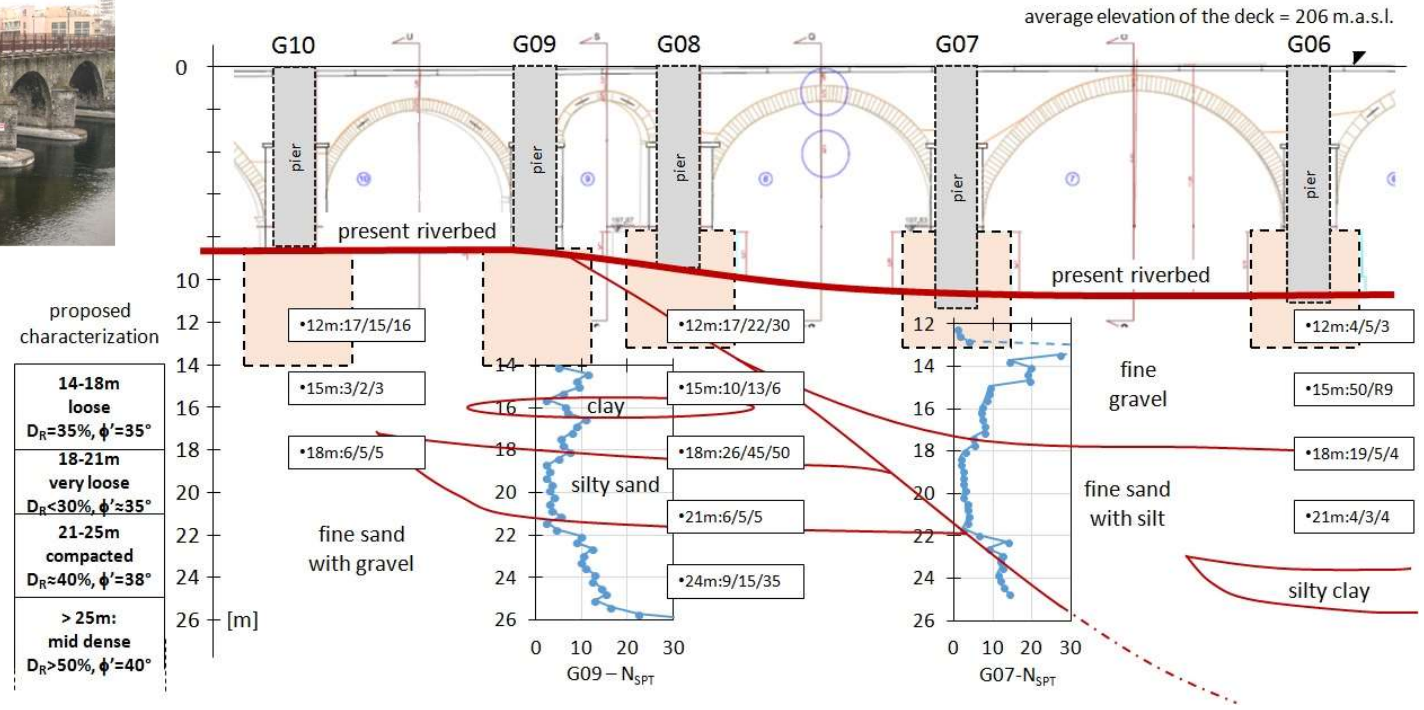
Annone, 1960s (56.1 m, 3 spans)



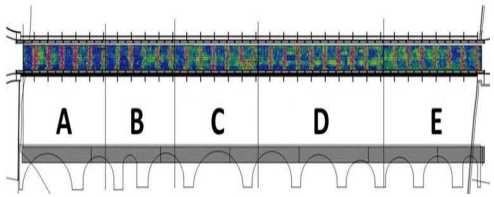
prefab prestressed beams and cast-on-site

Uncertainties in the diagnosis of ancient bridges

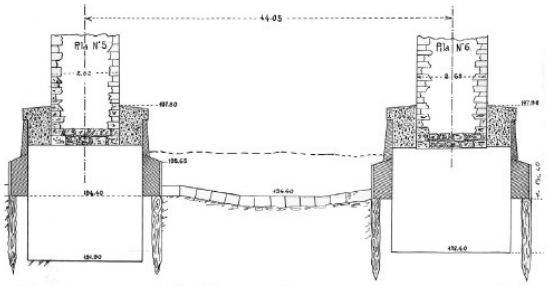


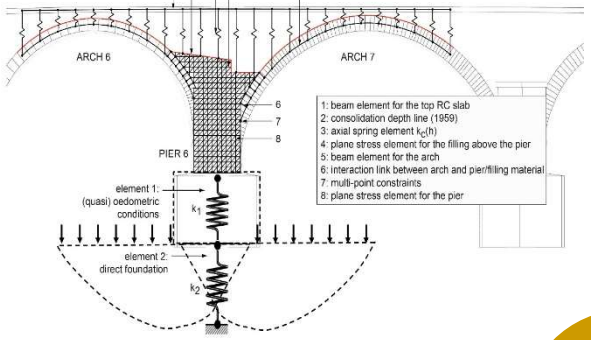


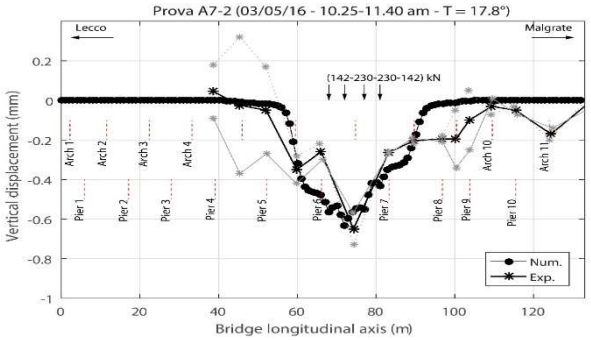
Advanced diagnostics



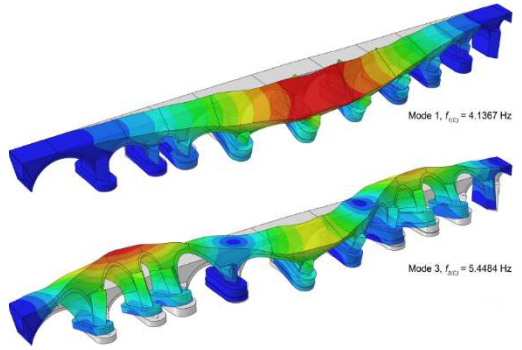
Controlled static tests

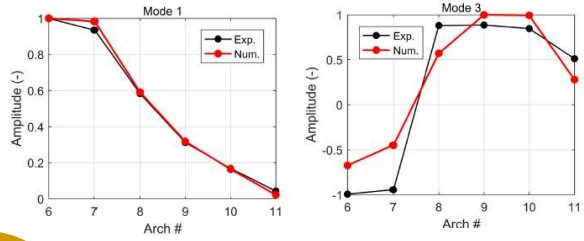






dynamic tests





BIM Model

Mella Bridge

Multicellular RC bridge

Built in the 1950s

Skew deck, deck width 17.6 m

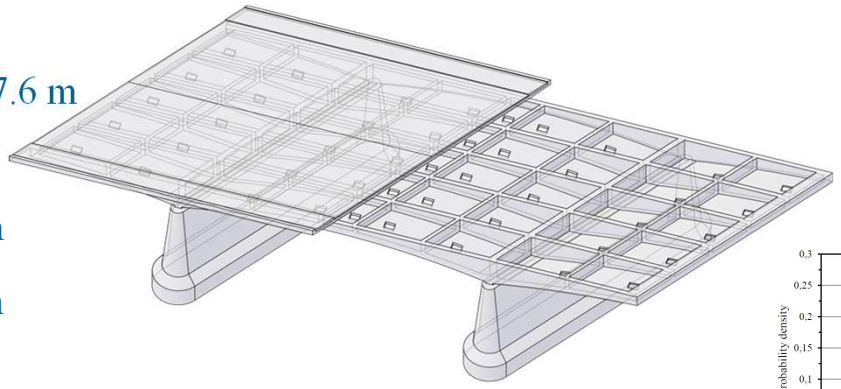
Total length 42.8 m

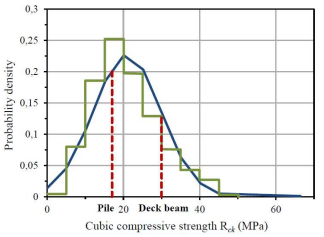
3 spans: 22 m + 2×10.4 m

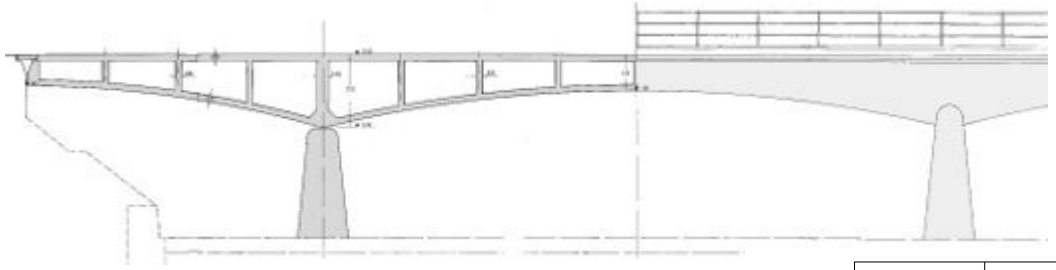
Variable depth 1.4 - 2.8 m

Lead sheet bearings

2 piers on deep pile foundations







Element	$f_{cm}(t)$ (MPa)	f_{cm} (MPa)
Pier	**21.4**	14.8
Deck	**37.1**	25.7
	70 years	**28 days**

Original design report ✓

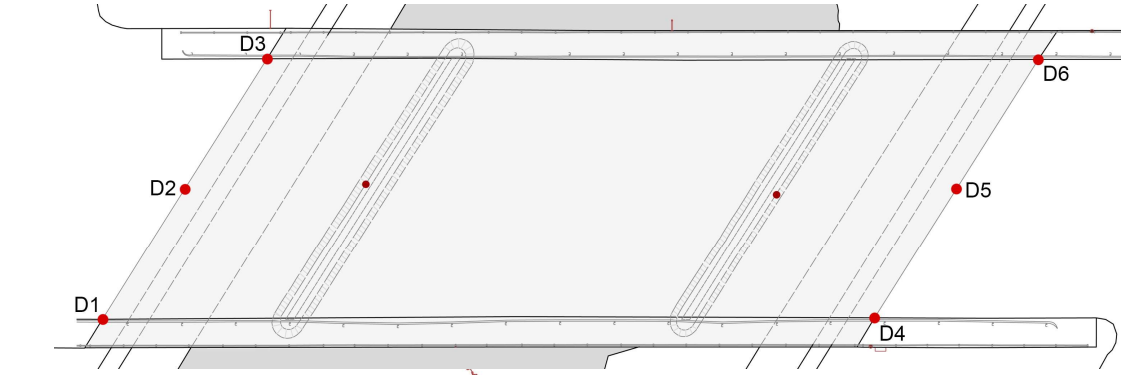
Original technical drawings ✓

Photos ✓

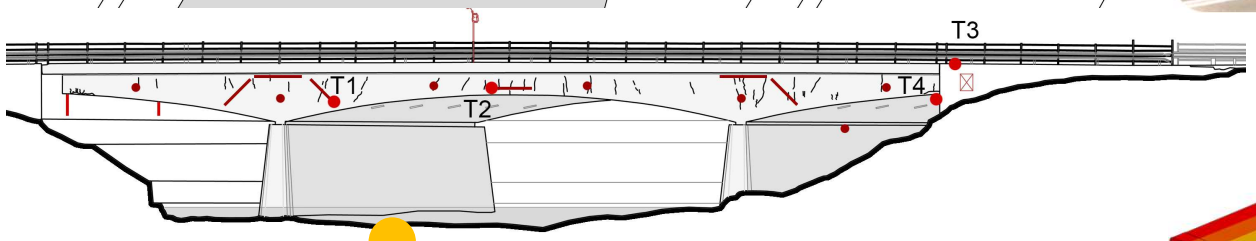
Inspection report ✓

Last inspection ≤ 10 years ✓

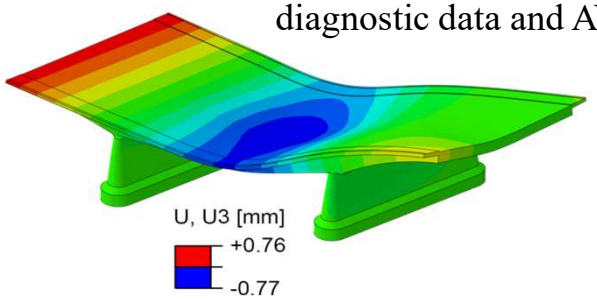
	Design reports	Technical drawings	Photos	Inspection reports	Date of the last inspection ≤ 10 y	Date of the last inspection > 10 y	Bridges per case	Bridges per level of completeness
LC-I	✓	✓			✓		48	67 (23.2%)
	✓	✗			✓		5	
	✗	✓			✓		14	
LC-II	✓	✓				✓	12	162 (56%)
	✓	✗				✓	2	
	✗	✓				✓	13	
	✗	✗	✓		✓		115	
	✗	✗	✗	✓		✓	20	
LC-III	✗	✗		✗		✓	13	60 (20.8%)
	✗	✗		✗	✗		47	



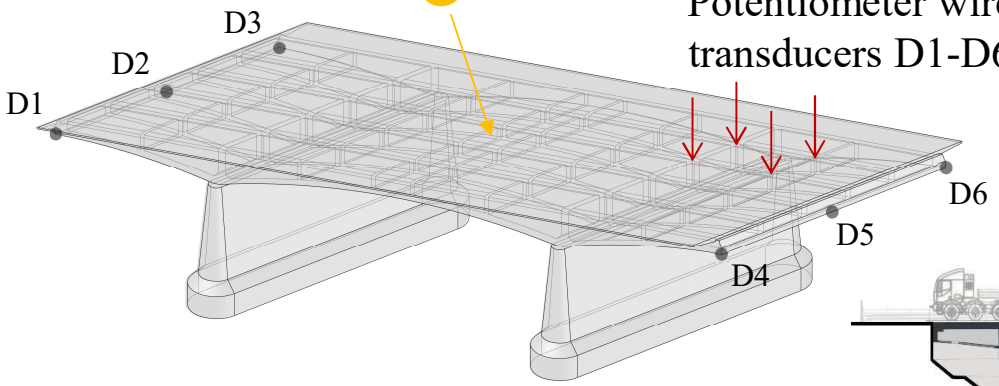
(34 axles, 76 m, 380 t)

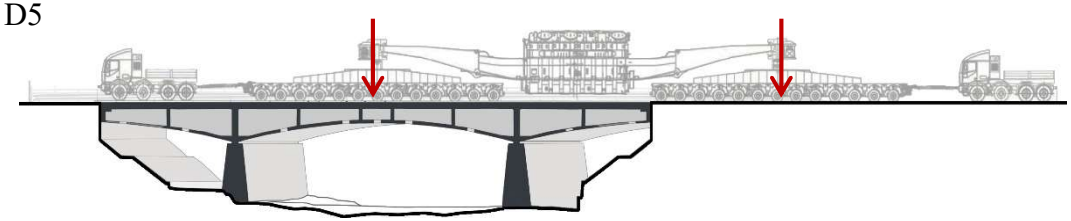


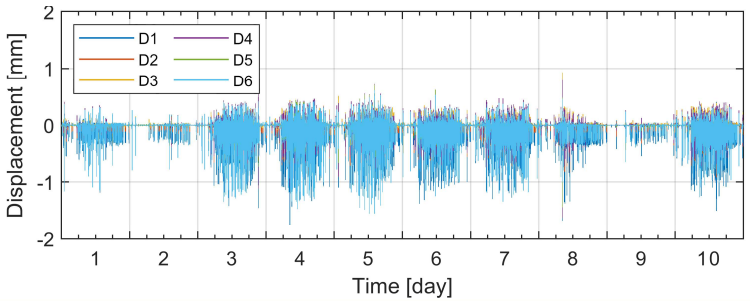
Model calibrated on diagnostic data and AVT



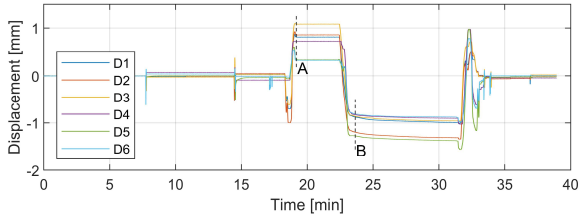
Potentiometer wire transducers D1-D6





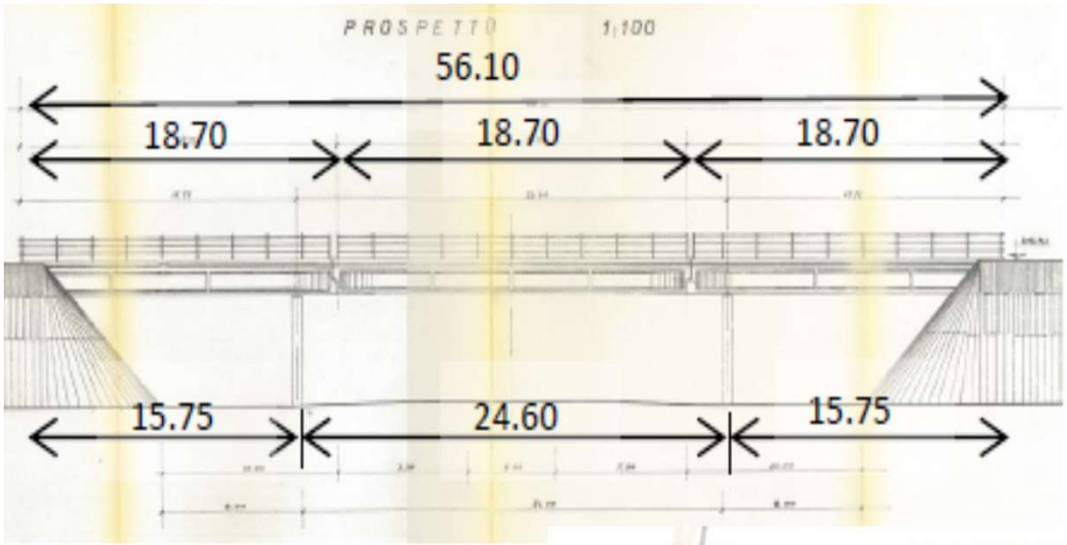


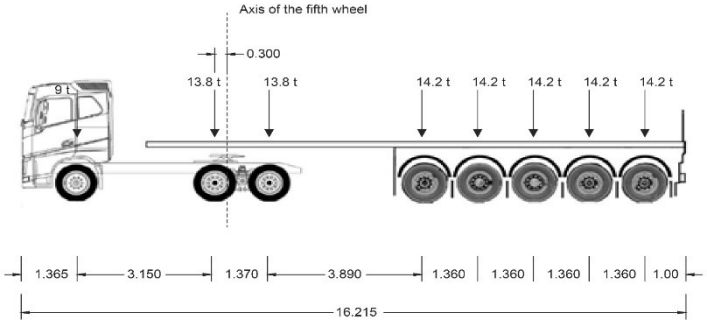
Under traffic loads, the vertical displacements range between +1 and -2 mm



Annone bridge

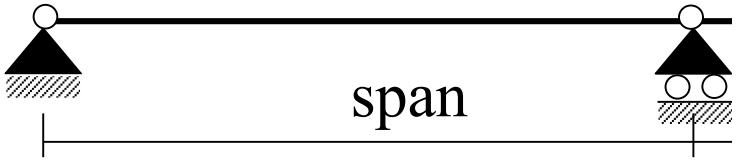
1 killed, 3 injured

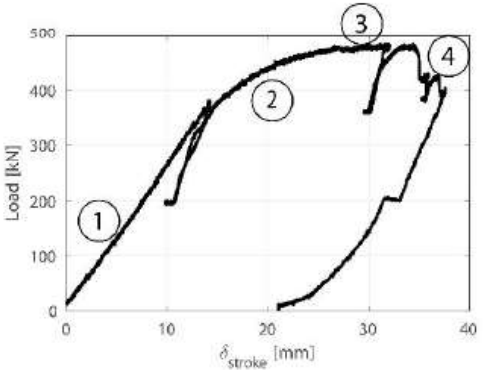


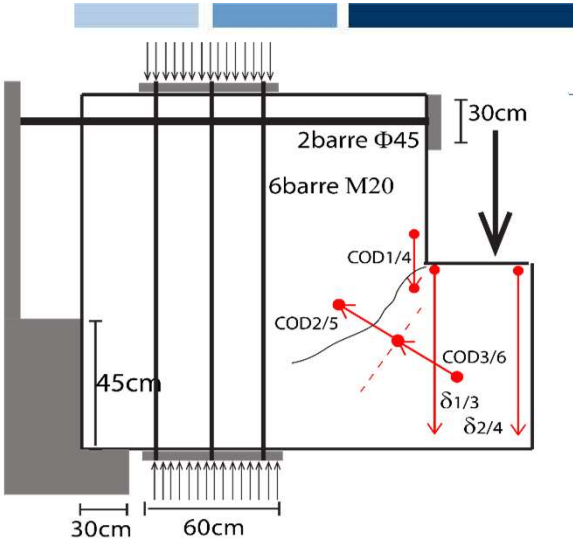


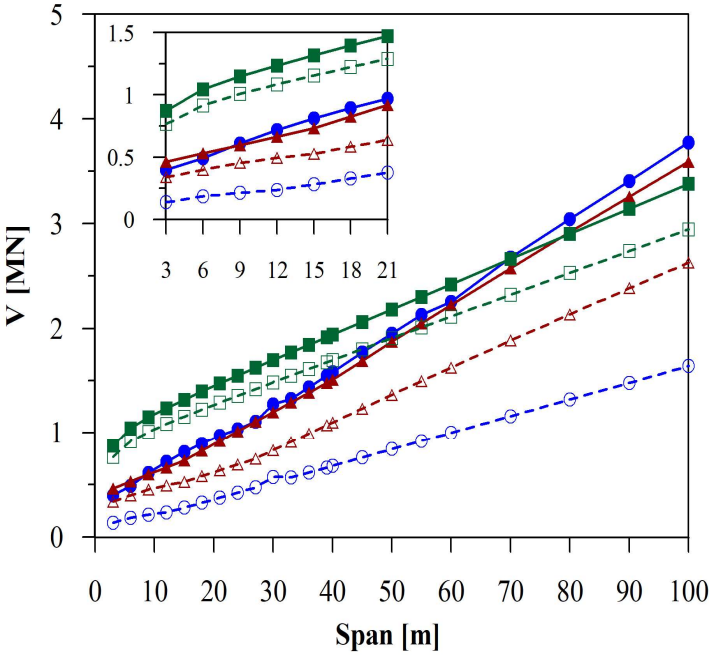
Total weight vehicle 107.6 t

Total load mid-span
172.3 t (> P_{calc} = 155t)

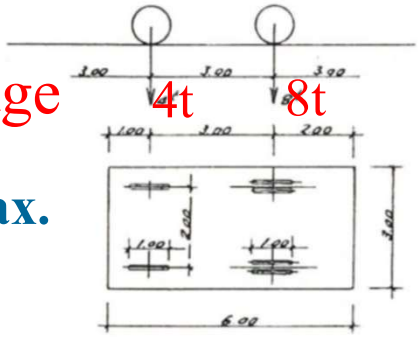




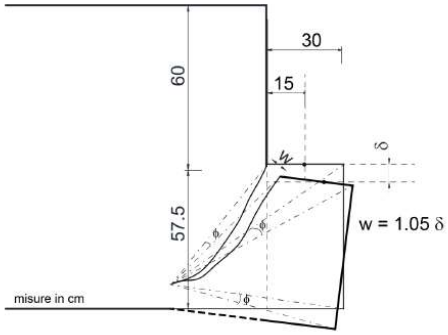


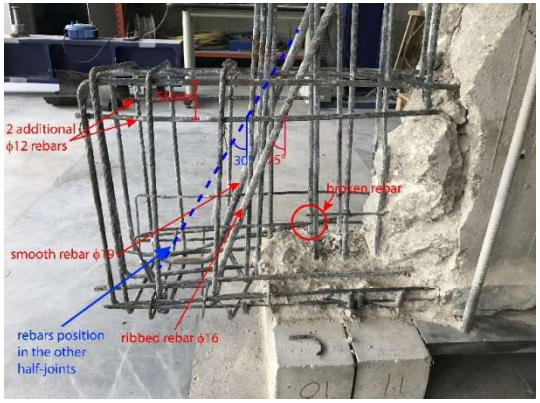


II class bridge



In 18.7 m, max. load of 36 t





August, 14th 2018

August, 3rd 2020

What reaction?

- ✓ **The project Lombardia Region – Politecnico di Milano** (2018-2021)
- ✓ **Strong increase of year-budget for bridge maintenance** (about 1 order of magnitude after 2016)
- ✓ **National guidelines issued by MIT** (April 2020)
- ✓ **MIMS/RELUIS national research project** (2021-2022)

Ministero delle Infrastrutture e dei Trasporti
Consiglio Superiore dei Lavori Pubblici

April 2020

LINEE GUIDA PER

LA CLASSIFICAZIONE E GESTIONE DEL RISCHIO,

LA VALUTAZIONE DELLA SICUREZZA

ED IL MONITORAGGIO DEI PONTI ESI

Allegate al parere del Consiglio Superiore dei Lavori Pubblici n.88/2019,
espresso in modalità "agile" a distanza dall'Assemblea Generale in data 17.04.202

Level 0 - census of infrastructures

Level 1 - visual inspections and defect cards

Level 2 analysis of relevant risks and classification on a territorial scale

Level 3 - preliminary evaluation of the infrastructure

Level 4 – Accurate verification

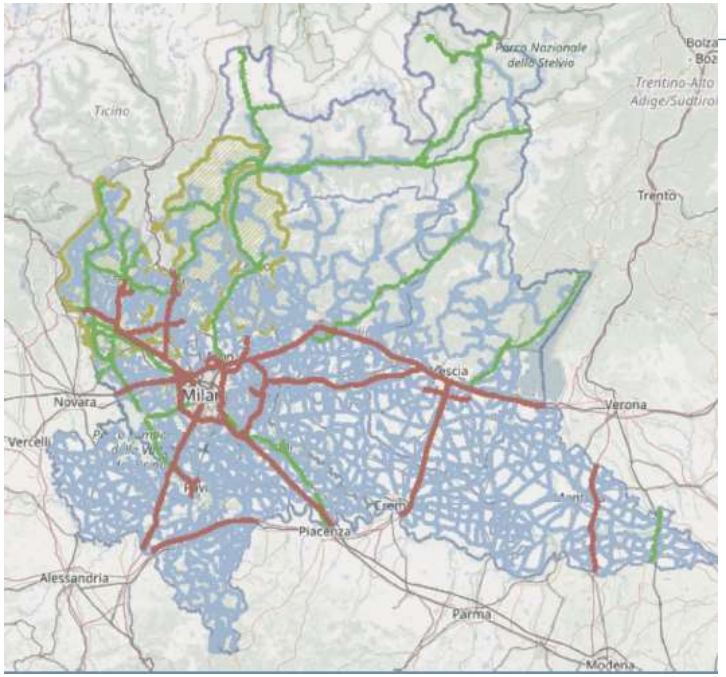
Mims
Ministero delle infrastrutture
e della mobilità sostenibili

15 M€
22 Universities
Check in 18 months

reluis

To the earth of the problem:

- ✓ *How to identify the priorities*
- ✓ *How to plan the interventions*



more than 10.000 bridges

AIM: measure of vulnerability, risk, social and economical impact

The Project – key steps

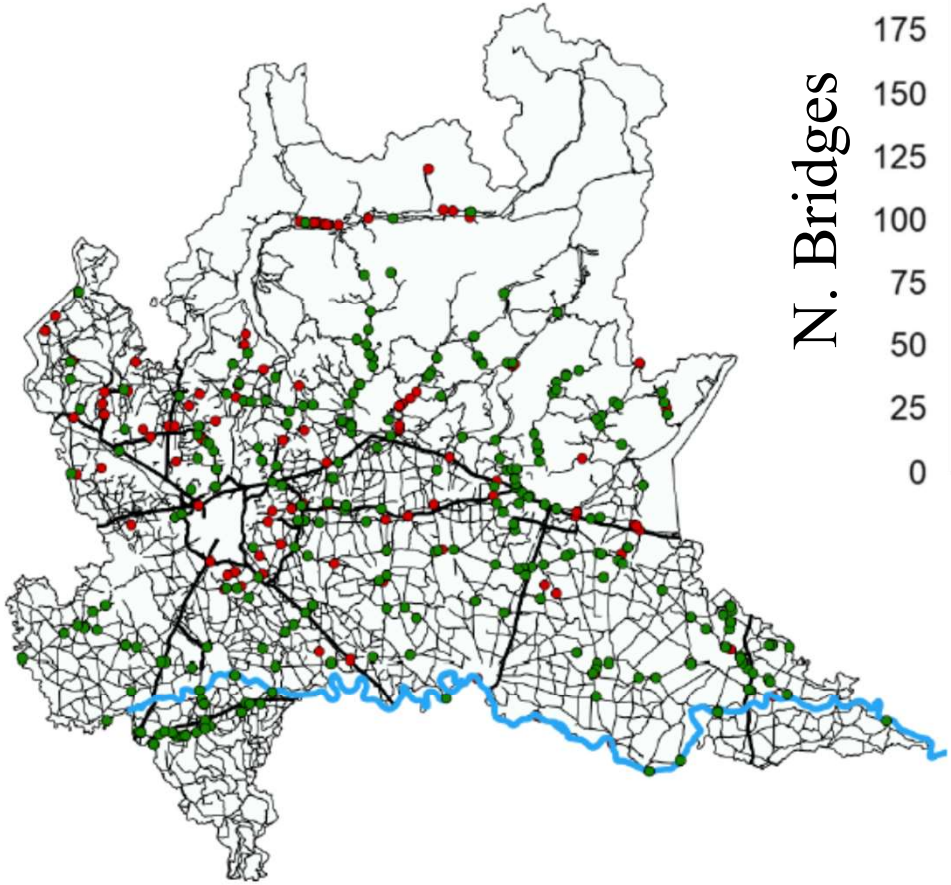
1. Identification of a representative sample
2. Composition of artefact register
3. Determination of a Risk Index system for every artefact
4. Attention and Priority threshold definition
5. Identification of Demonstration cases on which developing an advanced project of knowledge and design of the monitoring and intervention system
6. Guidelines and decision making support system

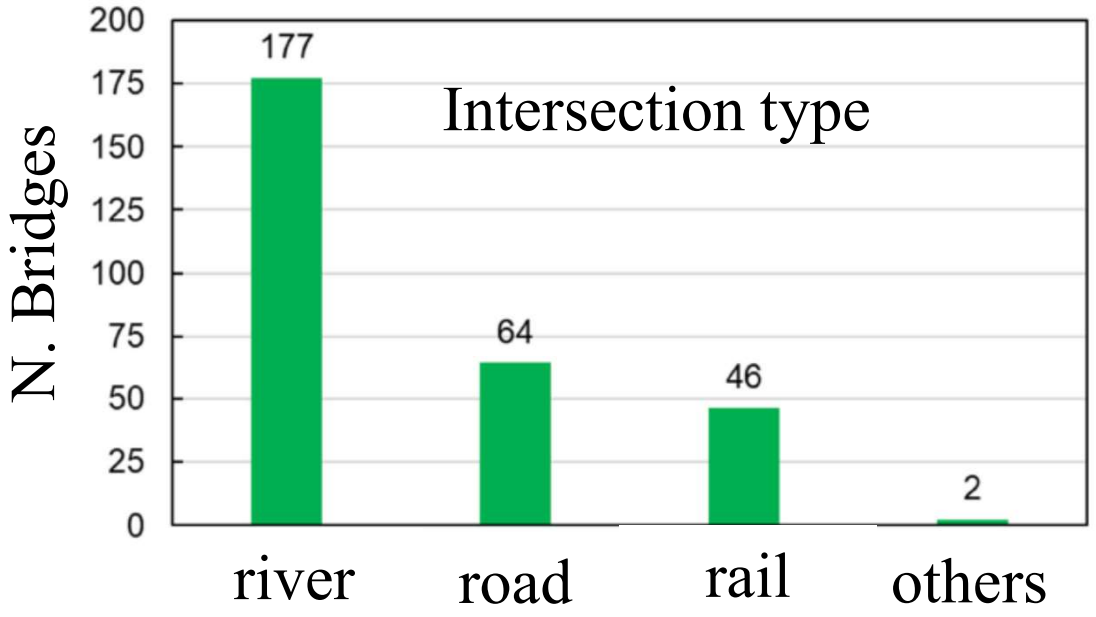
Bridge identity card

- ✓ Section 1 – Identification
- ✓ Section 2 – Localization
- ✓ Section 3 – Technical description of the structure
- ✓ Section 4 – Construction features
- ✓ Section 5 – Historical data
- ✓ Section 6 – Hydraulic data (for river bridges)
- ✓ Section 7 – Functionality data
- ✓ Section 8 – Exposure data
- ✓ Section 9 – MIT census

Around 90 data entries

12 province technical office involved





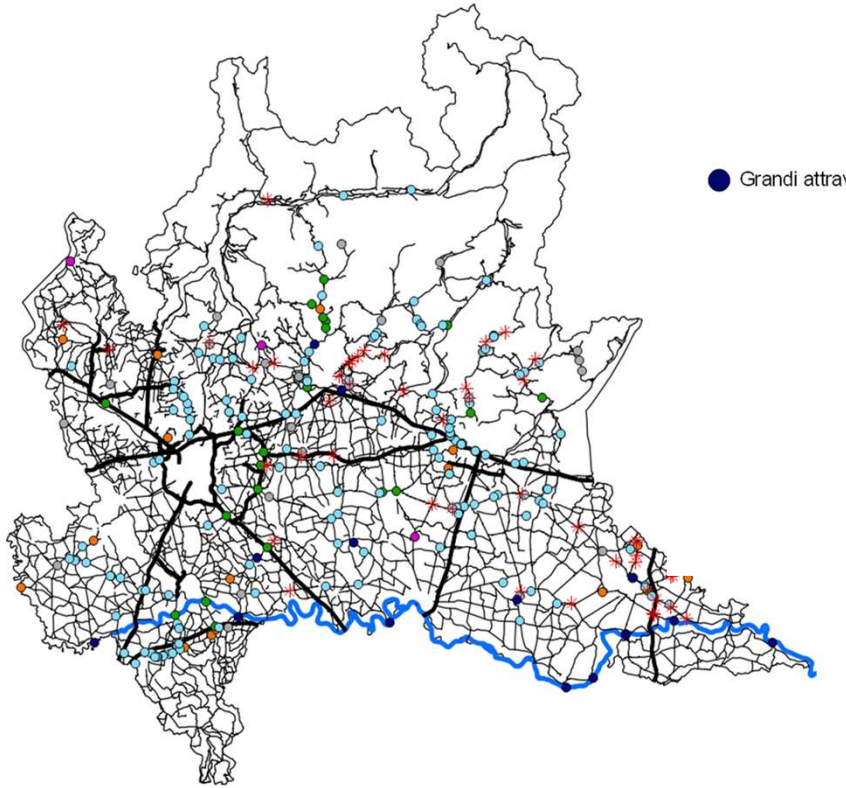
381 Selected bridges

289 Completed forms

~76% Completed forms

Completed form

Uncompleted form



CLUSTER	fluvial	others	total
RC and PC large crossings	12	3	15
RC and PC average span	74	82	156
Steel and hybrid	13	12	25
Masonry	16	2	18
RC and PC arches	24	1	25
Cable stayed	3	0	3
Not classified	35	12	47
Total	**177**	**112**	**289**

TECHNICAL DESCRIPTION OF THE STRUCTURE	• MATERIAL • MAX SPAN • …
TECHNICAL FEATURES	• DECK • PIERS, …
HISTORICAL DATA	• CONSTRUCTION YEAR • …
HYDRAULIC DATA	• FREE WIDTH • RIVERBED FOUND. …
FUNCTIONALITY DATA	• TGM • % HEAVY VEHICLES • …
EXPOSURE DATA	• SEISMIC RISK • HYDROGEOL. RISK …

Elaboration by means of logical and algebric operators with calibrated rules based on expert judgements

ATTENTION CLASS *k*

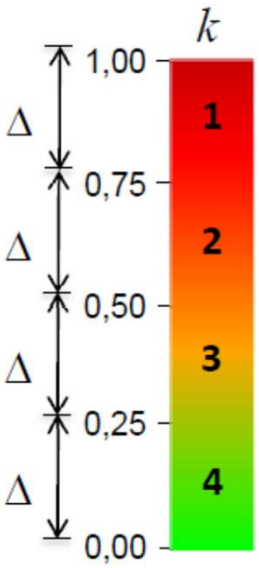
1 HIGH

2 MEDIUM-HIGH

3 MEDIUM-LOW

4 LOW

Priority Index



$$PI = PI_0(k) + \alpha(k)\Delta(k)$$

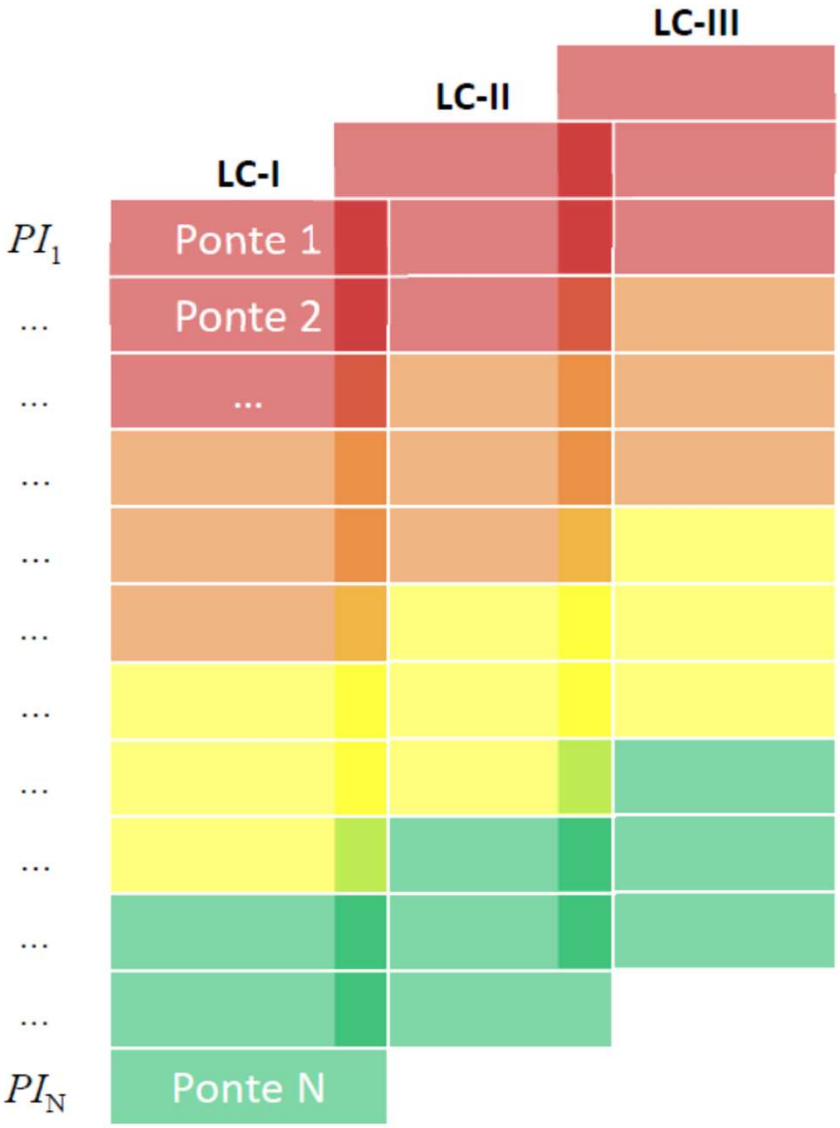
k : Attention class

PI : Priority Index

$PI_0(k)$: Initial Priority Index

$\Delta(k)$: Amplitude of class k

$\alpha(k)$: Class coefficient



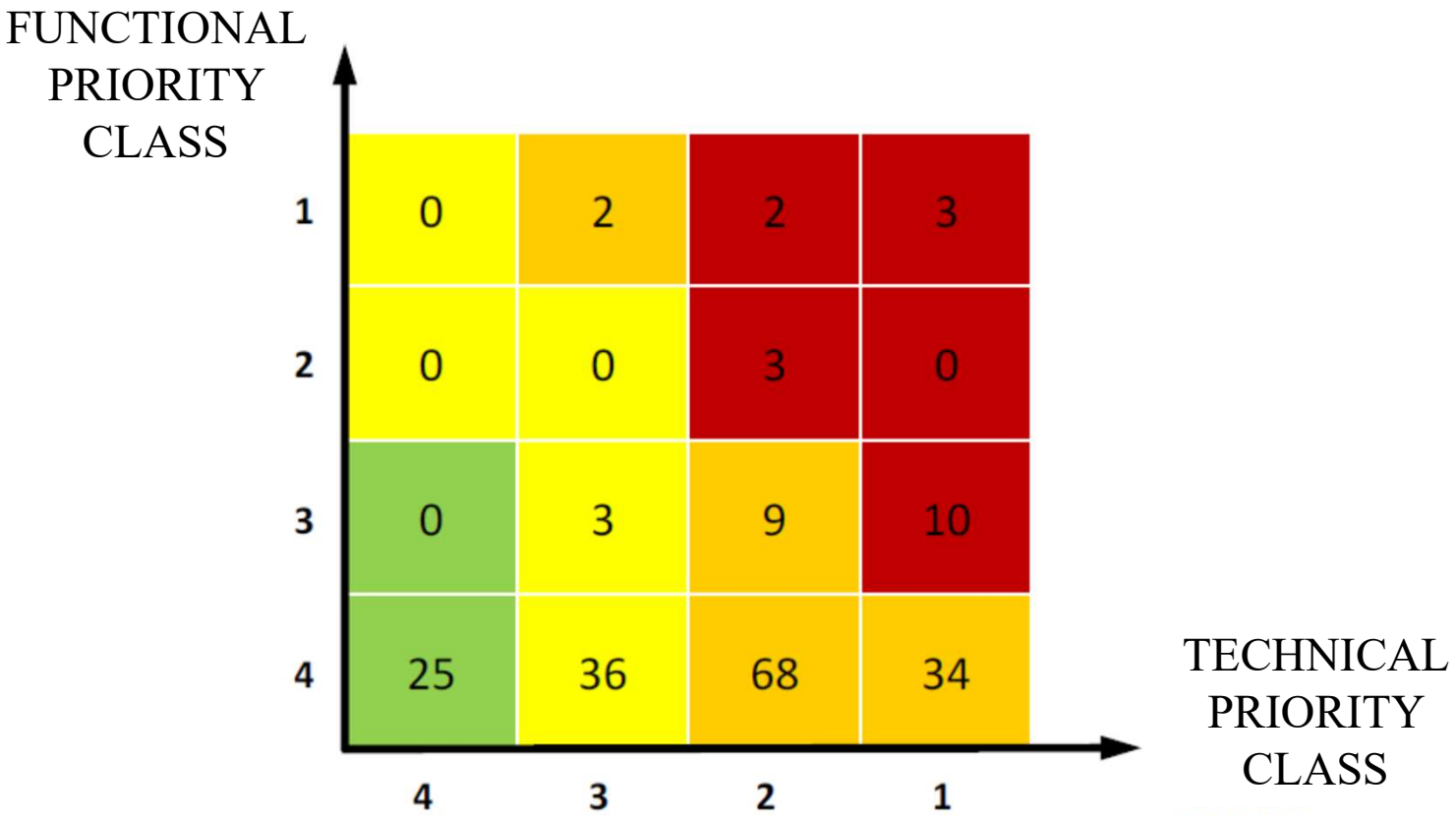
LEVEL OF COMPLETENESS

LC-I Complete information

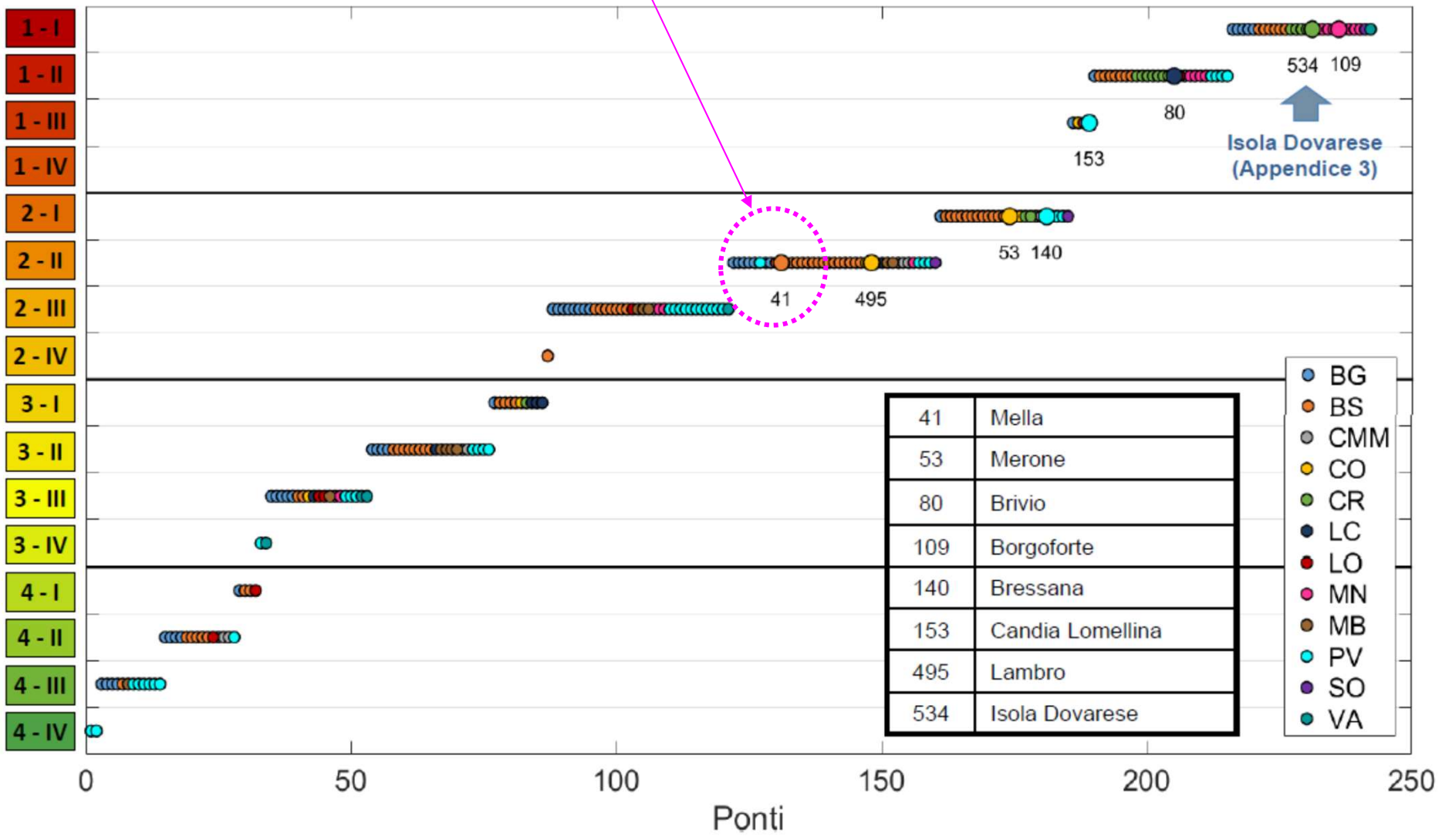
LC-II Sufficient information

LC-III Insufficient information

1	Urgent need of re-classification and, if needed, intervention (monitoring, maintenance, repairing, restrictions and functional alterations)
2	Need of re-classification and, if needed, intervention (monitoring, maintenance, repairing, restrictions and functional alterations)
3	Inspection priority, check and implementation of the maintenance plan
4	Regular inspection activity, as prescribed by the law



Case study: Bridge on Mella river

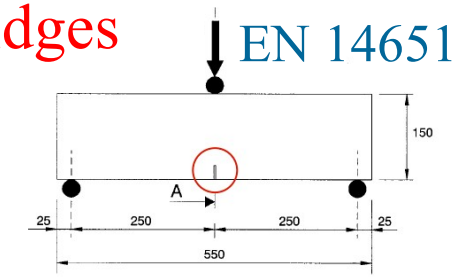


Concluding remarks

- ✓ The bridge failure of the last years corresponds to a quite high risk, athough aligned with other accepted risks
- ✓ Only a significant increase of maintenance resources will be able to progressively reduce it
- ✓ The bridge construction wave, scantly documented, will require strong efforts to improve diagnostics devices as well as durability and retrofitting research
- ✓ There is an urgent need to suggest prioritization rules to suitably canalize the first available resources
- ✓ The introduction of carefull maintenance plans should homogeneize maintenance policies to control bridge serviceability and safety during their life (that often does not coincide with that adopted to define the design loads)
- ✓ A clear definition of roadway corridors for exceptional load trucks could allow an important resource saving

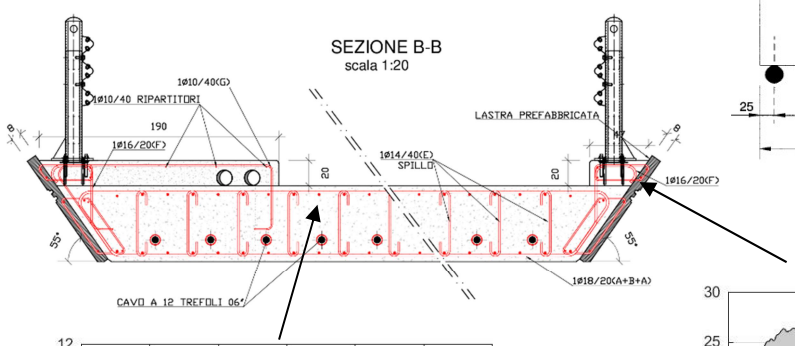
Use of FRC and HPFRC in bridges

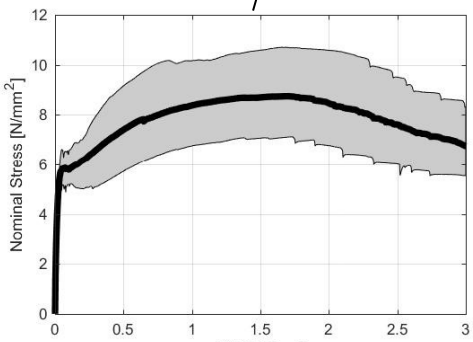
EN 14651

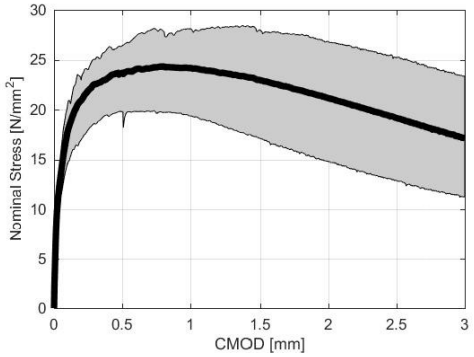


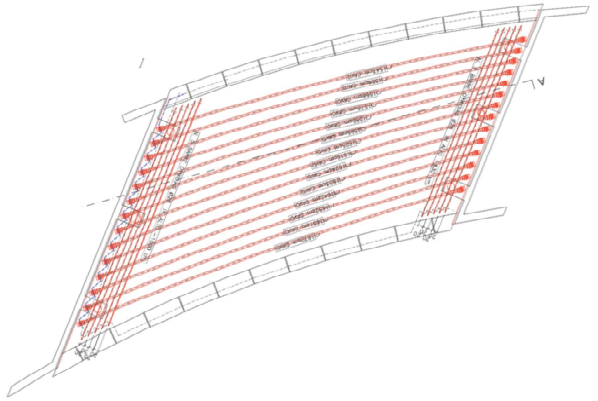
L = 16,5 m; h = 0.6 m

L/h > 27









Cost increase = 20k€ (+5%)

Total cost = 420 k€

= 3,2 k€ /m²

Swiss maintenance cost

6800 € /year ≅ 3 year cost

Thank you for your kind attention!

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