SHM for civil engineering assets – a client view

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Introduction

Structural materials – rough timeline

Masonry	from Roman times
Cast iron	pre 1800 to 1850
Wrought iron	1840 to 1900
Steel	from 1890
Reinforced concrete	from 1920
Prestressed/post tensioned concrete	from 1960
Fibre reinforced polymers	from 2000

UK infrastructure networks

Network Rail (Great Britain)	16,000km of railway with 40,000 bridges, 17,000 retaining walls, 700 tunnels and 2,500 stations
London Underground (London)	400km of railway with 270 stations and 180km of tunnels
Highways Agency (England)	7,754km of trunk road and motorway with 17,000 structures including 8,800 bridges
Local roads (Great Britain)	380,000km of roads with around 80,000 bridges
British Waterways (Great Britain)	3,540km of canal with 1,654 locks, 54 tunnels, 3,115 bridges, 417 aqueducts and 91 reservoirs
Water supply & waste water (Great Britain)	700,000km of mains and sewers with 1,000 reservoirs and 11,500 sewage and water treatment works
Transco - electricity transmission (Great Britain)	7,206km of overhead cables with 21,863 towers 994km of underground cables
Transco - gas transmission (Great Britain)	7,600 km of underground pipelines

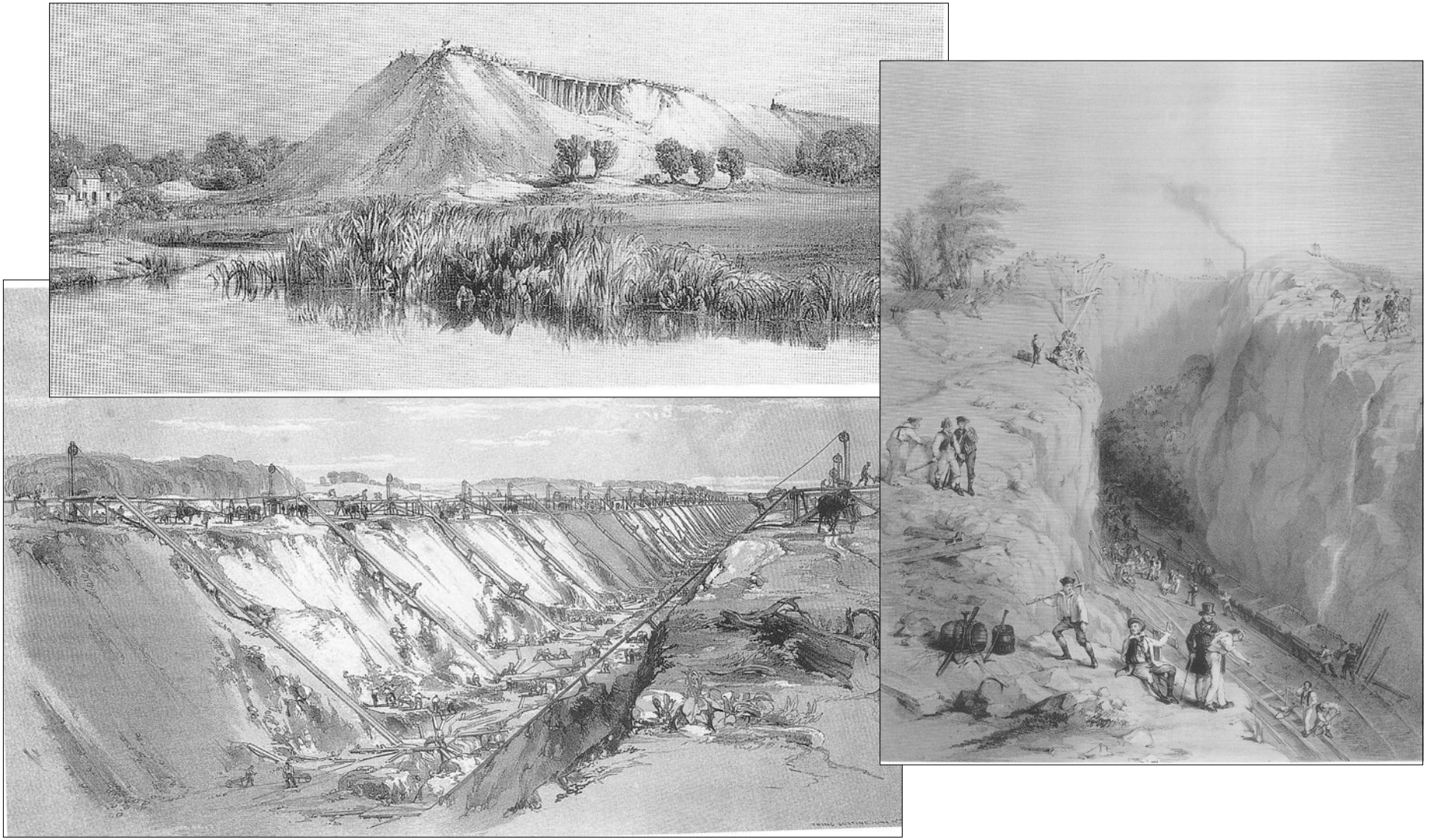
The growth of railways in the UK

1832	166 miles
1842	1839 miles
1852	6913 miles
1862	8300 miles
1872	11300 miles
1882	14050 miles
1892	14550 miles
1902	15000 miles

The growth of motorways

1958	8 miles
1968	623 miles
1978	1579 miles
1988	1908 miles
1998	2112 miles

How most canals and railways were built



How most railways and canals were built

Network Rail's bridges – age profile

70%	over 100yrs old
13%	50 - 100 yrs old
10%	20 - 50 yrs old
7%	less than 20 yrs old

Network Rail's bridges – material profile

50% masonry arches	(average age 145 yrs)
40% steel or wrought iron	(average age 70 years)
10% concrete	(average age 35 years)

Do we man what we say?

- "Failure" is an emotive word and means different things to different people
  - I would prefer "loss of functionality" or "collapse"
- Does the public really understand the concept of "risk"?
- Does the industry really understand the concepts of "serviceability limit state" and "ultimate limit state"?
  - No owner ever wants to get near ULS, but is probably happy to approach SLS
- What is meant by "service life" or "design life"?
  - Should a structure be fully serviceable at the end of its design life?

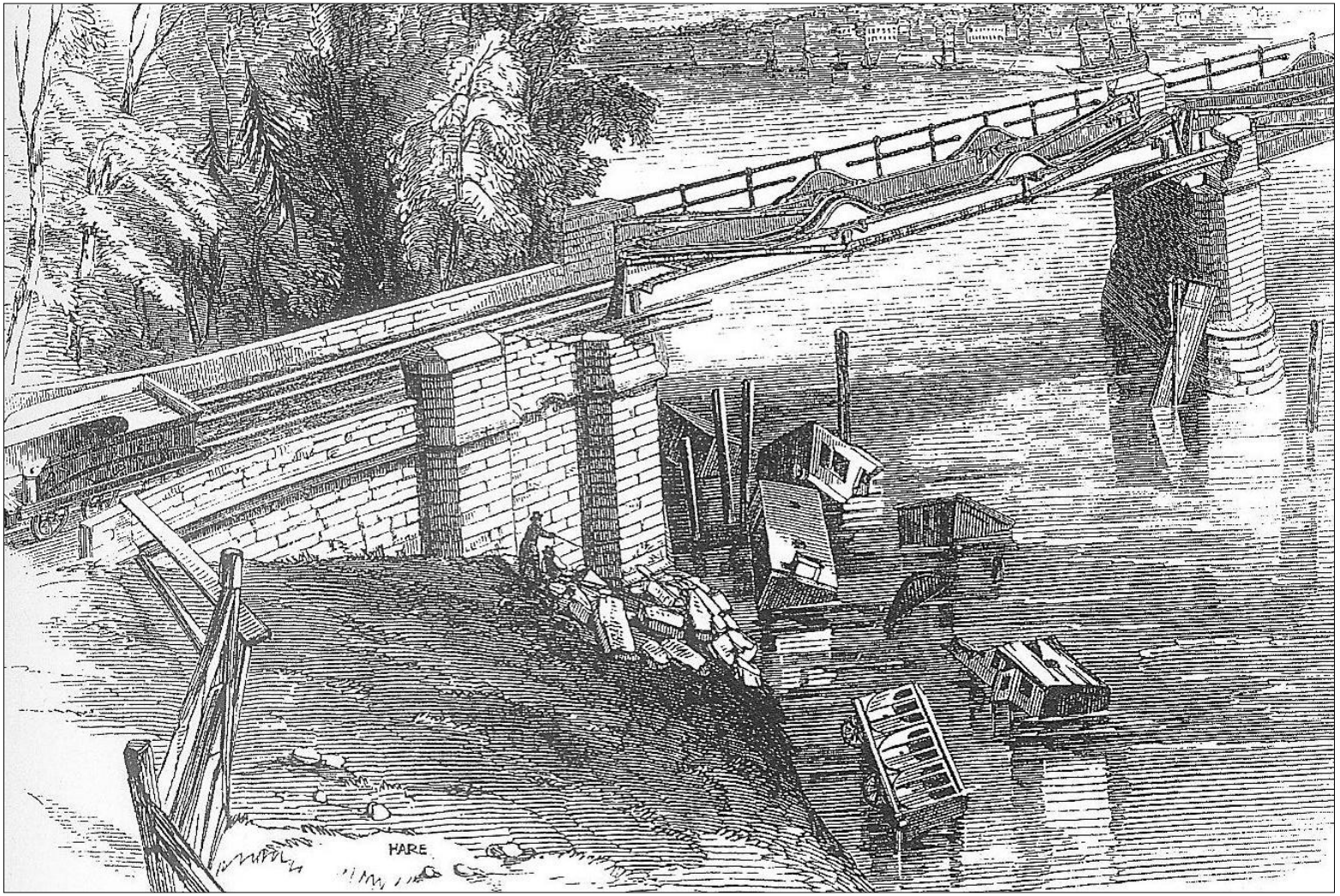
Bridge failures

Most failures occur during construction or in early life

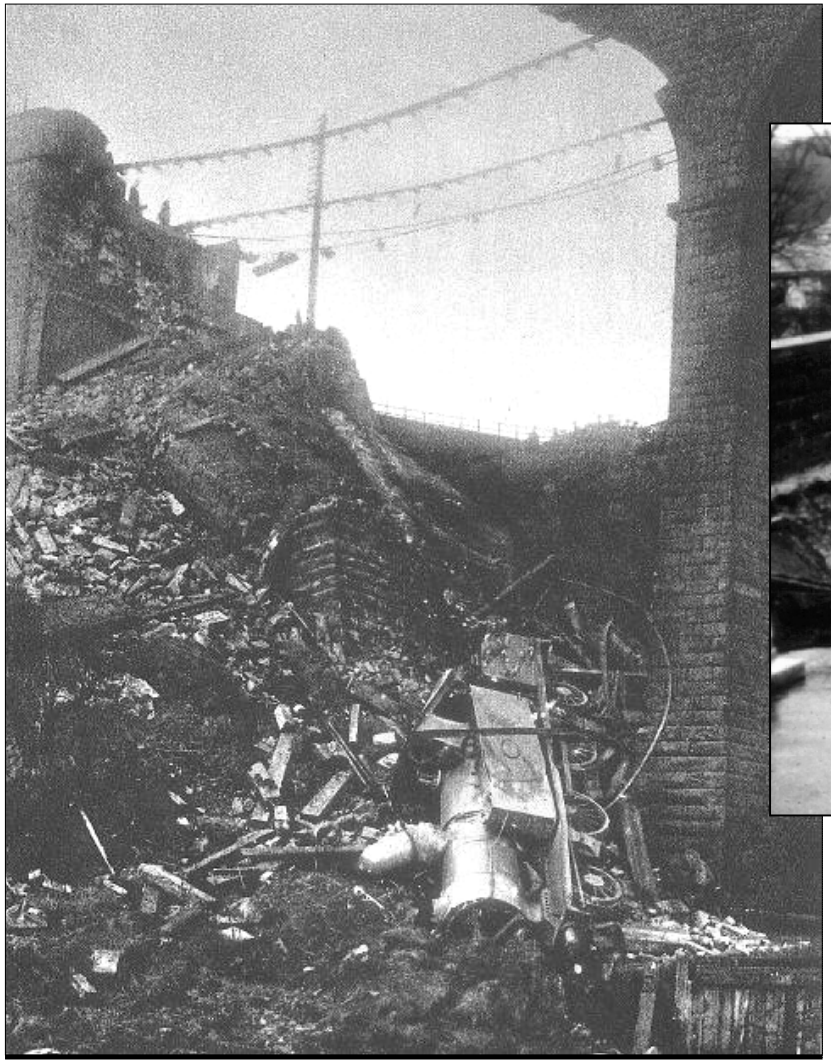
Those that don’t are usually due to external events

A collapse during construction

A 19th century collapse in service



20th century collapses in service



21st century collapses in service

Structural health monitoring for civil engineering

What are we monitoring for?

- An owner's needs of a structure are quite easily defined at a basic level
  - How much functionality is left?
  - How much life is left?

Current monitoring methods

Transport infrastructure	Mainly visual
Utility infrastructure	Aerial surveying/thermal imaging
	Line walking
	“Pigging”

How can SHM help?

Future vision

- Sensors are unlikely to replace the human eye
  - Safety criticality
- Intelligent sensors
  - Self monitoring
  - Only react if pre-set levels exceeded
  - EMC issues
  - Remote interrogation
- Able to detect gradual deterioration

What do we want to be measured?

- Data that will assist with managing the stock/support higher assessment capacity
  - Stress
  - Strain
  - Vibration
  - Deflection
  - Load transfer
  - Dynamic effects
- Demonstrating the effectiveness of maintenance interventions
  - FRP bond line defects

Practical considerations

- Accessibility for installation and maintenance
  - Positioning and fixing of equipment
  - Operationally difficult to access sites
  - Power sources
- Data recording equipment may have to be remote
  - Wireless technology may not work or be allowed
- Equipment and data collection & management systems must be sensibly future proof
  - Smart (intelligent) systems which may be designed to give early warning of incipient failure, or other adverse event, may have to sit quietly monitoring and recording for years before being activated with their expected response

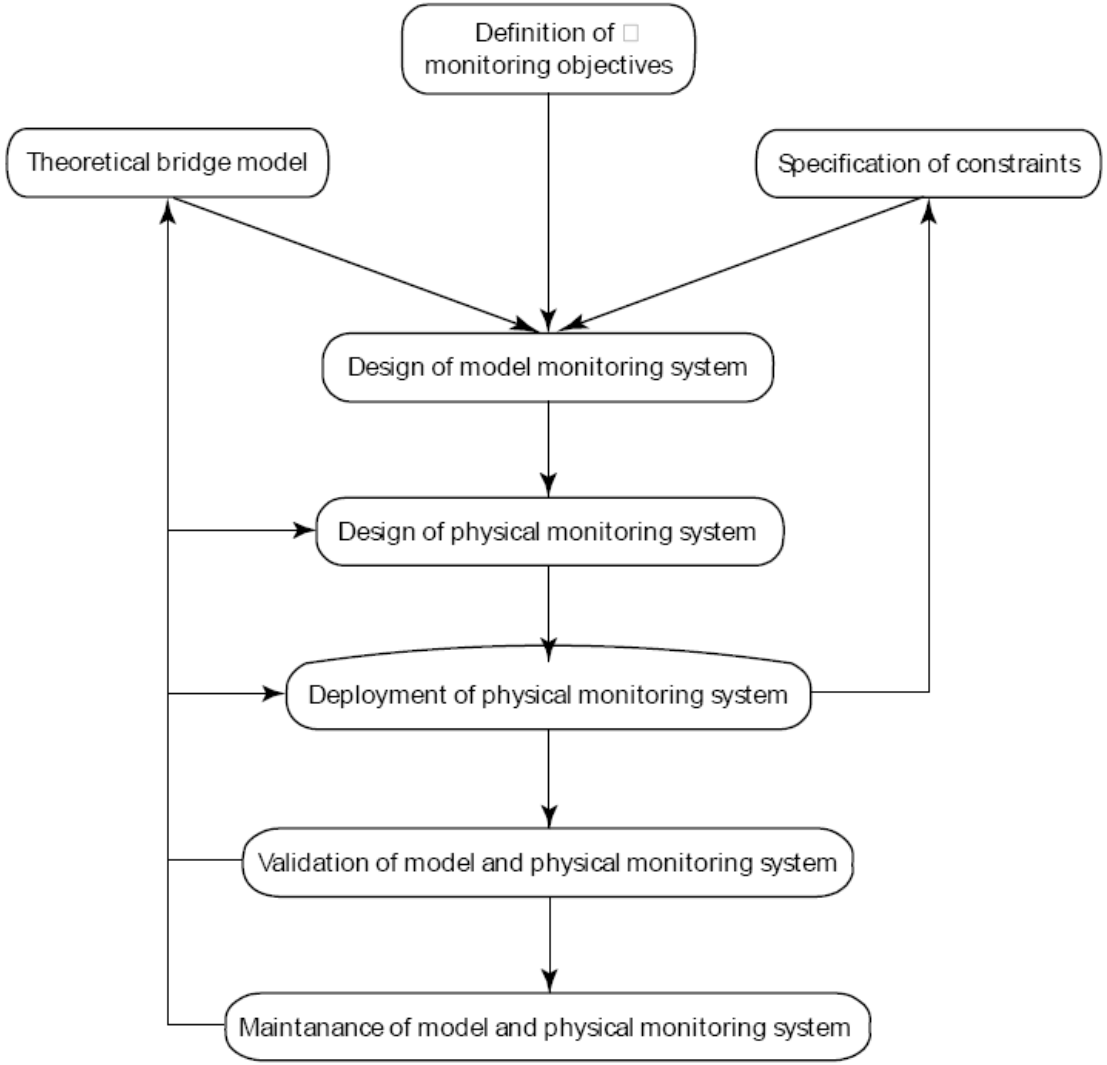
The Sustainable Bridges monitoring report

(www.sustainablebridges.net – project reports)

Roles & responsibilities

- Bridge owner
  - formulate the monitoring objectives, specify the monitoring constraints and define the budget
- Structural engineer
  - provide a theoretical model of the bridge and an interpretation scheme for the data generated by the monitoring system
- Monitoring specialist
  - collaborates with structural engineer in the design of the model monitoring system
  - designs, deploys, operates, validates, updates and maintains the physical monitoring system

Suggested monitoring methodology



Monitoring outputs

- Monitoring reports must use language that the bridge owner understands
- Interpretation must be left to the structural engineer
- All raw data must be provided in addition to the report

Into the future

How should future SHM R&D be organised?

- Future R&D should:
  - Seek to deal with the issues affecting existing infrastructure
  - Be a collaboration between instrumentation, communication and structural experts
  - Identify, and then seek to fill, the gaps between what existing SHM methods can measure and what the structural engineer needs to measure
  - Produce systems that can be retrofitted to existing infrastructure
  - Look carefully at future proofing

Current projects with NR involvement

- NR funded
  - Corrosion in elderly metallic structures
- NPL funded
  - Concrete demonstrator project
- TSB funded
  - IMAJINE (paper later in this event)
- EPSRC funded
  - Fibre optic corrosion detector
- EU funded
  - SmartEN (Marie Curie ITN)

Concluding remarks

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- It is unlikely that SHM will be widely deployed
- Uses will continue to be targeted at specific areas
  - New structural applications
  - To answer a specific question relating to a particular structure or family of structures
  - New major “landmark” structures

A challenge to the SHM community?

On behalf of the Modern Built Environment KTN, CIRIA issued a briefing titled “Innovative approaches to life extension of infrastructure” (CIRIA ref 20-03-10), which contains the following statements:

- Unlike M&E assets residual life is not routinely considered or established for civil infrastructure
- Establishing the overall health of a structure is more important that minute performance detail
- If technologies do not provide some answers to the questions of strength and life expectancy they are of little value
- Monitoring is being heavily oversold


Thank you