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800 YEARS 1209–2009

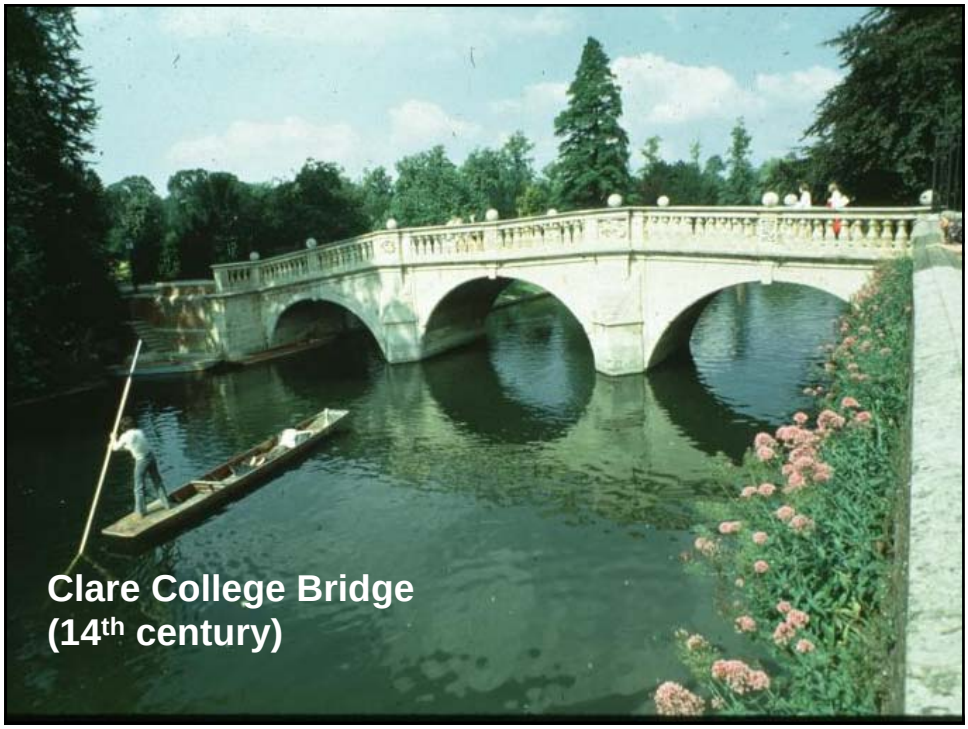
BOF
Bridge Owners' Forum

Assuring Bridge Safety & Serviceability

US Scanning Tour

11th June 2009

Cam Middleton crm11@cam.ac.uk **Bridge Research Group**



Bridge of Sighs - 1830

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Riverside Bridge – Cambridge Present

Ramboll Whitby Bird

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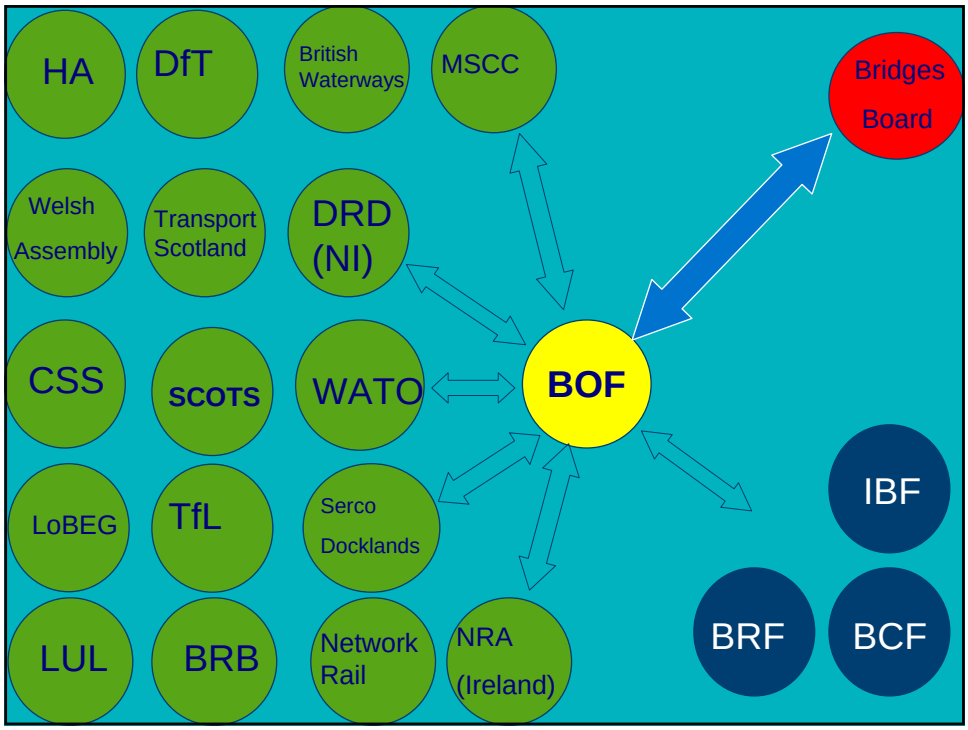
Brooklyn Bridge – New York

Brooklyn Bridge – New York



Bridge Owners Forum
Terms of reference

1. Promote co-operation, collaboration and partnership amongst bridge owners
2. Identify technical & research needs/topics to promote best practice management of the bridge infrastructure
3. Disseminate information (avoid duplication)
4. Recommend research priorities

Identifying research priorities

- Owners – recent, current & proposed research
- BCF1 & BCF2 - Consultants
- BRF1 - Researchers – capabilities
- IBF1 - International
  - US
    - – AASHTO “Grand Challenges”
    - - FHWA “Long Term Bridge Performance Program”
  - Australia
    - PBS for bridge assessment
  - EU
    - ECTP
    - Sustainable bridges

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AASHTO

Grand Challenges:
A Strategic Plan
for Bridge Engineering

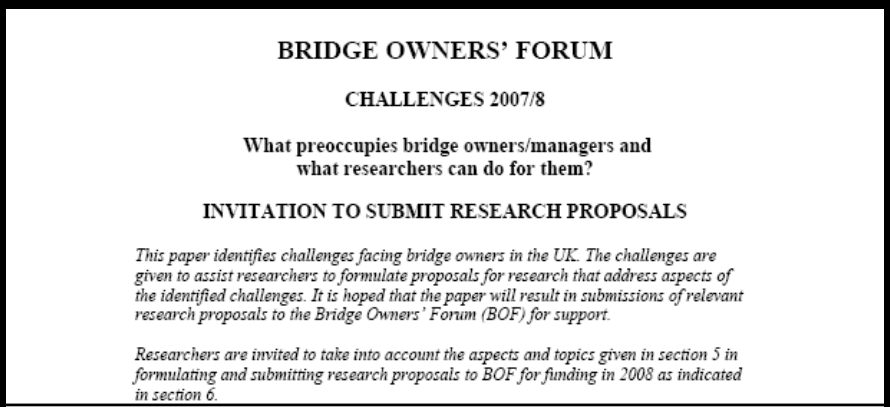
AASHTO Highway Subcommittee on
Bridges and Structures

June 2005

BOF Challenges 2007/8

17 topics (*Aspects*)

www.bridgeforum.org



BRIDGE OWNERS' FORUM

CHALLENGES 2007/8

What preoccupies bridge owners/managers and what researchers can do for them?

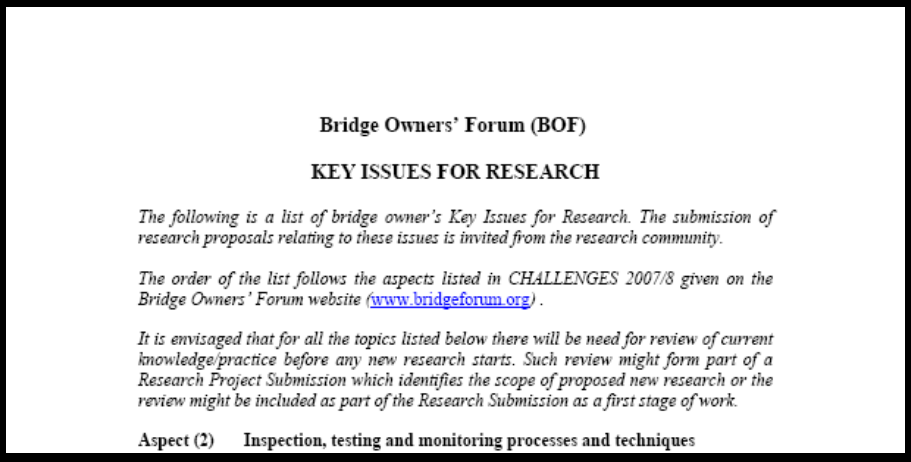
INVITATION TO SUBMIT RESEARCH PROPOSALS

This paper identifies challenges facing bridge owners in the UK. The challenges are given to assist researchers to formulate proposals for research that address aspects of the identified challenges. It is hoped that the paper will result in submissions of relevant research proposals to the Bridge Owners' Forum (BOF) for support.

Researchers are invited to take into account the aspects and topics given in section 5 in formulating and submitting research proposals to BOF for funding in 2008 as indicated in section 6.

BOF Key Issues – *The Wish List*

Owners list of 21 specific problems



Bridge Owners' Forum (BOF)

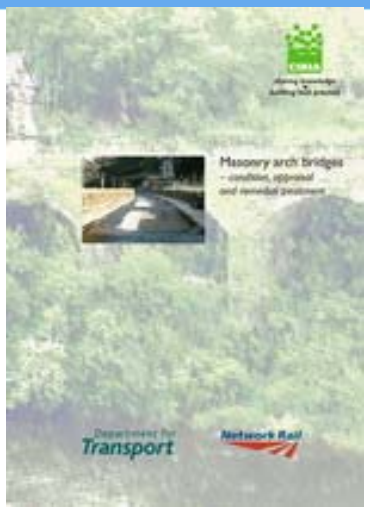
KEY ISSUES FOR RESEARCH

The following is a list of bridge owner's Key Issues for Research. The submission of research proposals relating to these issues is invited from the research community.

The order of the list follows the aspects listed in CHALLENGES 2007/8 given on the Bridge Owners' Forum website (www.bridgeforum.org).

It is envisaged that for all the topics listed below there will be need for review of current knowledge/practice before any new research starts. Such review might form part of a Research Project Submission which identifies the scope of proposed new research or the review might be included as part of the Research Submission as a first stage of work.

Aspect (2) Inspection, testing and monitoring processes and techniques



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Other BOF initiatives

- Database of unpublished HA research reports
- Imhof bridge failure database

ESDAL ELECTRONIC SERVICE DELIVERY FOR ABNORMAL LOADS

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Strength & safety assessment of bridges

- Collapse analysis
- Safety / Reliability analysis
- Deterioration modelling
- Non destructive test techniques
- (Wireless) Structural health monitoring
- Bridge modelling & management systems
- Computer vision applications

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Design, analysis & assessment

"*You can build anything you can draw* "

Christopher Burgoyne

"*You can analyse anything you can draw* "

…….*but is it meaningful?*

is it rational?

is it right?

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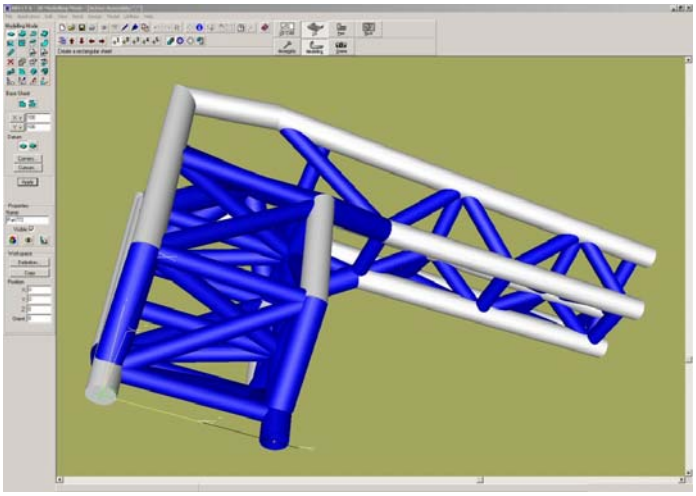
16

Structural analysis software



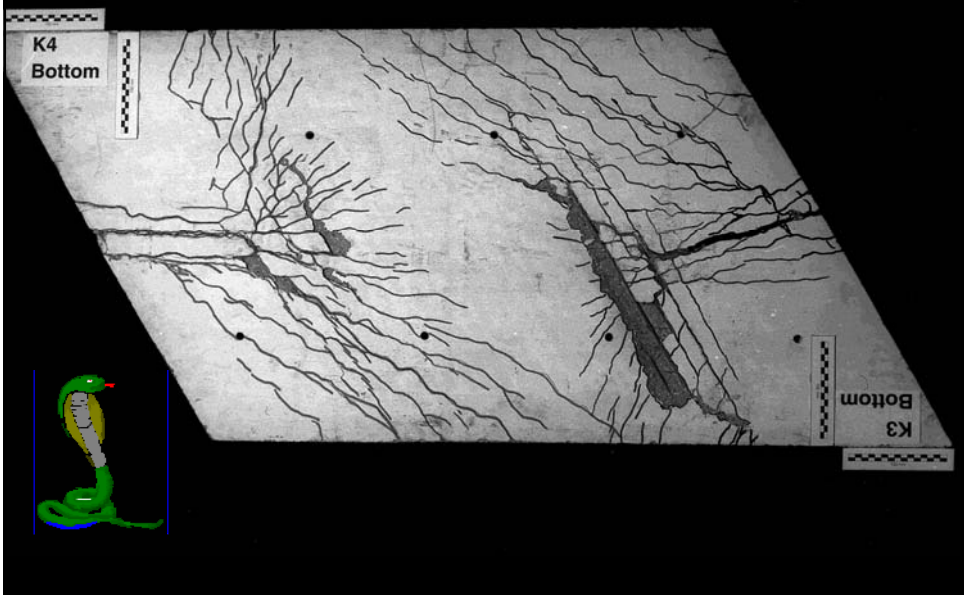
Analysis

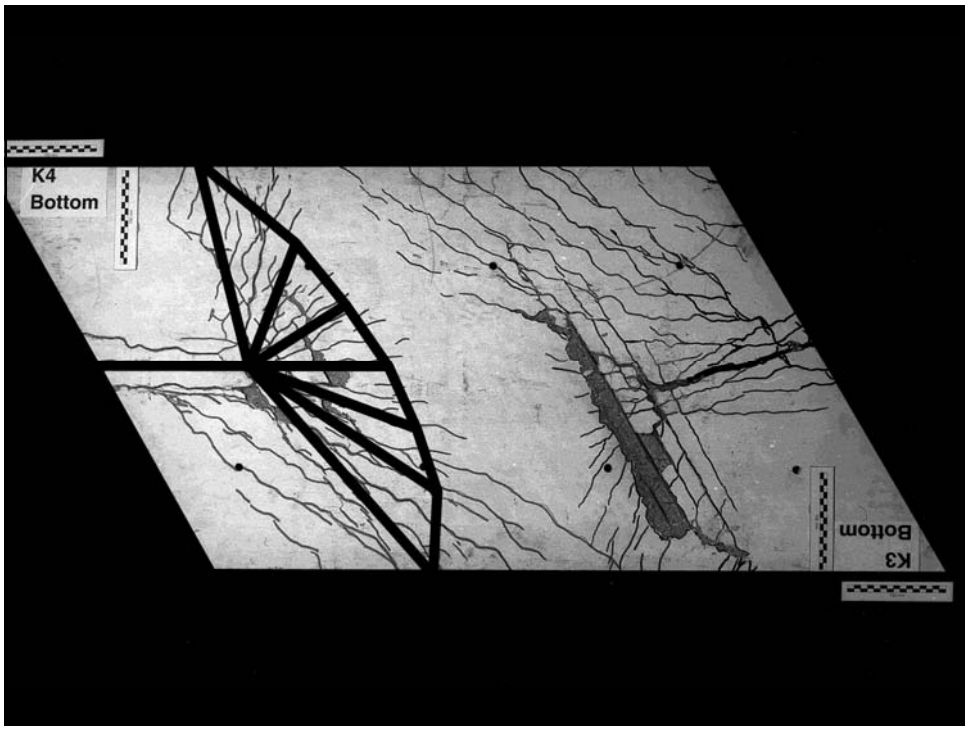
What is *Failure ?*

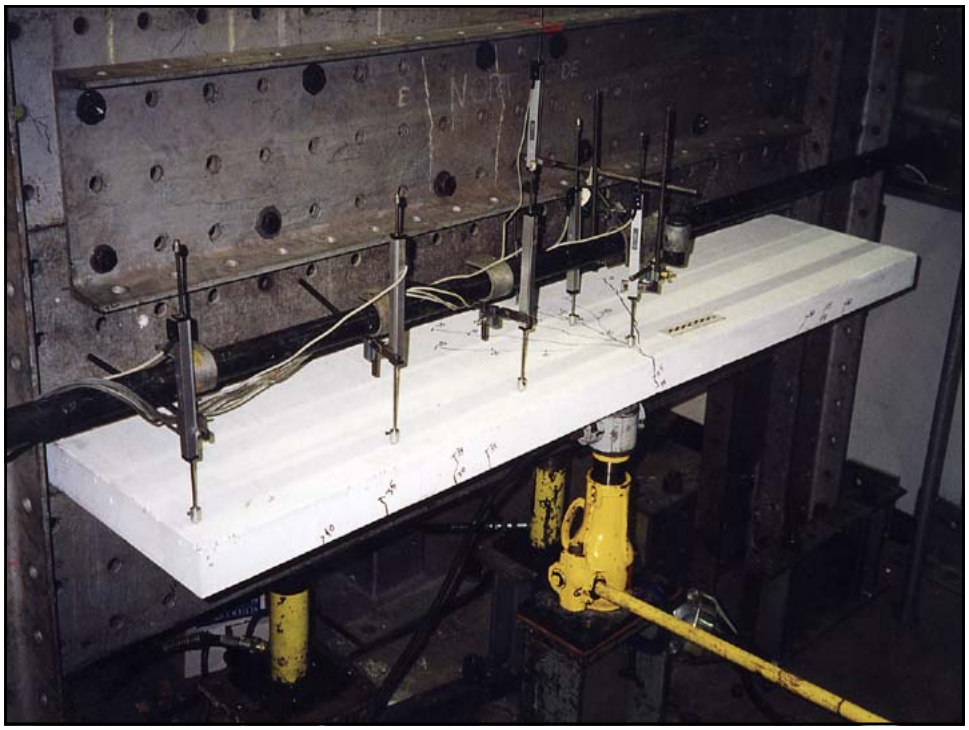
FAILURE ANALYSIS ?

ANALYSIS FAILURE ?

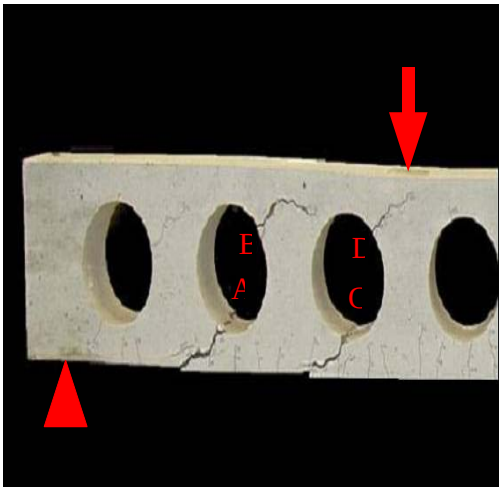
Yieldline analysis



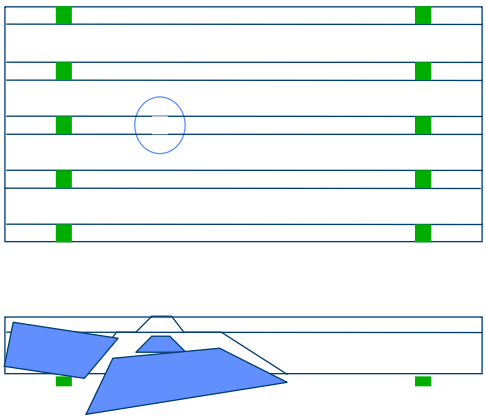

K4
Bottom
K3
Bottom



Non-linear finite element analysis for reinforced concrete



Punch-Shear Mechanism



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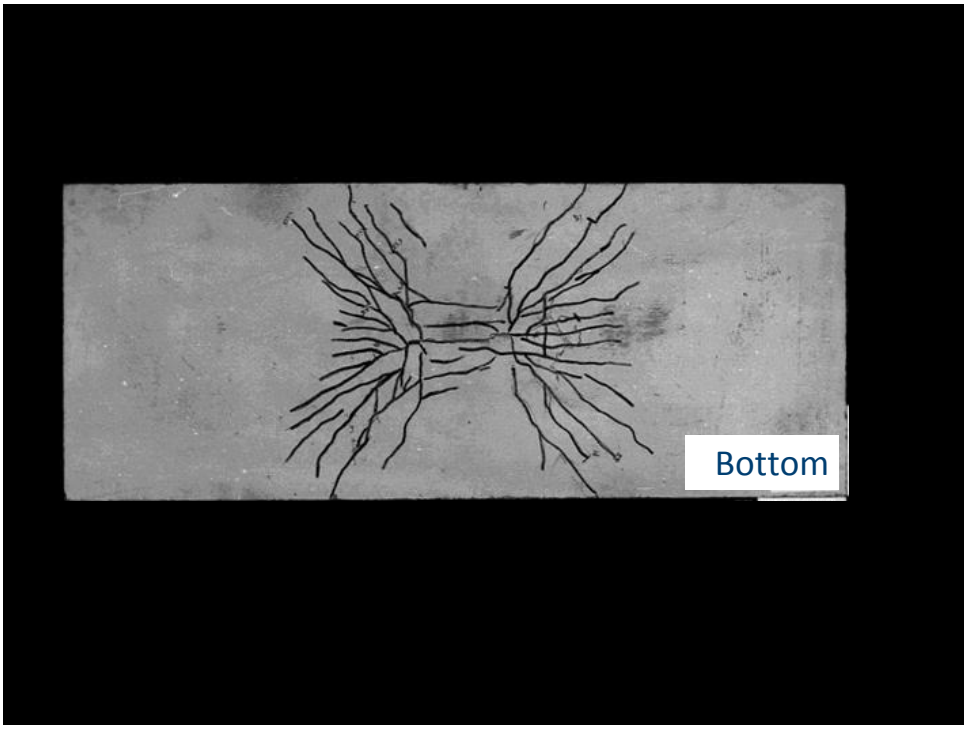

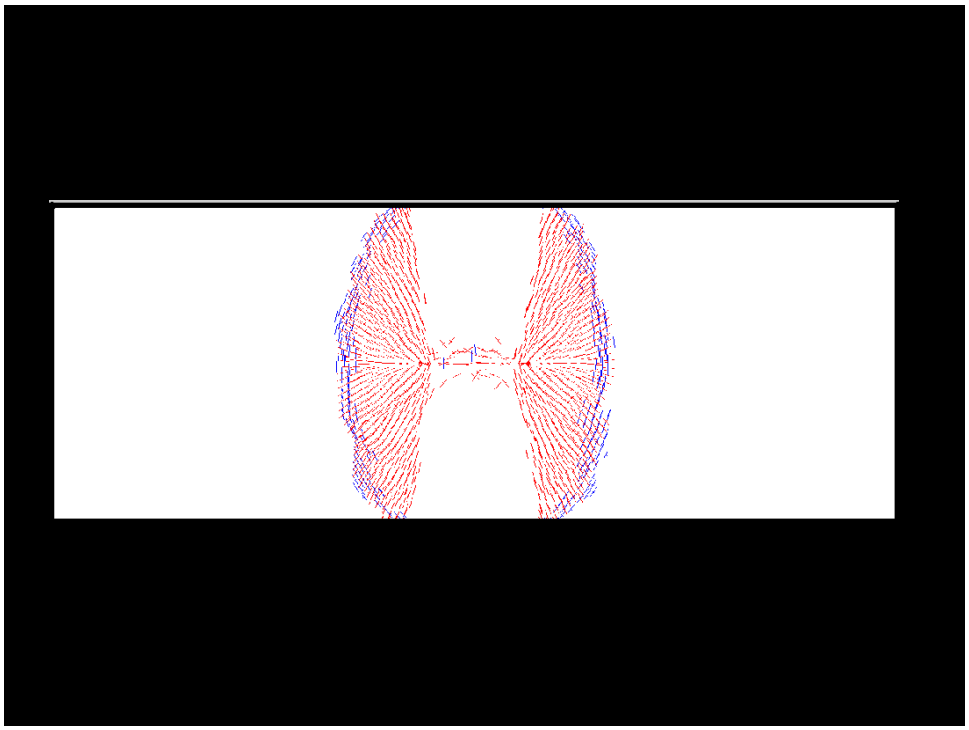

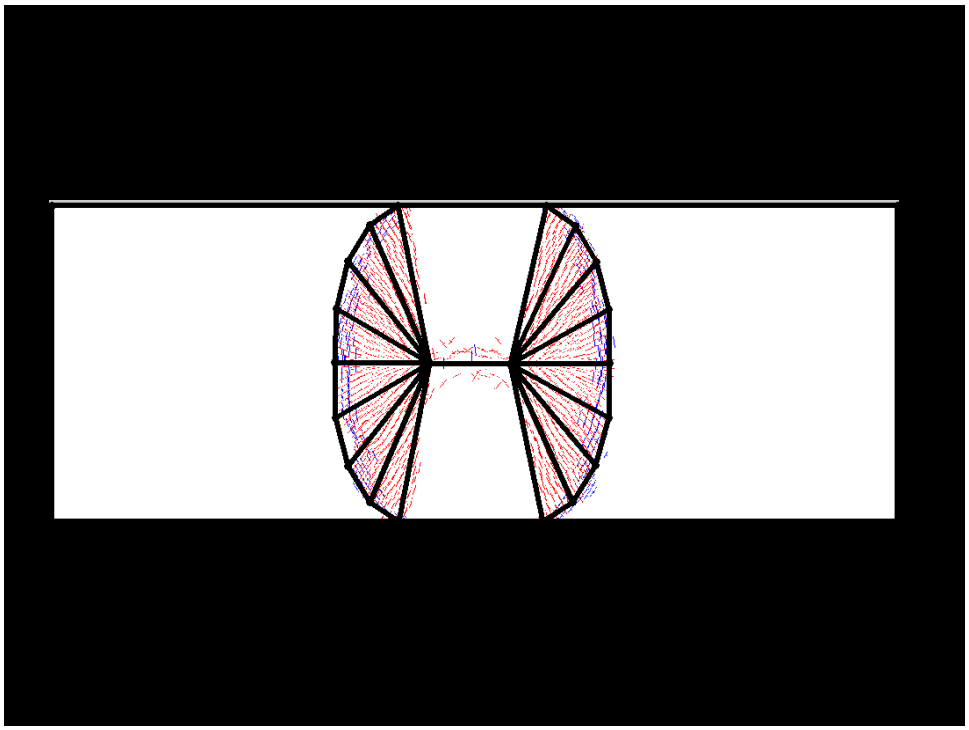

Inspection, testing & monitoring - the questions

- Loading

  - what are the loads – traffic volume & weight, impact?

- Strength

  - Material properties, dimensions, condition (deterioration models)?

- Condition

  - deterioration, rate and extent (severity & extent) of critical elements?

Wireless sensor networks

Smart Humber

Welcome to the Humber Bridge Structural Health Monitoring page. This page has been developed as part of an EPSRC funded collaboration between the University of Cambridge and Imperial College London as well as critical infrastructure partners including the Humber Bridge Board.

Available health monitoring systems:

- Hessle Anchorage environmental monitoring
- Fernby Road Bridge support bearings (to be installed)

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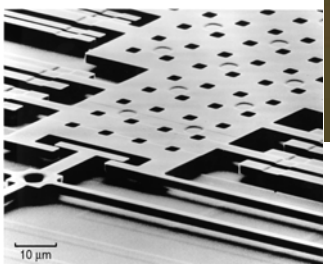
Wireless Sensors



Microelectromechanical Sensors (MEMS)

Fibre optic sensors - strain

Addenbrookes Bridge

Hammersmith flyover WSN - London

Forth Road Bridge

Access

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Forth Replacement Crossing - Scotland

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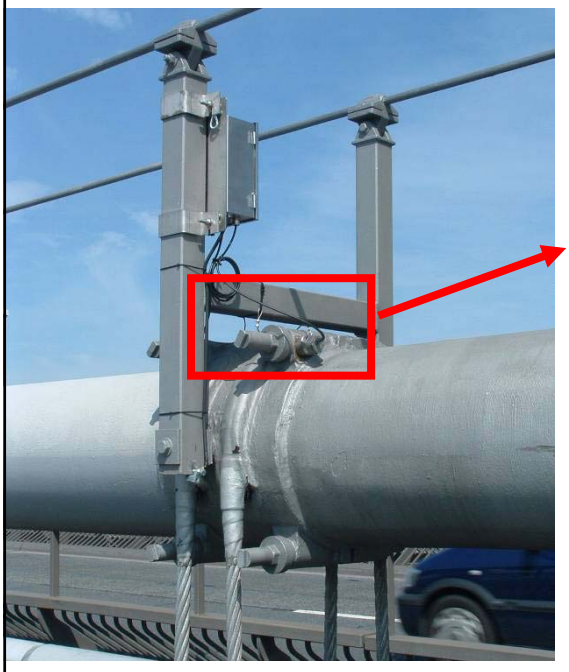
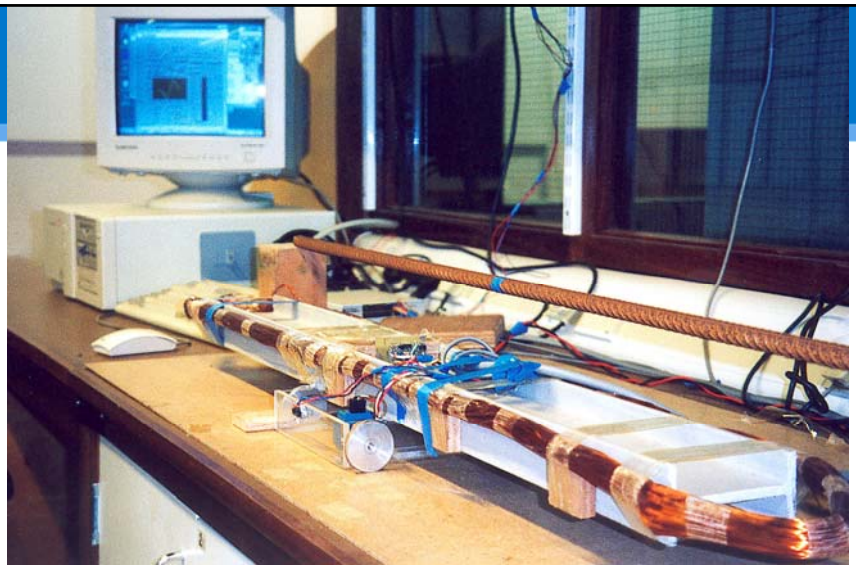
Forth Replacement Crossing - Scotland





Electromagnetic sensor for bar section loss

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Computer vision applications in bridge management

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Computer Vision Applications in Bridge Assessment

Julie Gonzalez Torres

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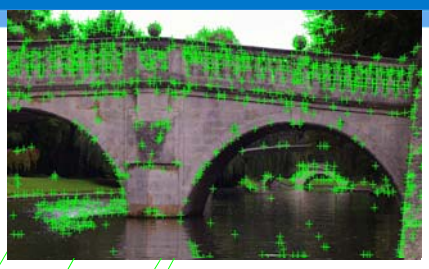
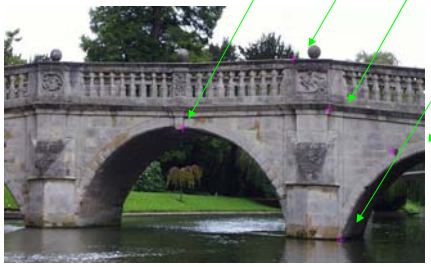
2D Image stitching

Corner detection

Finding correspondences

Transform estimation





$x = H x'$

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Visual inspection database

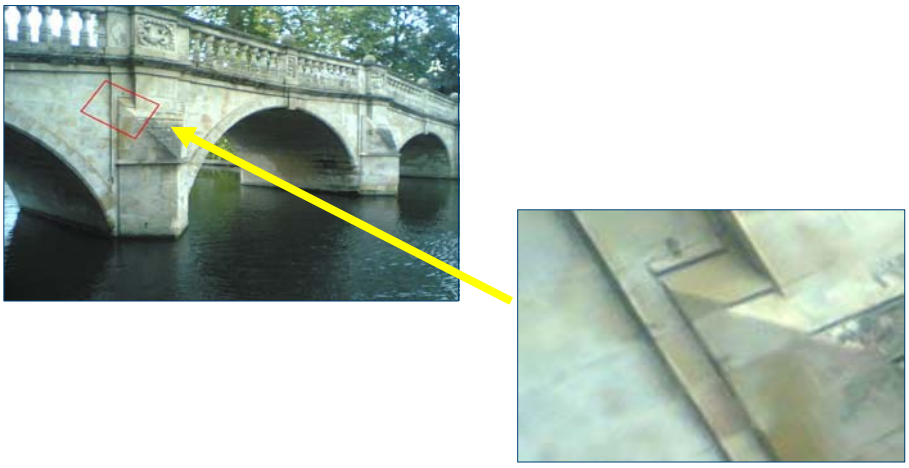

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Photo matching

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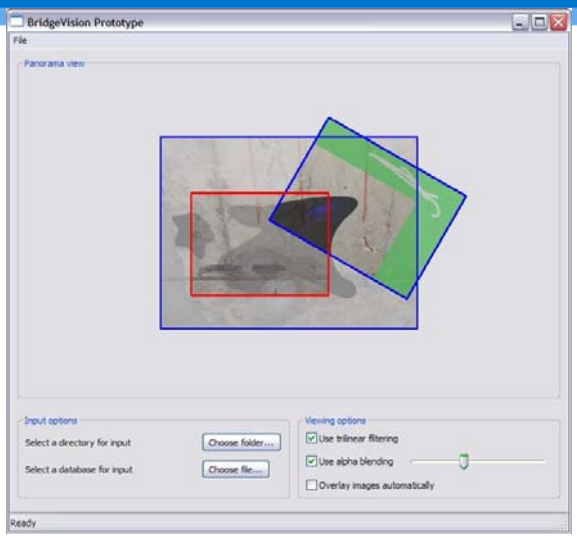
The BridgeVision program



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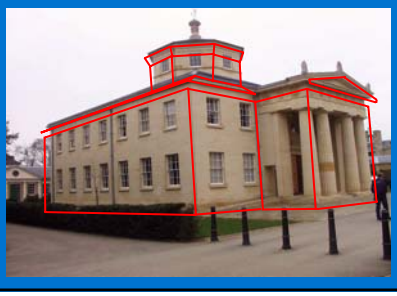
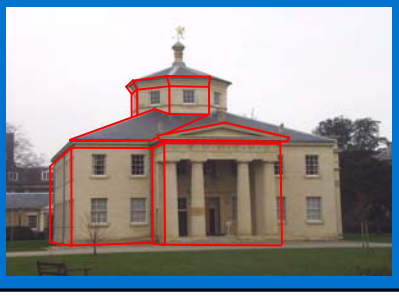
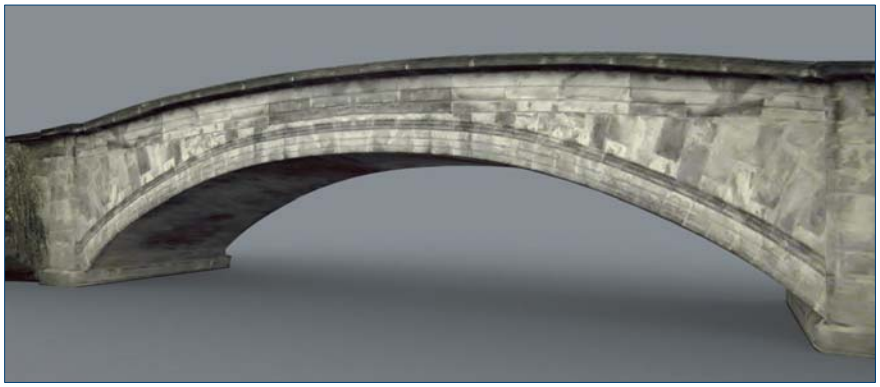
Computer Vision Applications





3D structure generation



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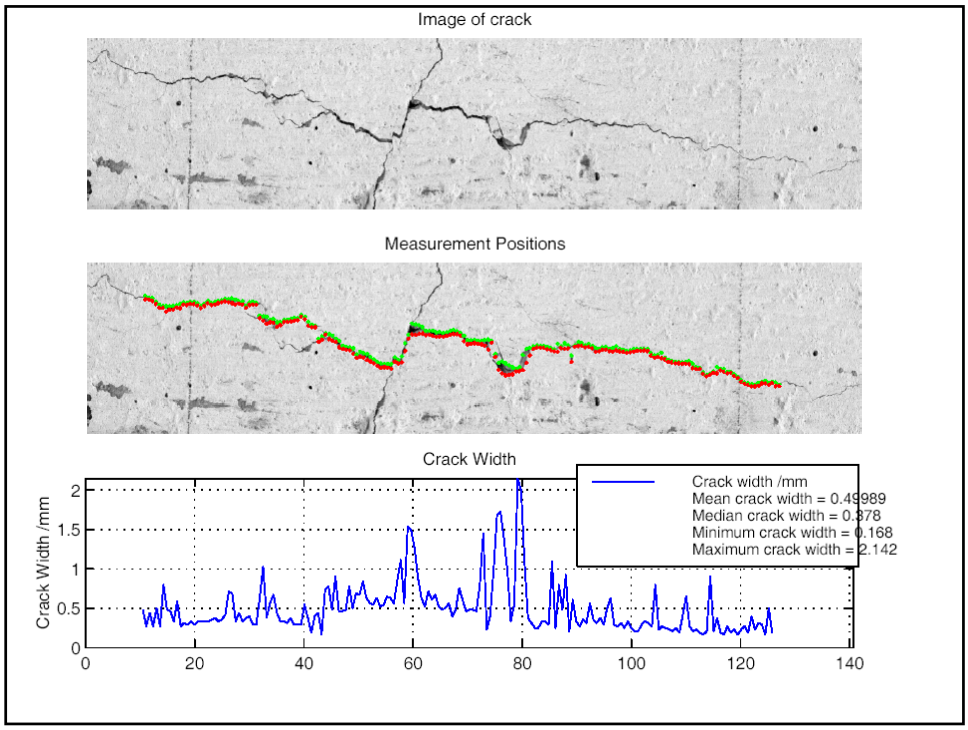
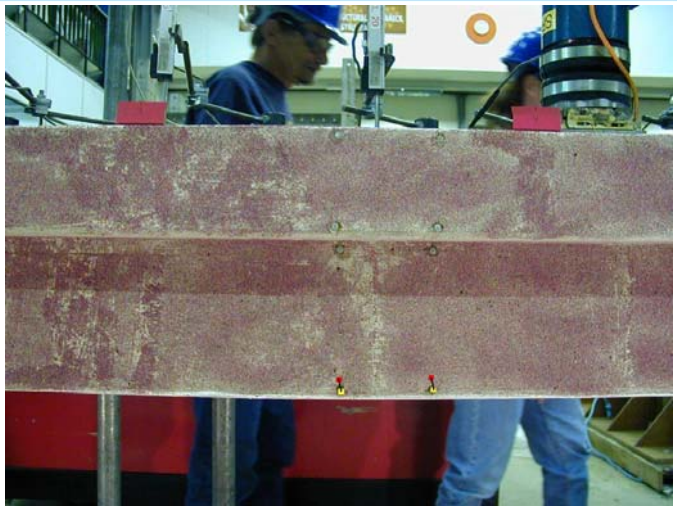


Particle Image Velocimetry (PIV) to determine strain fields



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Sustainability - Carbon & Energy Footprints

Nine Wells Road Bridge, Cambridge

GE19 Rail Bridge, London

Procurement

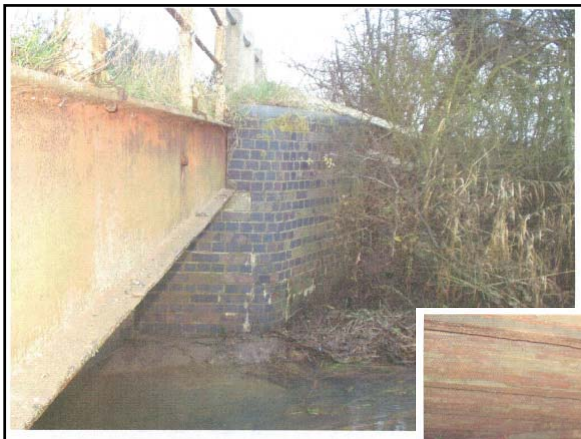
Procurement

- Does PFI work?
- Condition on hand-back
- QA doesn't work and it never will whilst humans are involved.
- Not a case of is it right but how wrong can it be and still be acceptable.

Bridge Management

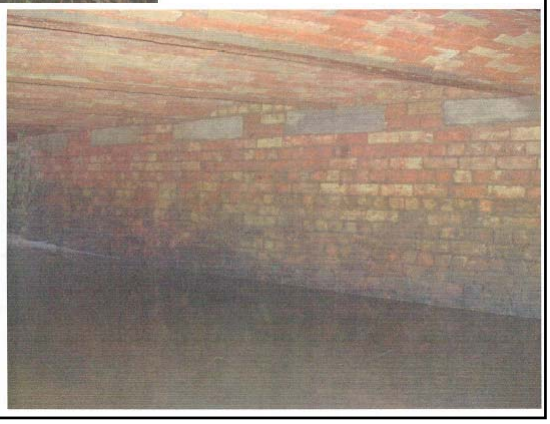
Procurement

The over-engineered bridge



Jack arch

4.2 m span



Assessed capacity

Zero live

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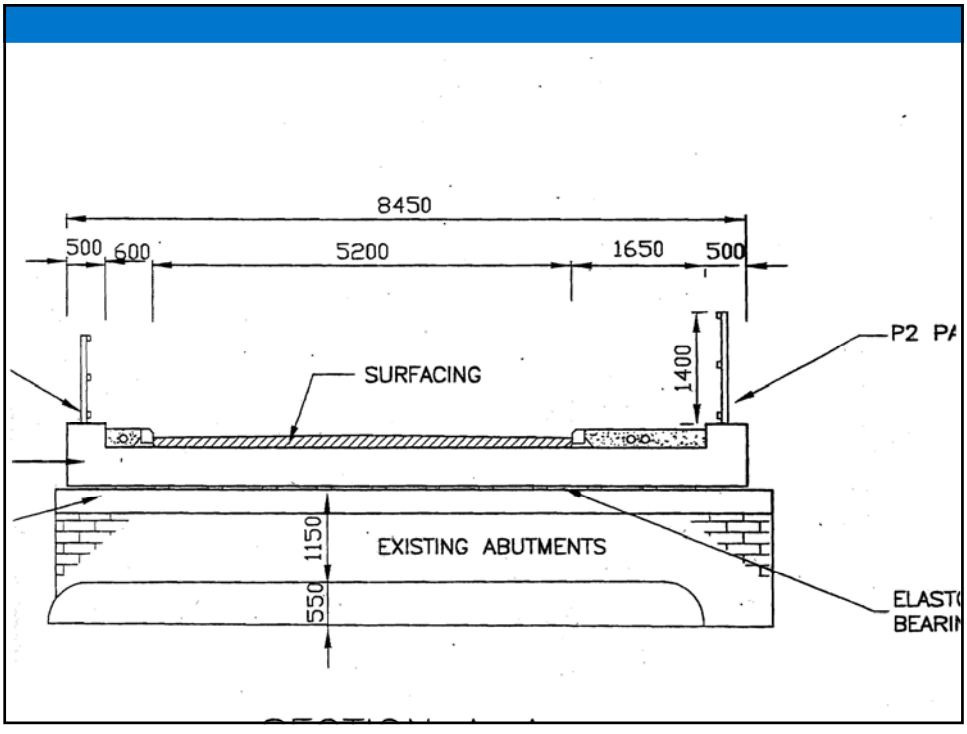
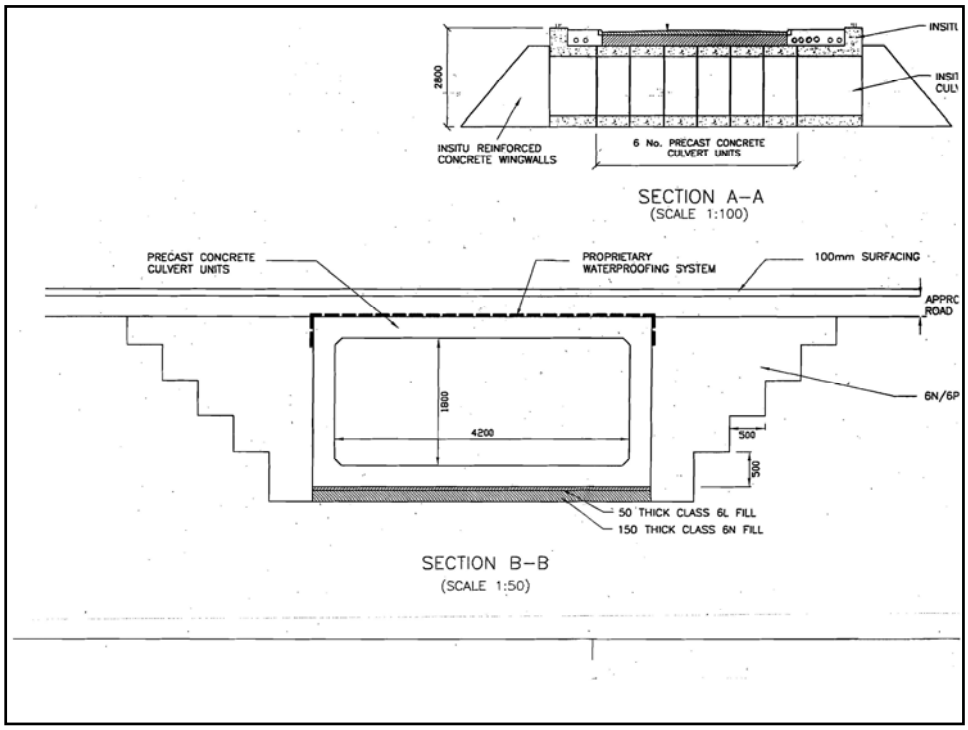
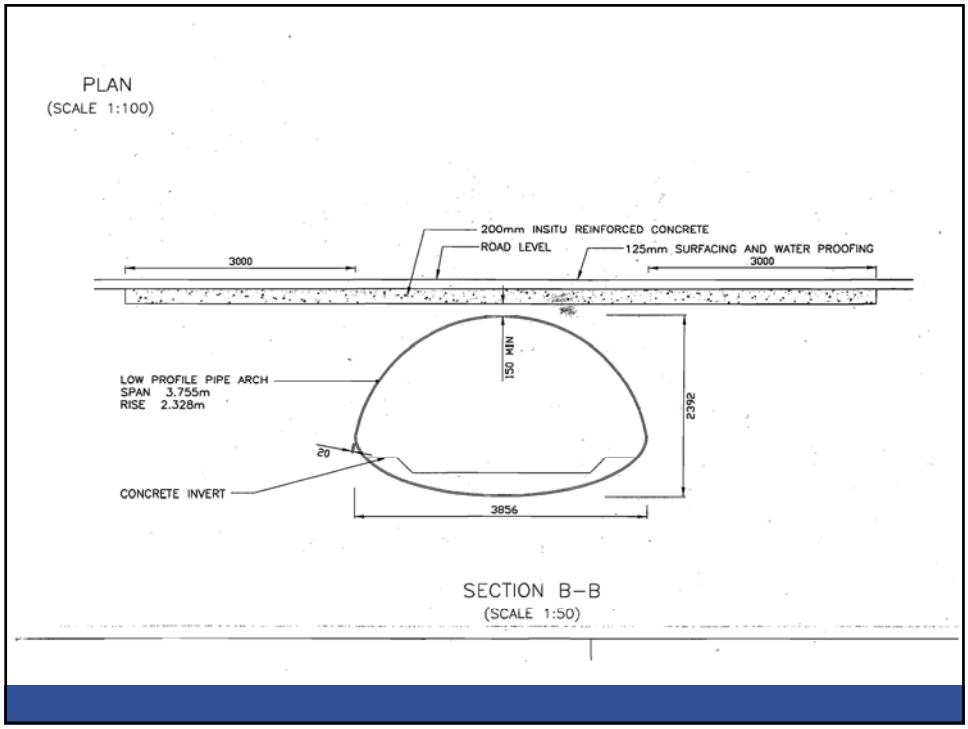



INSITU
INSIT
CUL
2800
INSITU REINFORCED
CONCRETE WINGWALLS
6 No. PRECAST CONCRETE
CULVERT UNITS
SECTION A–A
(SCALE 1:100)
PRECAST CONCRETE
CULVERT UNITS
PROPRIETARY
WATERPROOFING SYSTEM
100mm SURFACING
APPRC
ROAD
6N/6P
1800
4200
500
500
50 THICK CLASS 6L FILL
150 THICK CLASS 6N FILL
SECTION B–B
(SCALE 1:50)


PLAN
(SCALE 1:100)
200mm INSITU REINFORCED CONCRETE
ROAD LEVEL
125mm SURFACING AND WATER PROOFING
3000
3000
150 MIN
2392
LOW PROFILE PIPE ARCH
SPAN 3.755m
RISE 2.328m
20
CONCRETE INVERT
3856
SECTION B–B
(SCALE 1:50)

4.2m span RC bridge (14 weeks)

Item	*Cost*
Demolition	£11k
Bearings	£2k
Insitu concrete	£2k
Reinforcement	£7k
Formwork	£3k
Surfacing, Waterproofing	£3k
Sub-total	*£28k*

Cost of Bridge Replacement (14 weeks)

Item	*Cost*
Safety fencing	£3.5k
Contingencies	£16.5k
Other items (traffic, services etc)	£42k
TOTAL	

Cost of Bridge Replacement (14 weeks)

Item	*Cost*
Safety fencing	£3.5k
Contingencies	£16.5k
Other items (traffic, services etc)	£42k
Site hut	£46k
TOTAL	

Item	*Cost*
Safety fencing	£3.5k
Contingencies	£16.5k
Other items (traffic, services etc)	£42k
Site hut	£46k
Design	£40k
TOTAL	

Cost of Bridge Replacement (14 weeks)

Item	*Cost*
Safety fencing	£3.5k
Contingencies	£16.5k
Other items (traffic, services etc)	£42k
Site hut	£46k
Design	£40k
Site supervision	£20k
TOTAL	*£176k*

The Intelligent Client

Bridge Management

Procurement

- residual life
- end condition

Whole Life Costing

- disruption costs
- discount rate/ costs of actions
- stainless steel?

Records (database) – SMIS / ESDAL

Audit

Bridge Management

Procurement

Residual life

End condition

Whole Life Costing

- Disruption costs
- Stainless steel?

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Audit

- Independent audit of assessments ~ 5%
- Redesign by other consultants
- Audit of inspections – qualifications!
- Audit of costing – unit rates
- Site supervision – e.g. 4 C's + W/C

(cover, curing, compaction, cement content)

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Loading

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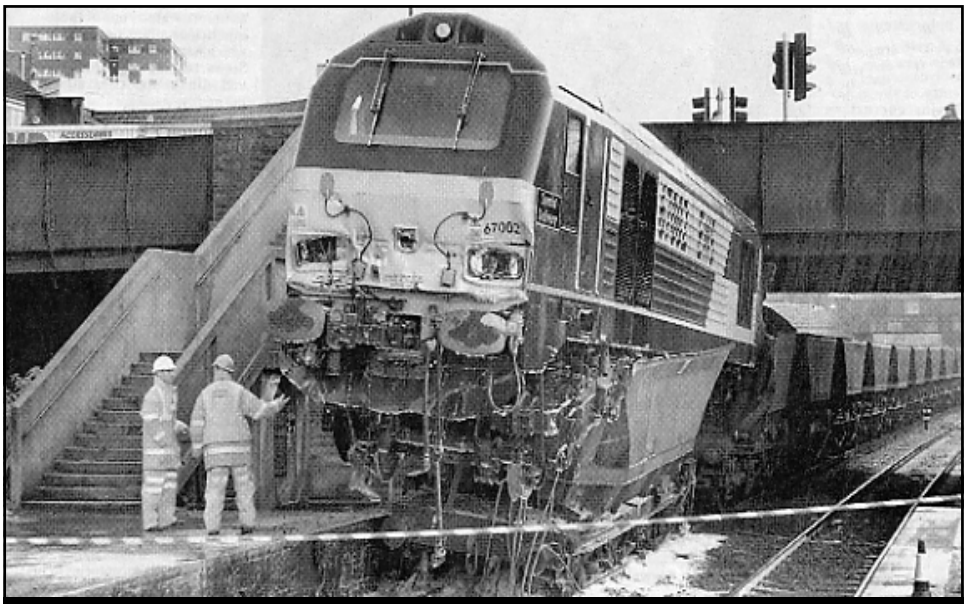

Bridge bashing

Hamburg

17th November 2007

Rail strike

OB-WIM

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Inspection

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Inspection Results – Bridge Route 1

Deficiency	No. Inspectors	% identifying deficiency
Paint system failure	44	66%
General corrosion	44	55%
Member distortion	44	11%
Fabrication error	44	2%
Crack indication w1	44	2%
Crack indication w2	44	5%
Bolt defect B1	44	32%
Bolt defect B2	42	19%

Covermeter

Covermeter data (from a bridge near Cambridge)

Location	*Year of test*	*Bar Diameter (mm)*	*Bar Spacing (mm)*
Longitudinal Soffit	1992	12	125
	1993	20	150
	1997	20-25	100-140

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Half-cell potential

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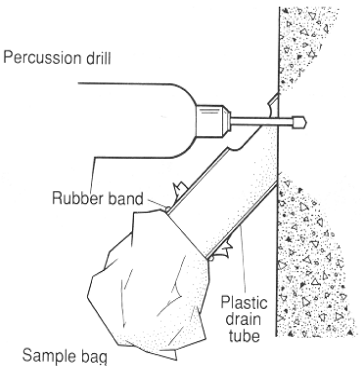
Chlorides content



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Reliability

Safety

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Ref: Nowak*

Referring to the new LRFD code:

"*The target reliability index is selected to provide a consistent and uniform safety margin for all structures*"

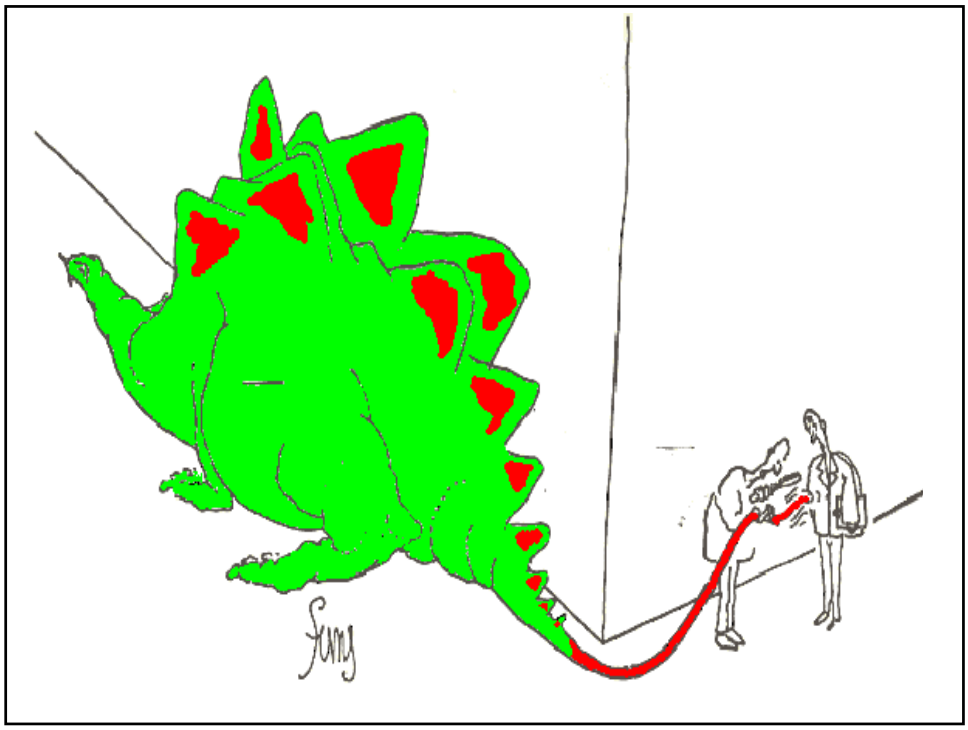
"The target reliability index was selected $\beta_T = 3.5$*"*

"Reliability indices calculated for bridges designed using the new LRFD AASHTO (code) are close to the target value of 3.5 for all materials and spans."

**Application of bridge reliability analysis to design and assessment codes*
in Safety of Bridges, Ed. P.Das, 1997, Telford.

Reliability or Safety Index - β

"The reliability index β is a measure of the *susceptibility* of the structure to the *variability* in the key parameters which govern its behaviour."



Main concerns

1. What target safety level is acceptable?
2. Do the tails of the distribution curves exist?
3. Model of failure must be realistic
4. Highly sensitive to input assumptions
   (analogy with NLFE) i.e. GI = GO

Statement to be wary of:

The structure is safe since $\beta > 3.5$

(magic numbers)

Attributes contributing to safety

1. Redundancy
2. Ductility
3. Connectivity (continuity)