Civil Infrastructure Systems

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Director Research, CCE

Future Infrastructure Forum – September 2011

EPSRC Network on Resilient and Sustainable Infrastructure

Relevant Expertise

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- Marios Chryssanthopoulos
- Gerry Parke
- Mike Mulheron
- Boulent Imam
- Imran Rafiq
- Juan Sagasetta

Peter Clarke, Matt Leach, Paul Smith,
David Jesson, Steve Ogin, Prashant Kumar

Research Themes

- Managing current assets
  - Water distribution networks (cast iron)
  - Rail infrastructure (wrought iron)
  - Steel structures (durability and maintenance)
  - Concrete structures (durability and maintenance)
- Facing future challenges
  - New materials (ECC – high ductility, self-healing)
  - Surface modifications (self-assembling bio-films)
  - Non-destructive assessment (NMR)
  - Smart Infrastructure Management
  - Climate change (weather prediction and mitigation)
  - Low CO_2 systems (energy, material security)
  - User impact on infrastructure robustness (Agent-based models)
  - Policy and law (Centre for Environmental Strategy)

Multi-scale approach

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- Materials level – properties and degradation
- Component level – micro environment
- Structure level – component interaction
- Network/Stock level – structure interdependencies

Quantifying Reliability and Consequences

$\Rightarrow$ Risk Management

Cast Iron Water Main

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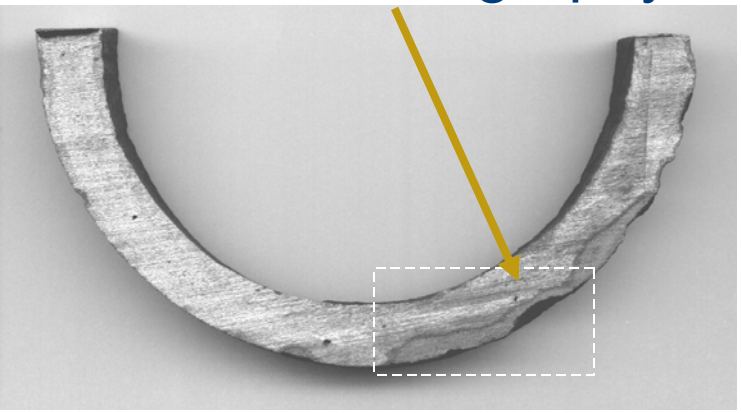
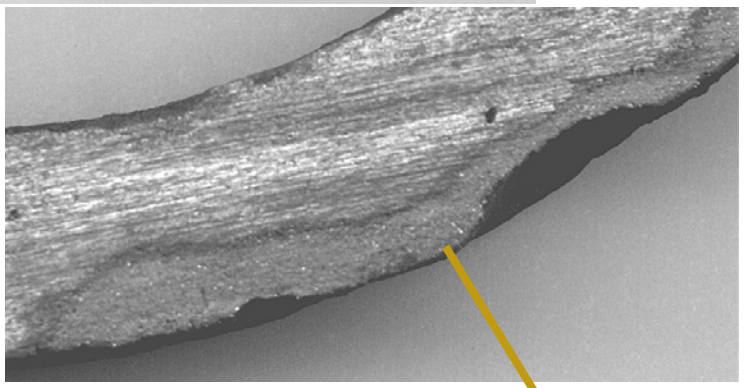
Metallography

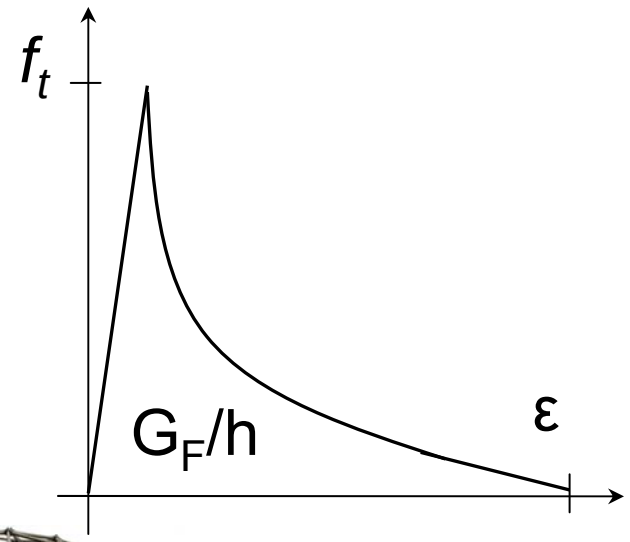
Mechanical Testing

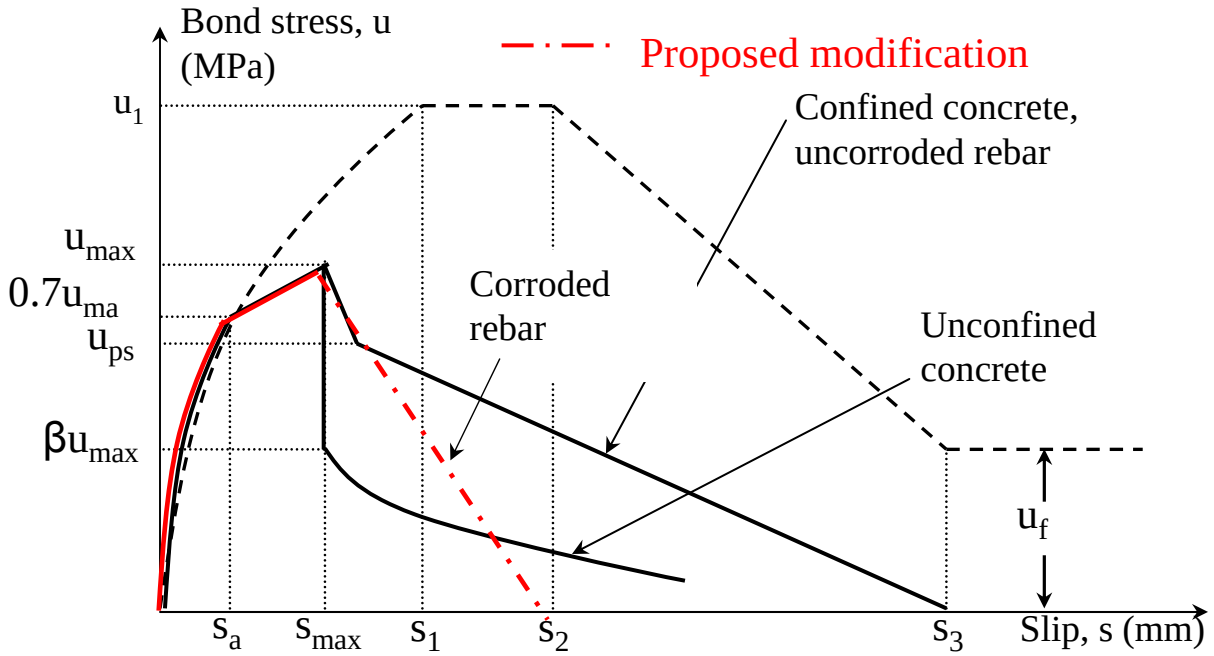




Modelling Reinforced Concrete

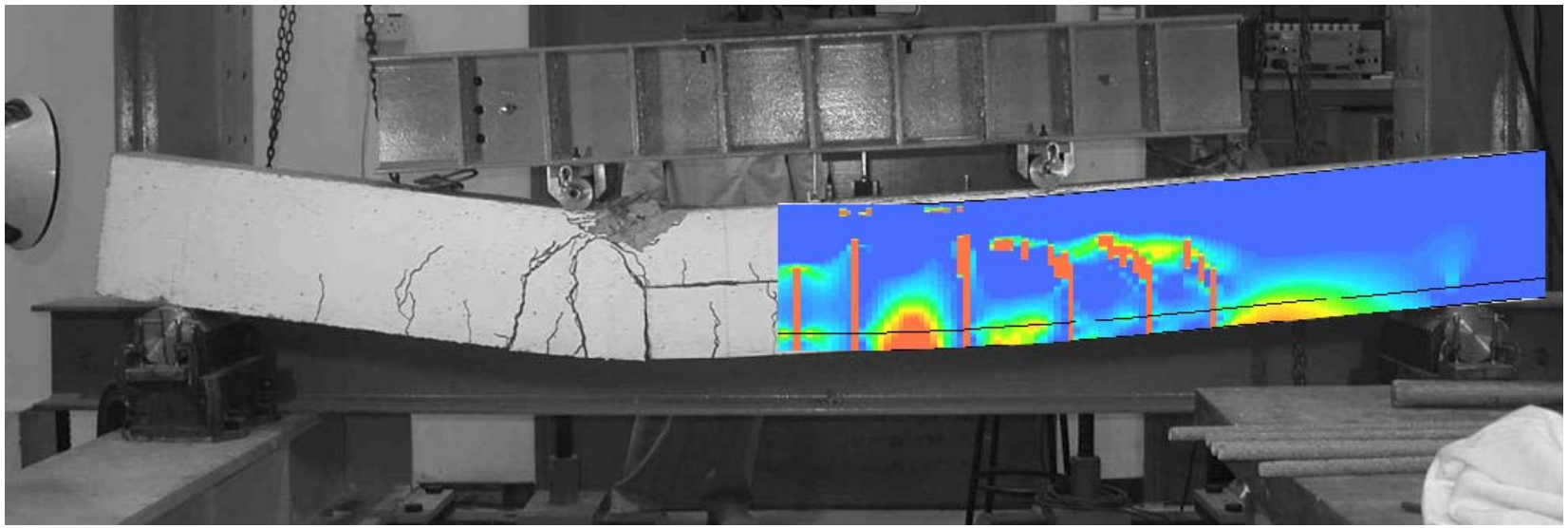
- Modelling for Normal / High performance concrete
- Development & utilisation of fracture mechanics-based material models through laboratory testing.
- Modelling interaction between steel and concrete, i.e. Bond
- Modelling tensioning softening of concrete





Deteriorating Components

- Micro-cracking related strength reduction in RC.
- Corrosion related strength and ductility reduction in steel.
- Degradation of bond between the two materials.
- Location of corrosion and implications on performance.



NLFEA of Deteriorated Beams

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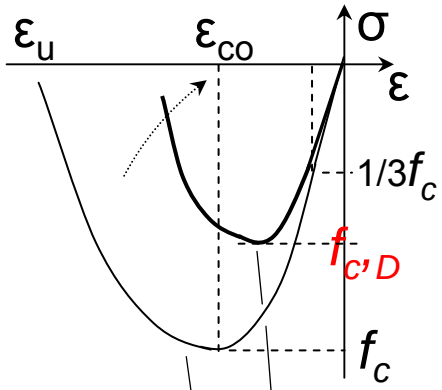
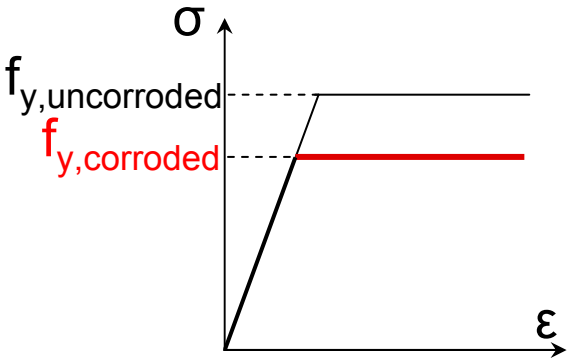
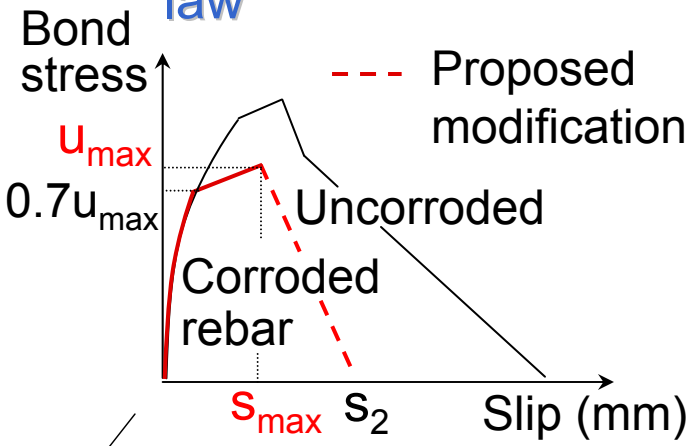
Concrete in compression

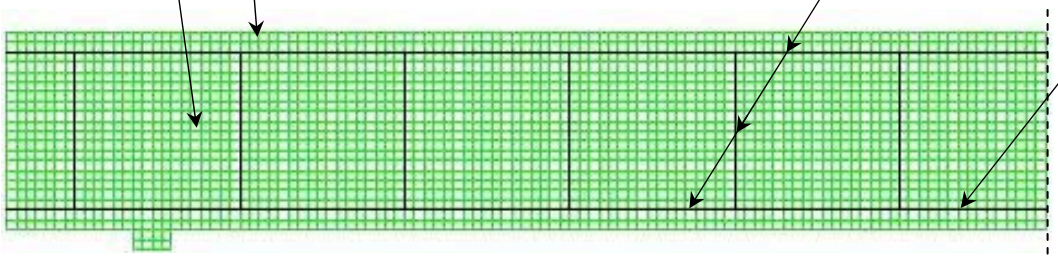


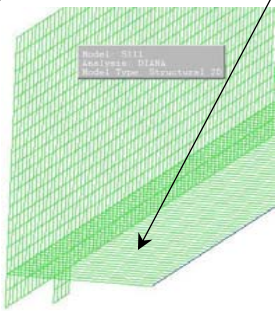
Elastic-perfectly plastic law for steel



Bond stress-slip law

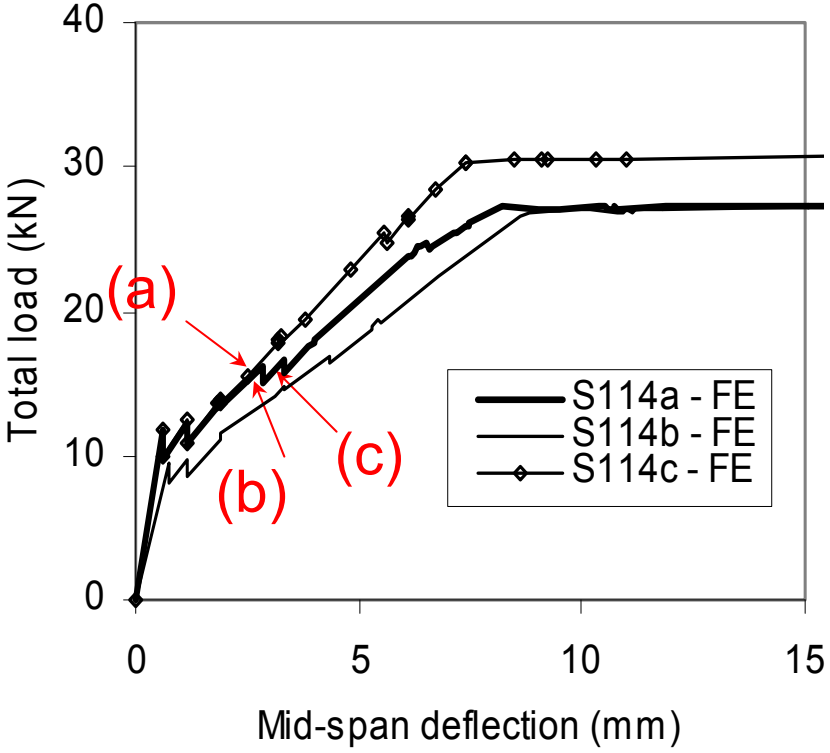


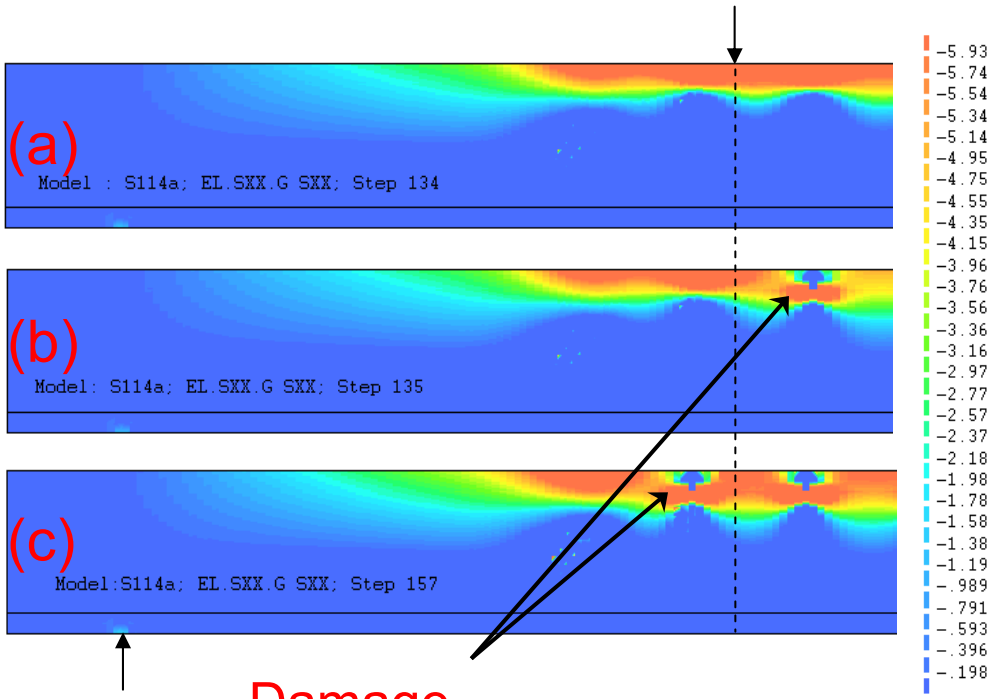




NLFEA of Deteriorating Beams

Crushing of corrosion damaged top cover beam S114a





Damage localization

$\Rightarrow$ reliability assessment of degraded RC members

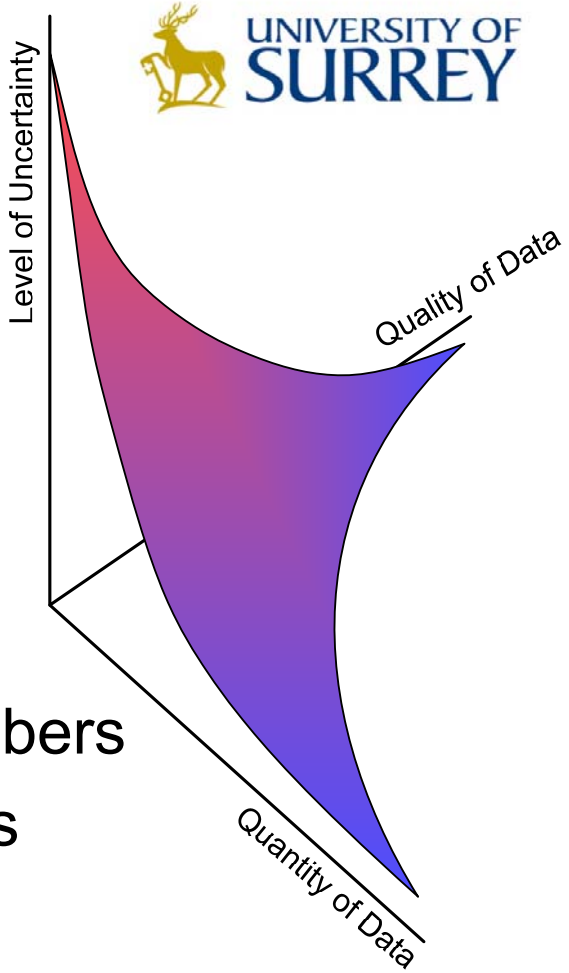
Health-monitoring based Deterioration Management

Uncertainty Sources

Incomplete knowledge

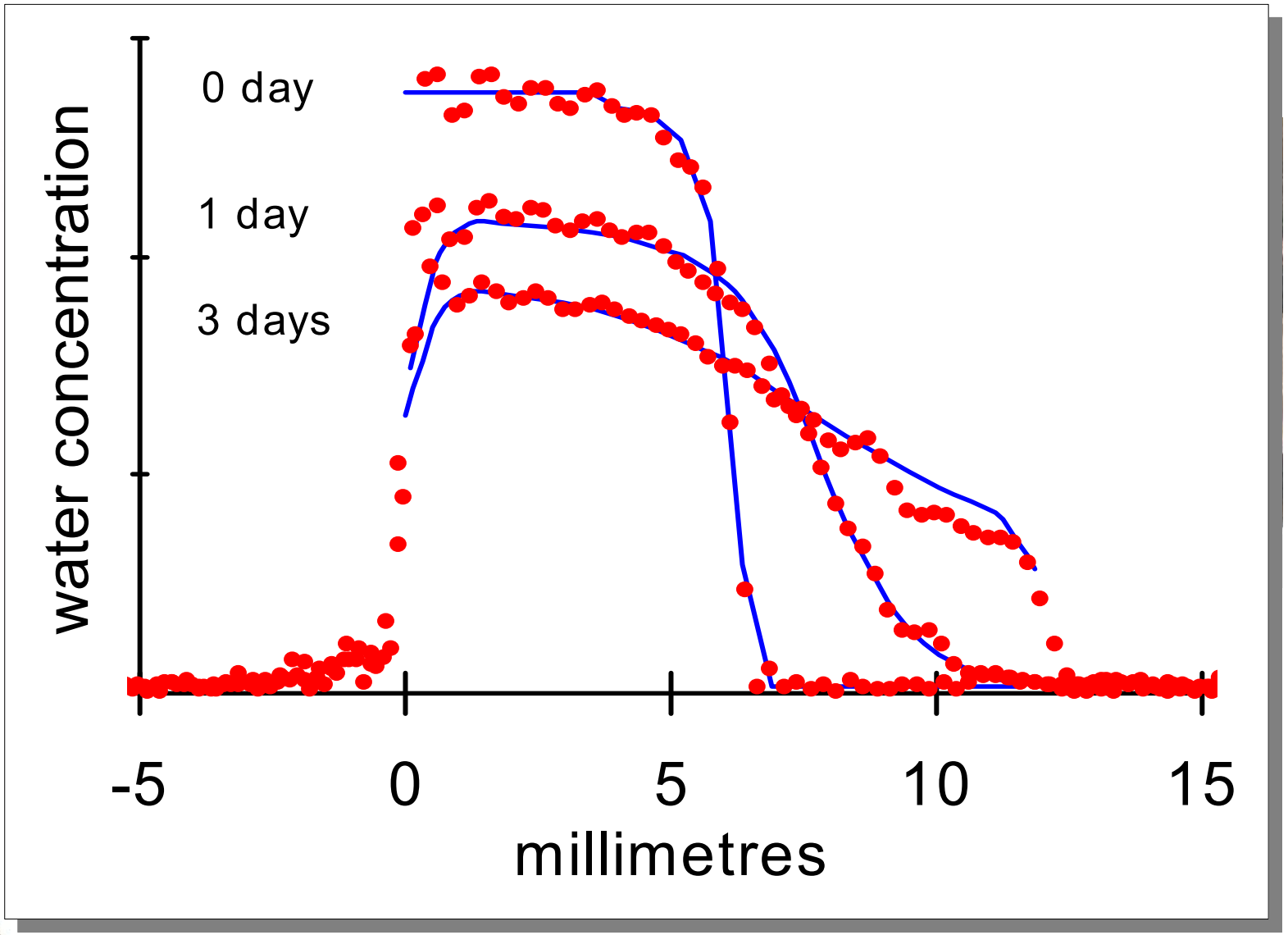
Future occurrence

Idealised modelling



- Testing / monitoring corrosion in RC members
- Reliability of instruments / testing methods
- Past performance of member
- Improving confidence in assessment through qualitative / quantitative methods.
- Bayesian event updating method

Performance monitoring - NMR



Performance updating

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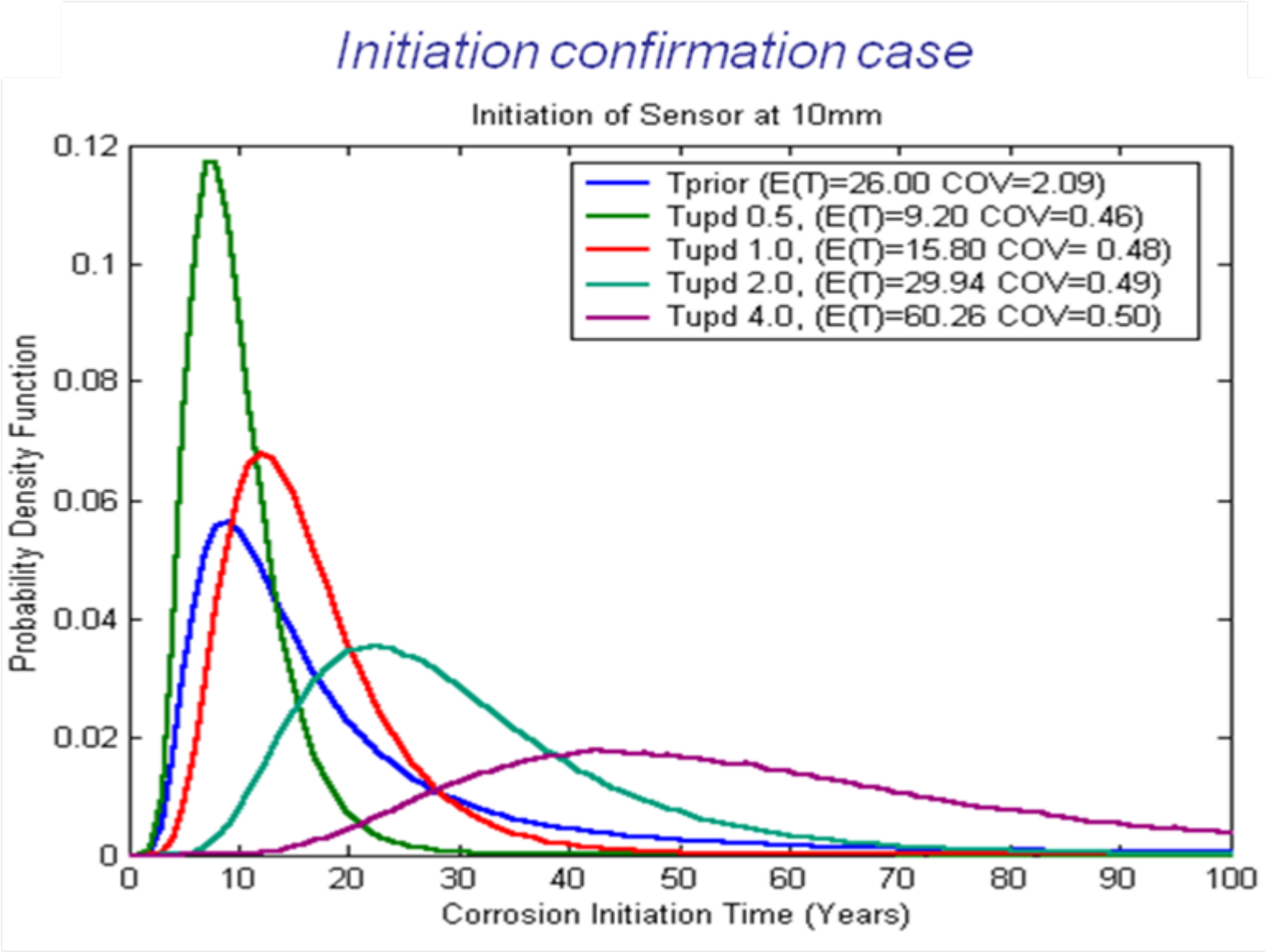
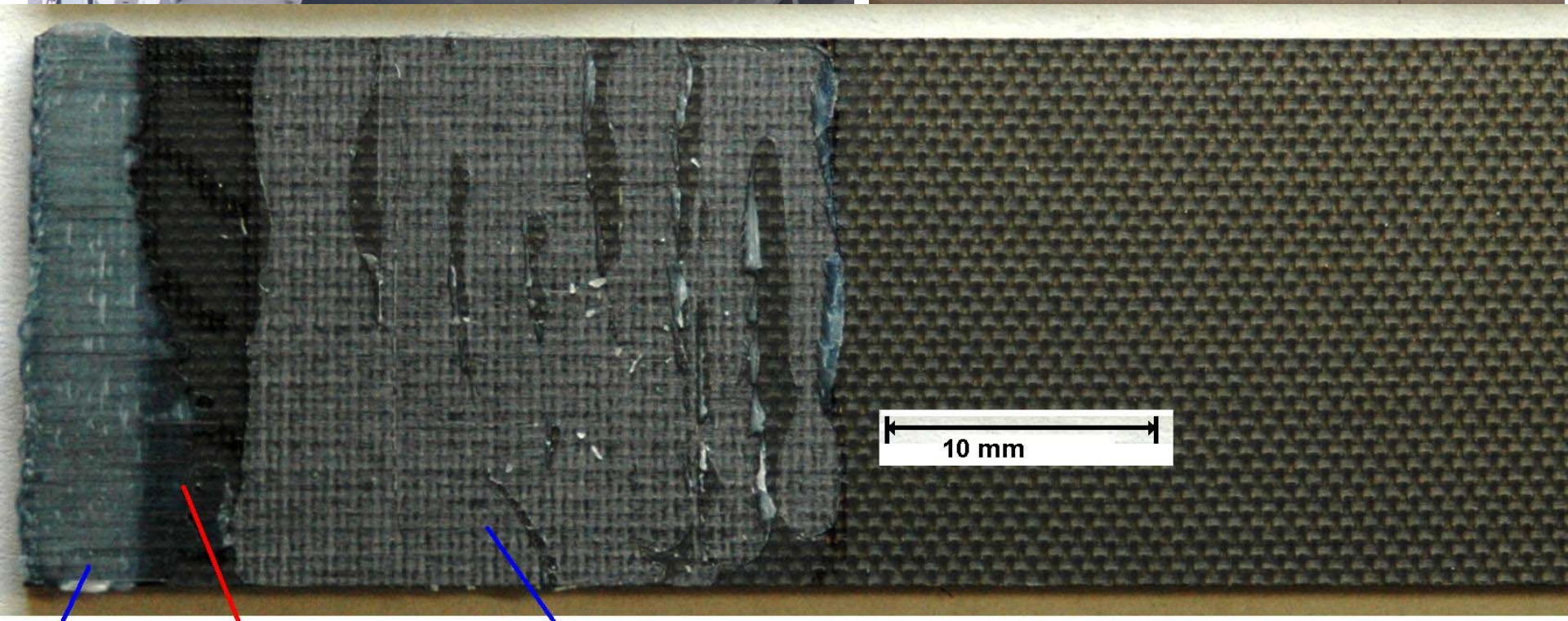
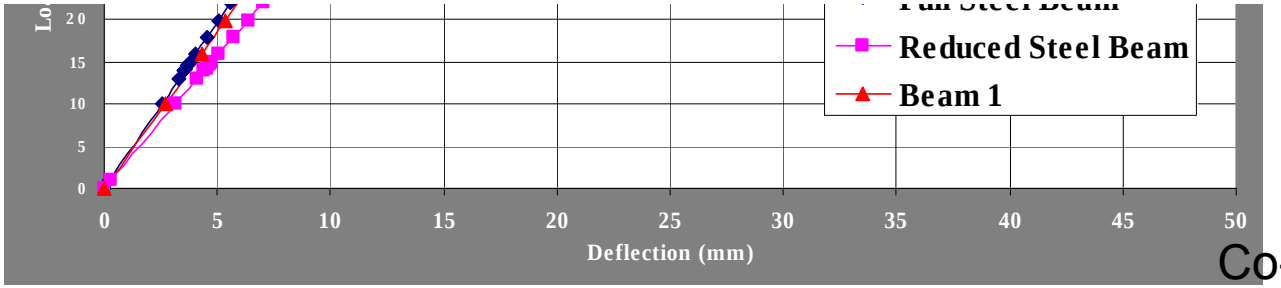


Strengthening and repair methods



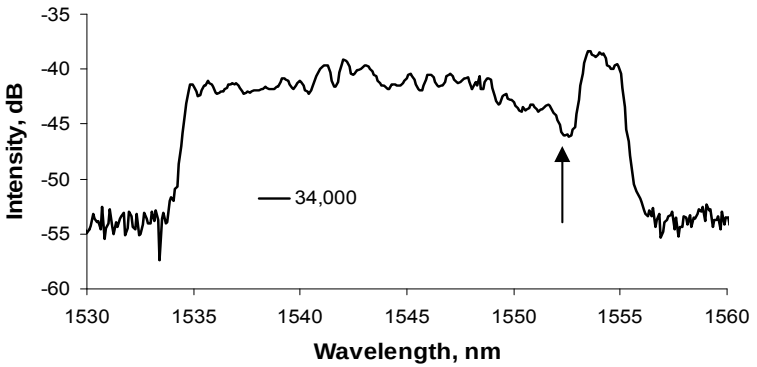


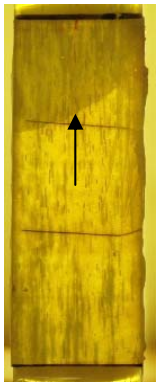
Co-PATCH EU FP7

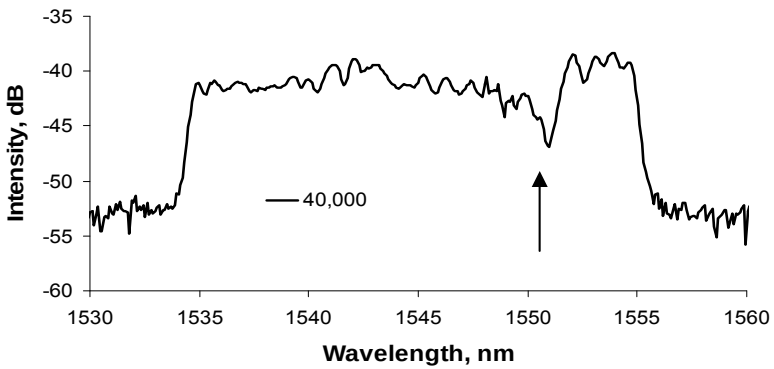
Monitoring Debonding in Repairs

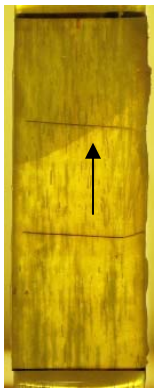
Use of Chirped Fibre Bragg Grating sensor:

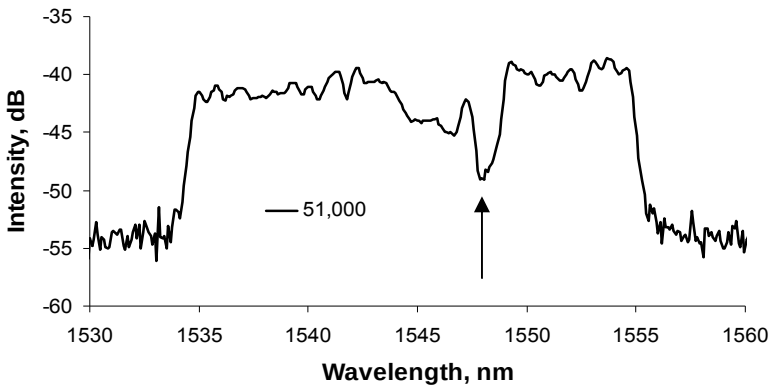
- Monitoring debond initiation and growth in composite-composite and composite-metal bonded joints
- Detecting defects in poorly bonded joints



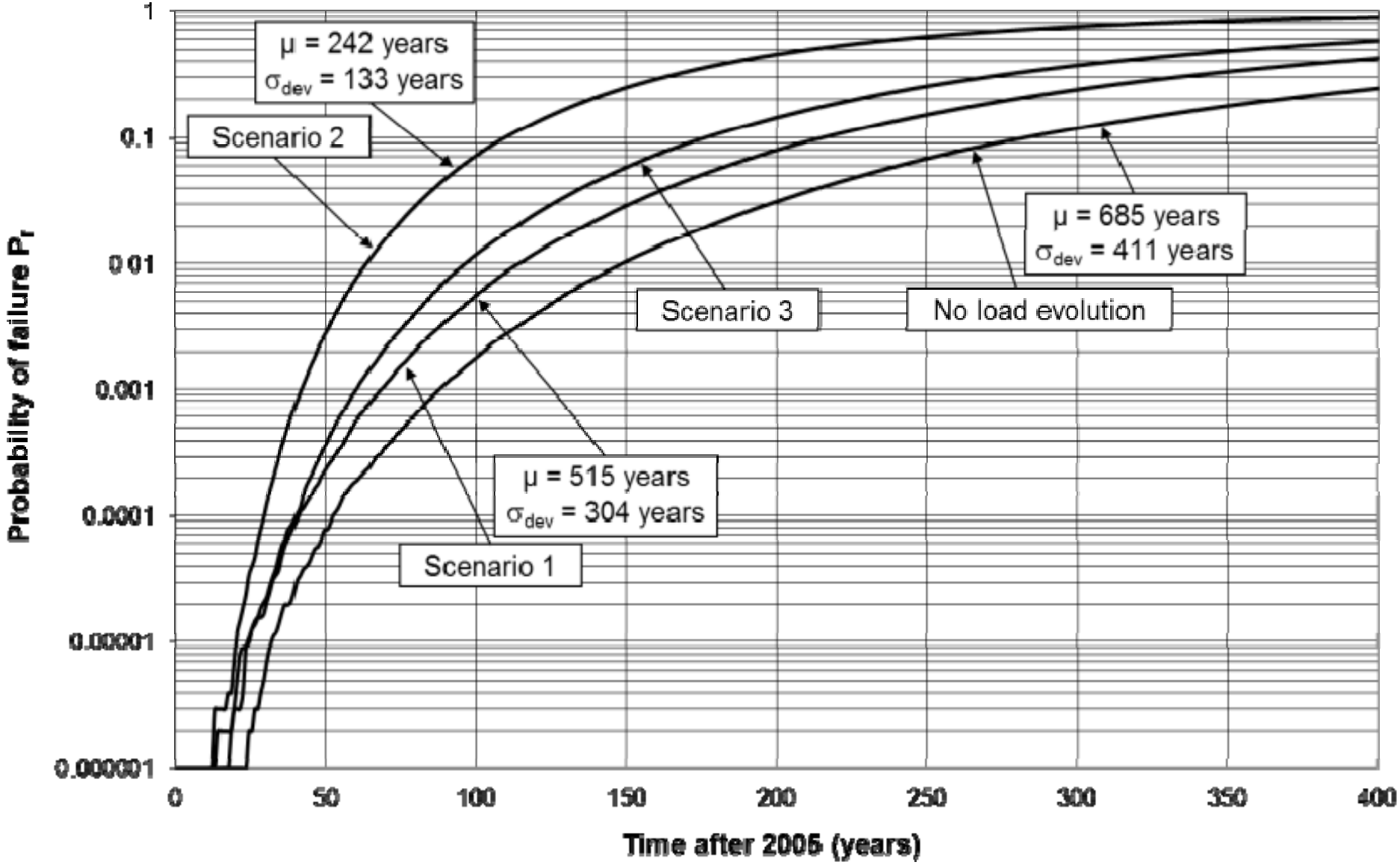








Deterioration assessment of metallic bridges



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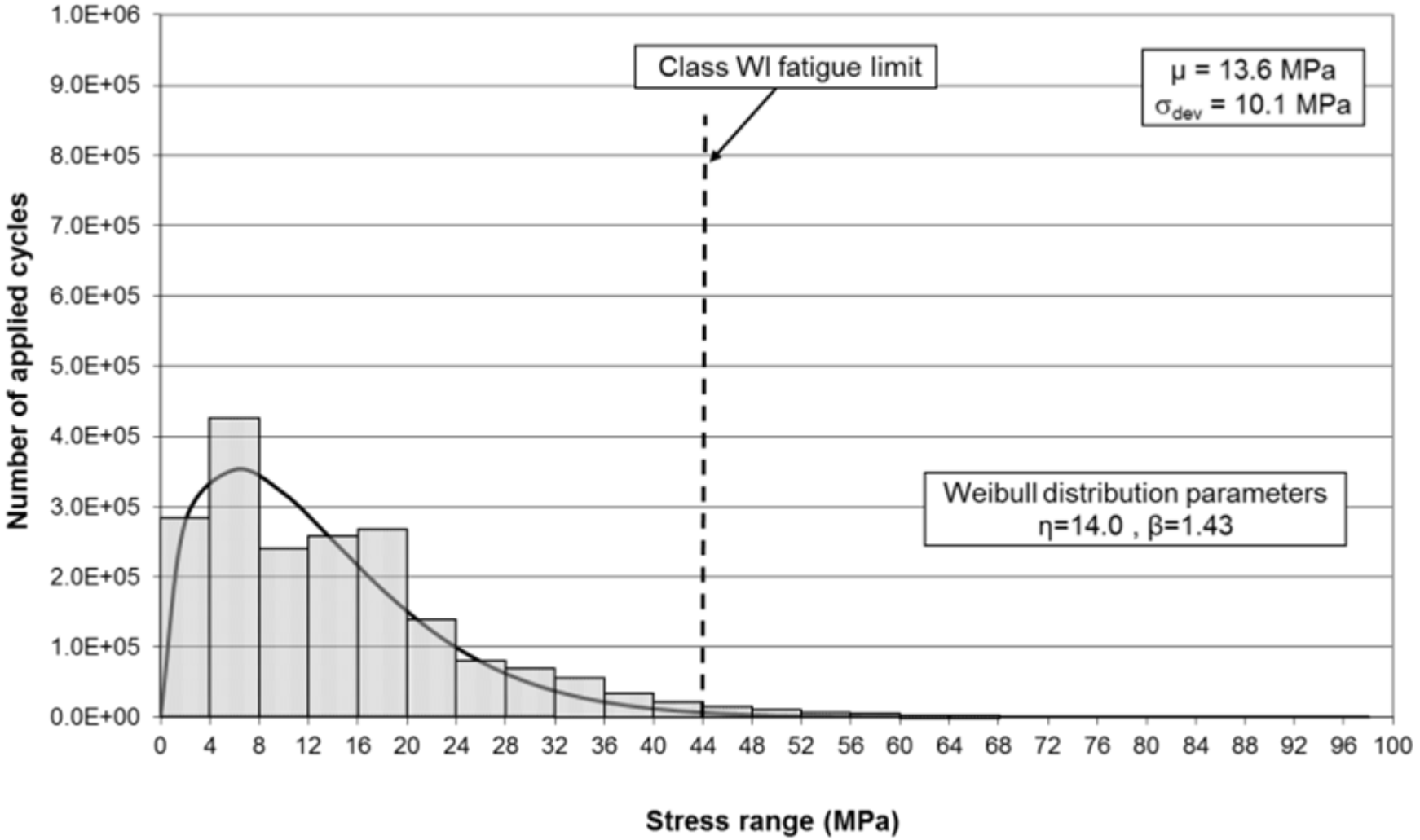
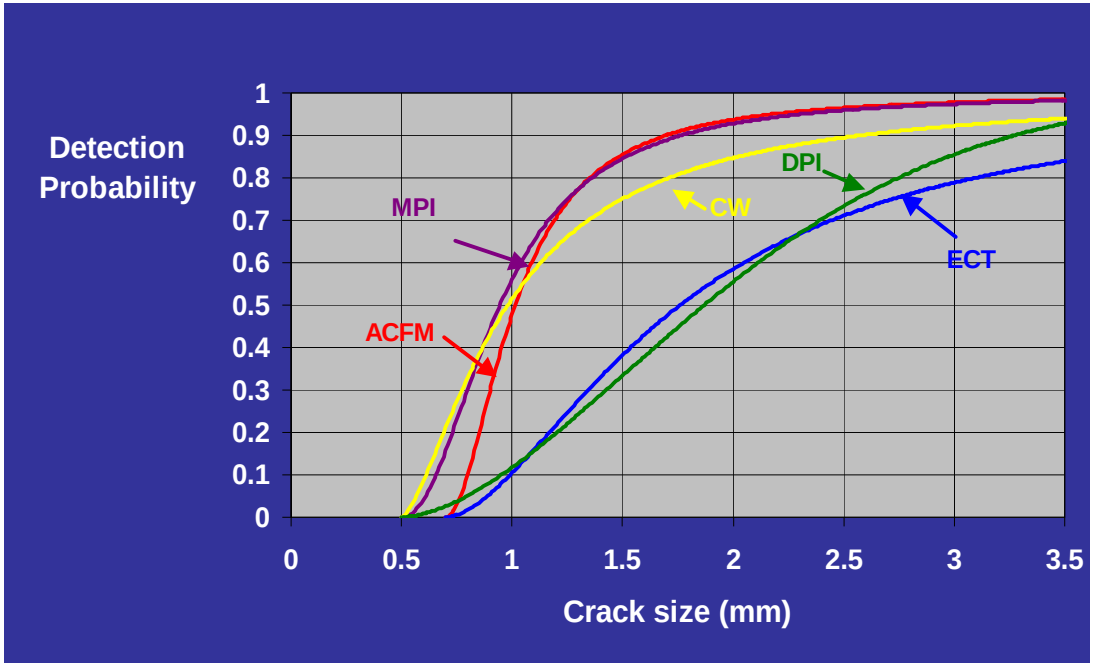


Network Rail

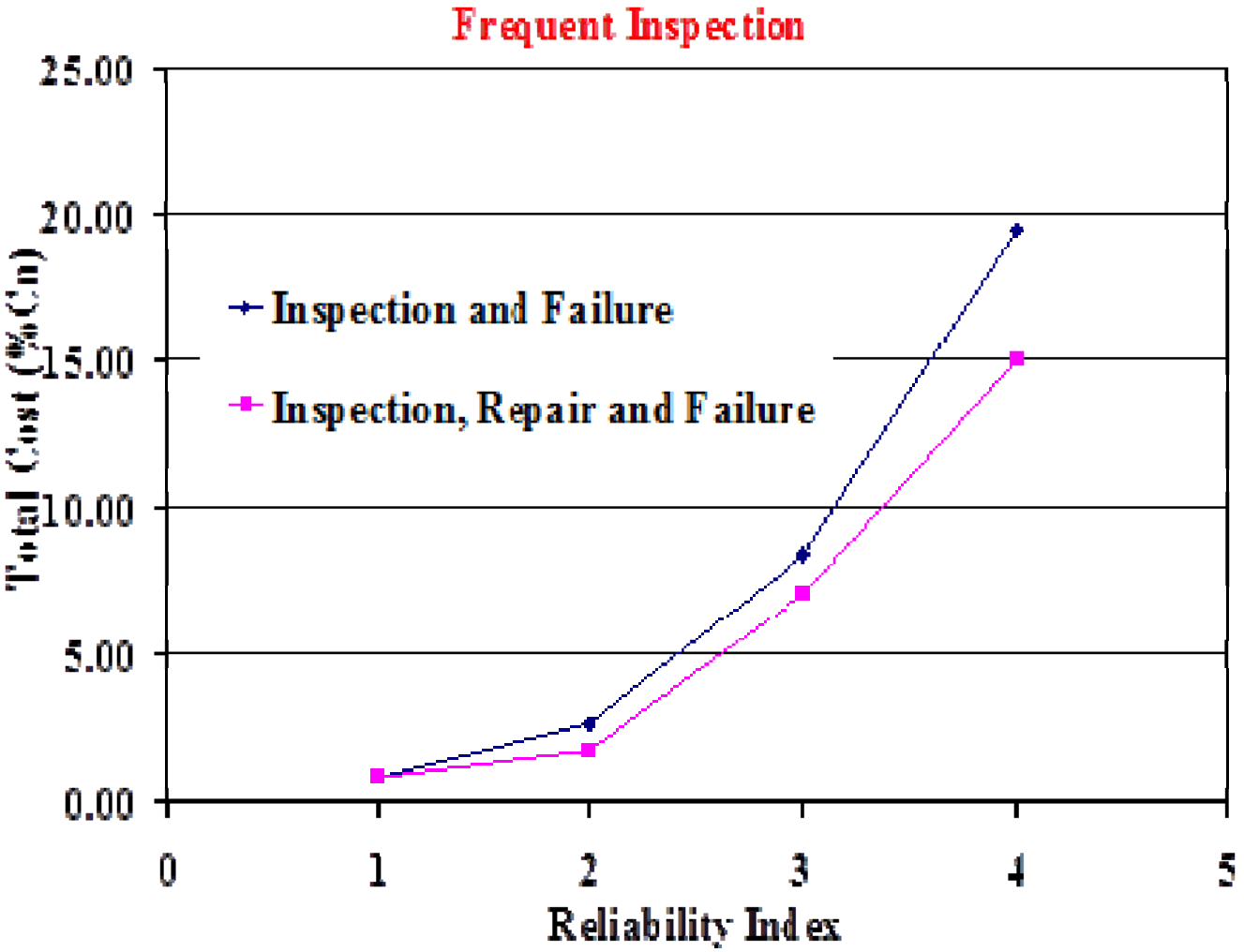
LEHIGH UNIVERSITY

Assessment of NDE performance

Variable	Distribution	Type
a_d	POD*	Inspection
a_g	Uniform	Repair
a_{fail}	Derived	Mixed
S_r	Rayleigh	Load
S_{max}	Gumbel	



Asset Management for Metallic Bridges



FP7 Grant MAINLINE

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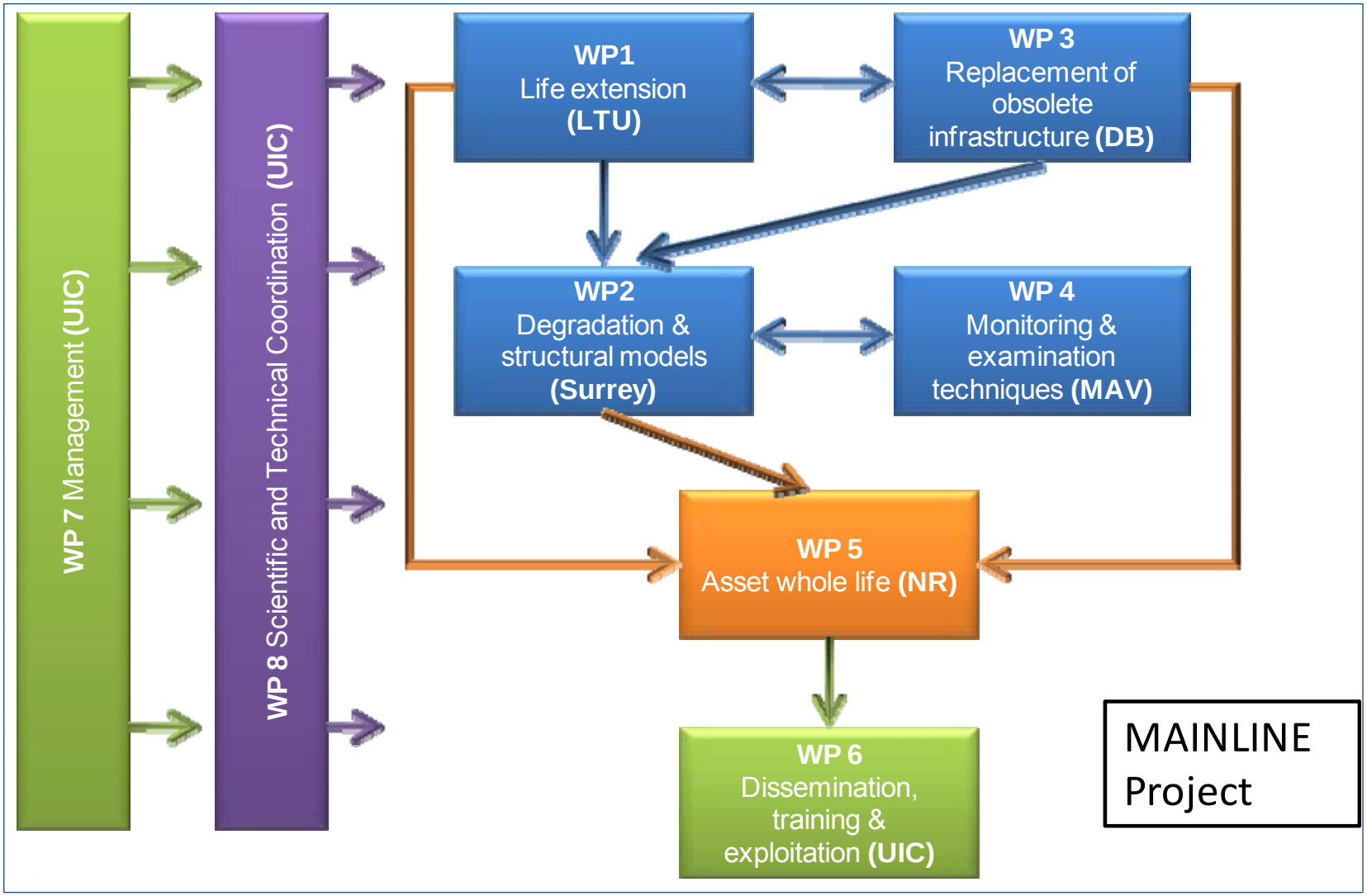
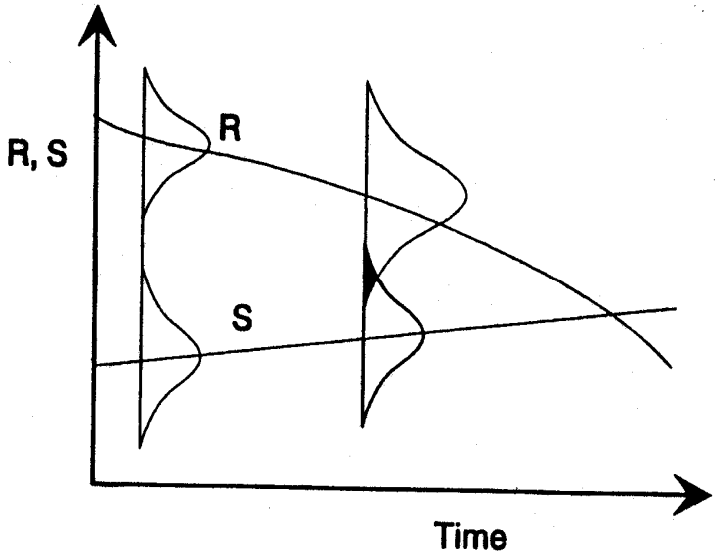
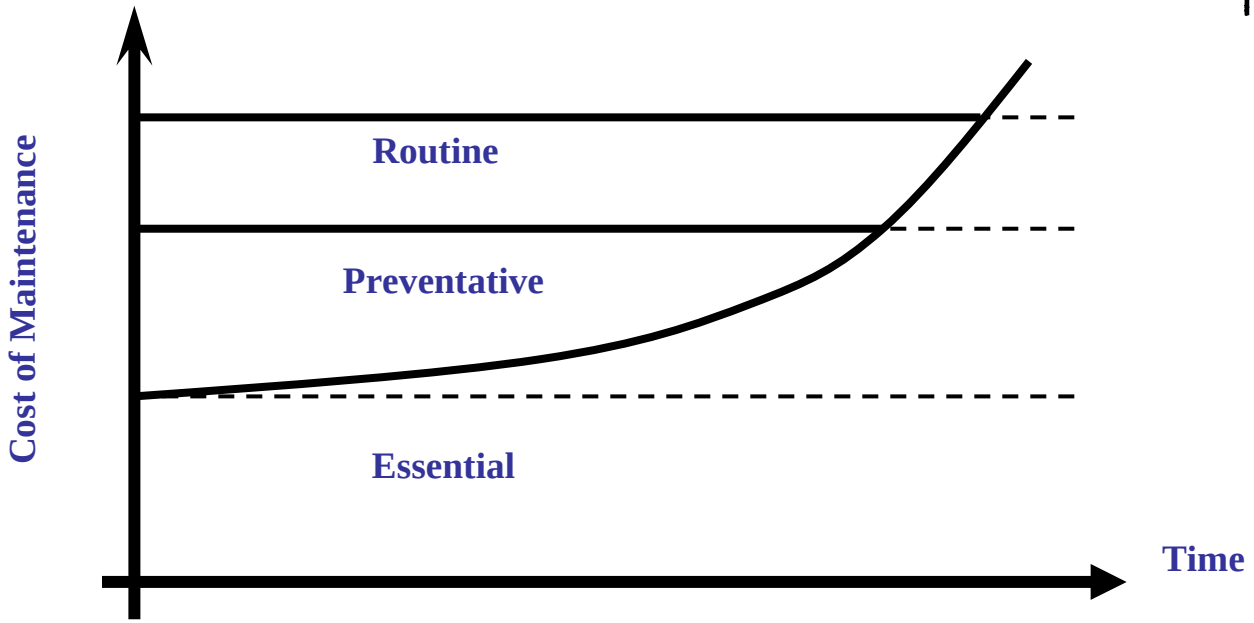
1. Facilitate the utilisation of **improved assessment and life extension** without increasing risk,
2. Improve existing **damage and deterioration mechanisms** and their effect on asset performance,
3. Identify and implement **new cost effective replacement/renewal construction methods and logistics**, bearing in mind the logistics and operational constraints across an expanding railway network, and the associated political aspirations towards a sustainable low carbon society,
4. Identify and compare new surveying and **monitoring technologies** in order to complement or replace existing techniques,
5. Develop methods for determining the **whole life environmental and economic impact** from track and infrastructure maintenance and renewal through the use of various scenarios and management policies.


WP 7 Management (UIC)
WP 8 Scientific and Technical Coordination (UIC)
WP1
Life extension
(LTU)
WP 3
Replacement of obsolete infrastructure (DB)
WP2
Degradation & structural models
(Surrey)
WP 4
Monitoring & examination techniques (MAV)
WP 5
Asset whole life (NR)
WP 6
Dissemination, training & exploitation (UIC)
MAINLINE Project

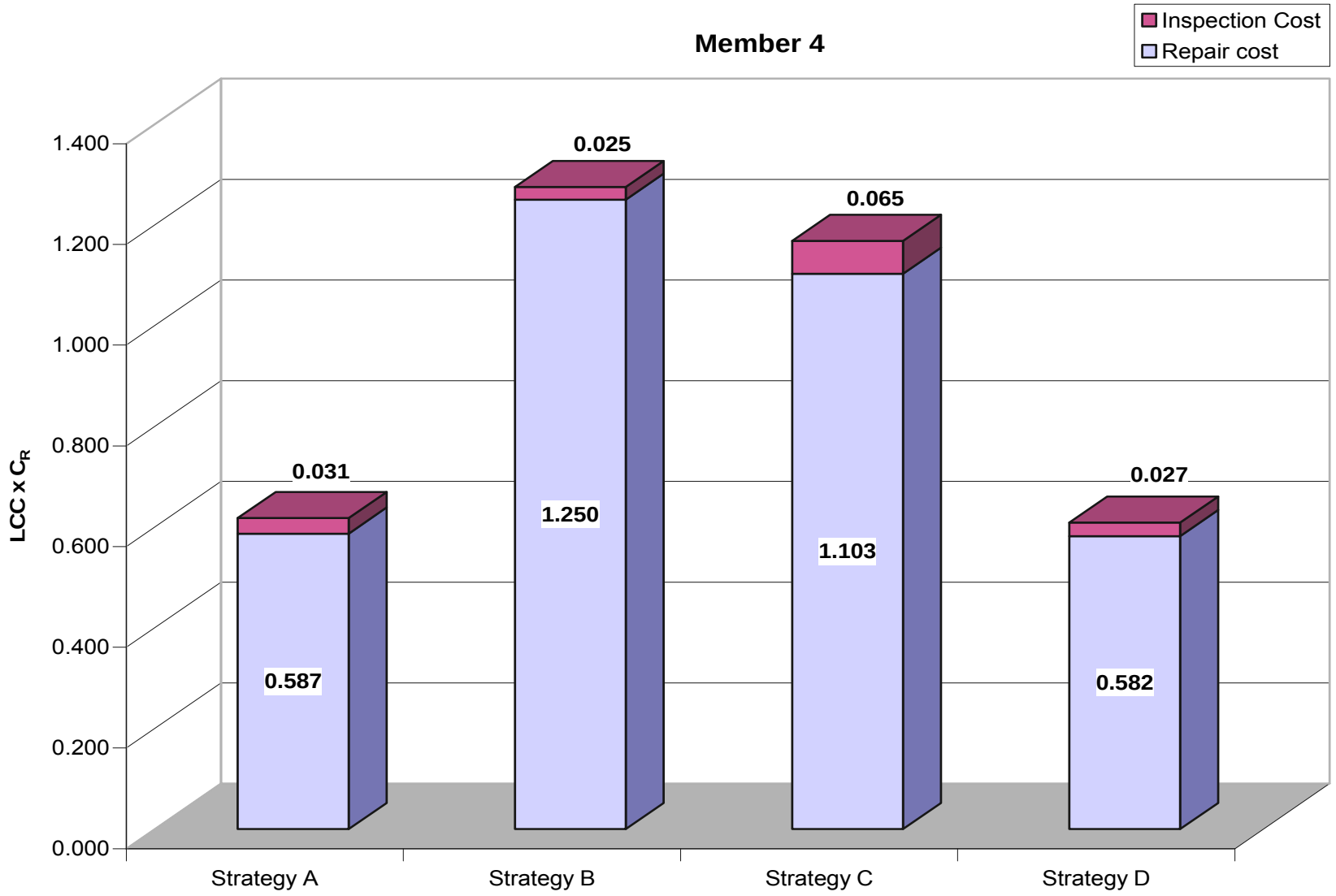
Whole-Life Performance of Structures

- Modelling deterioration and its effects
- Predicting load demands
- Quantifying safety reserves
- Optimizing maintenance strategies





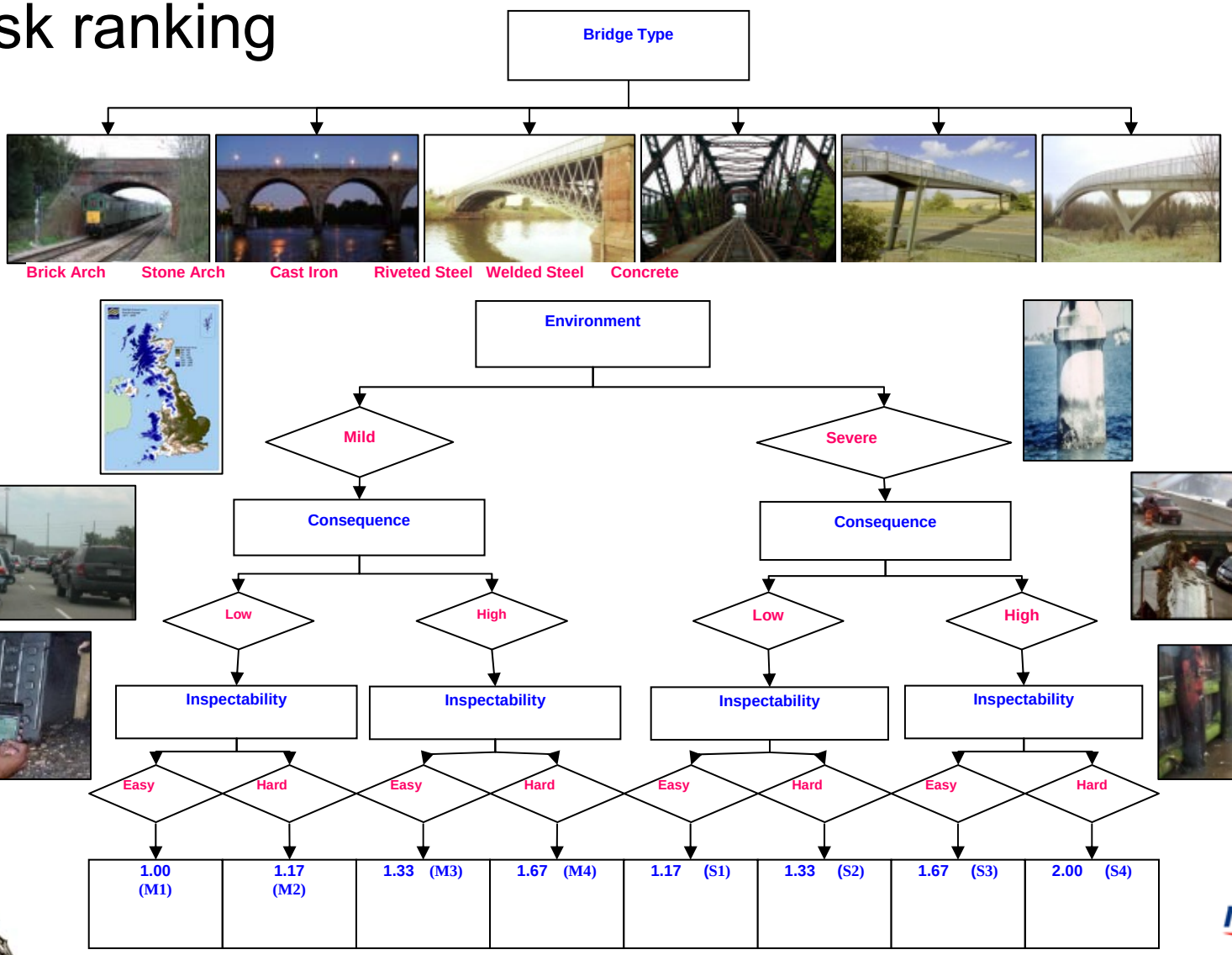
Health Monitoring Structures



Inspection Planning for Bridge Stocks

Inspection Planning for Bridge Stocks

Risk ranking



Inspection Planning for Bridge Stocks

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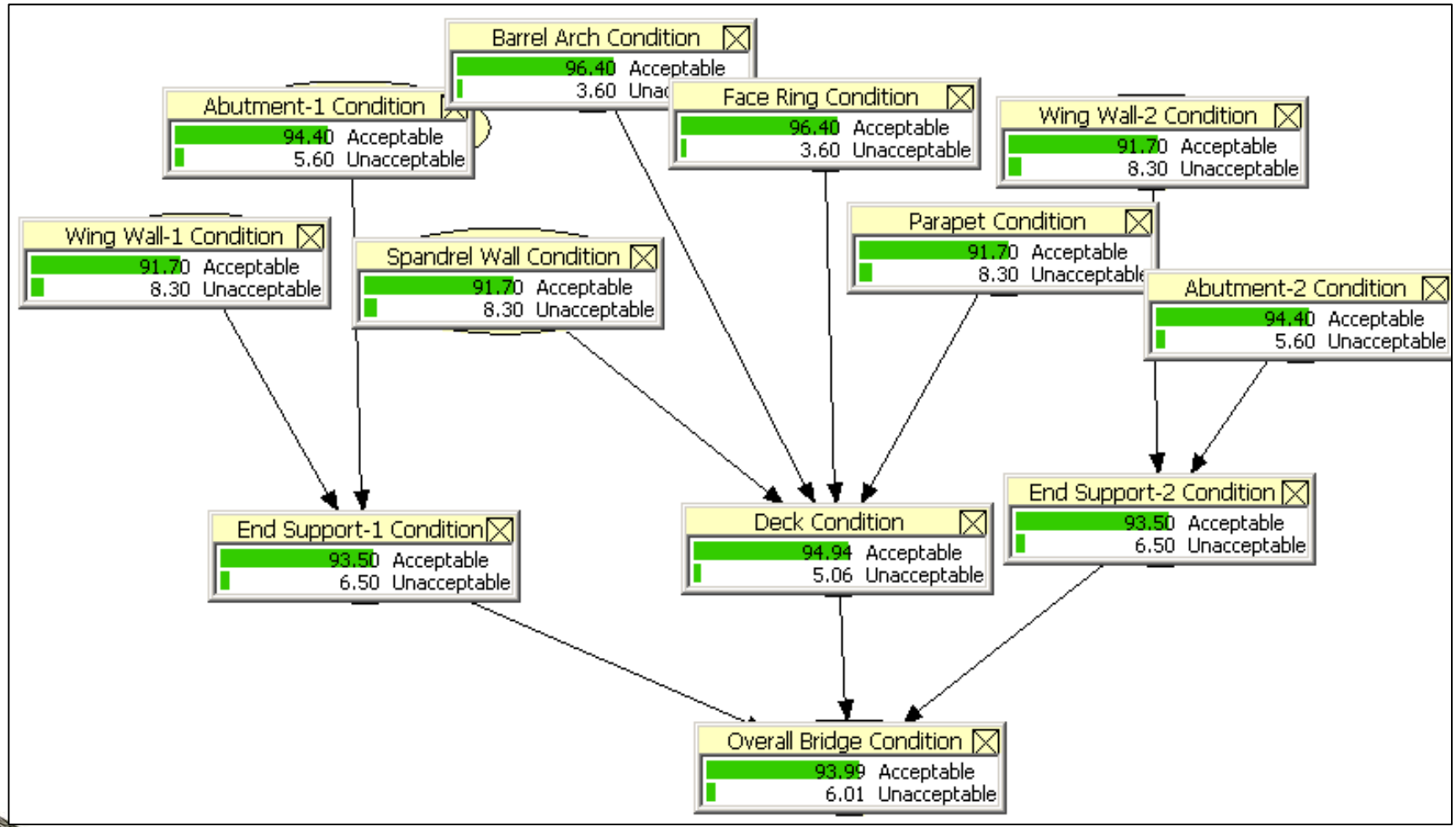
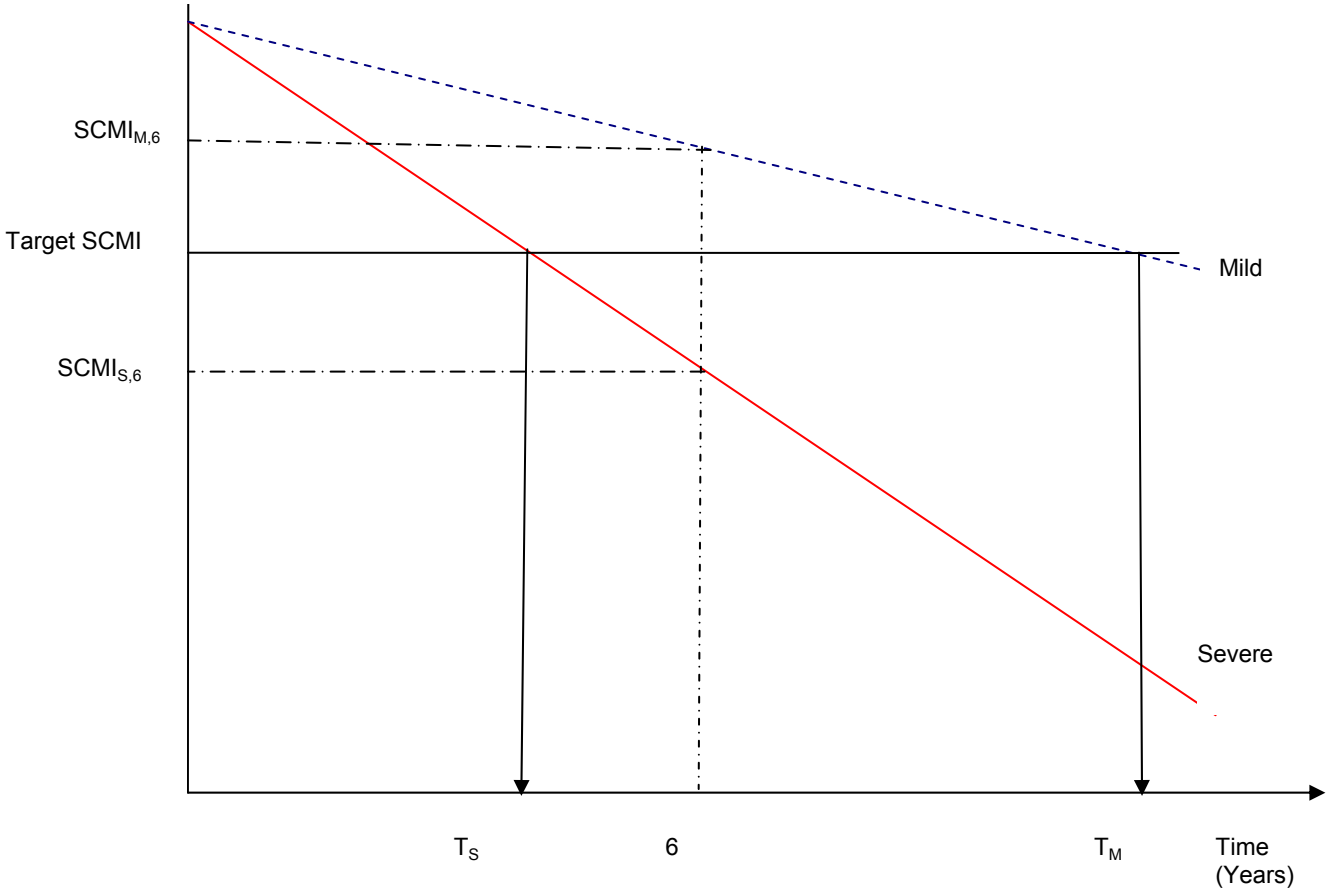
Modelling deterioration using Bayesian Belief Network



Network Rail

Inspection Planning for Bridge Stocks

- Estimation of Risk-Time Profile
- Development of Inspection intervals



CI Trunk Mains Networks

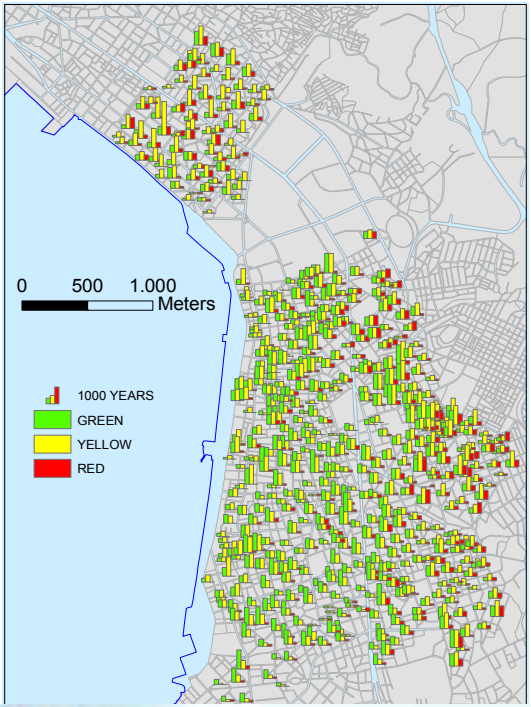
- Aged, complex, buried infrastructure
  - Delivers millions of tonnes of water/day, (24/7)
  - > 6,000's of km
  - > 50% > 100 years service, > 30% > 150 years service
- Develop trunk burst prediction models
  - Reduce risk of the occurrence of bursts
- Minimise impact of bursts
  - Consequence modelling
- Assess methods of mitigation
  - Minimal intervention, high return

Water industry funding £1M, plus £240k from EPSRC IDC's.

Damage and Loss Estimation

- Consequence models
- Modelling damage and collapse of structures under extreme loads (e.g. earthquakes).
- Individual buildings and bridges.
- Groups, portfolios, networks.
- Simplified methods for loss estimation.
- Uncertainty in loss prediction.

EU FP7 Less-LOSS



Resilience to Environmental Change

- Bridge scour
- Corrosion / deterioration
- Temperature stress cycling
- EPSRC Grant EP/I00744X "*Bridge reliability under the influence of changing environmental and demand conditions*"

EPSRC Engineering and Physical Sciences Research Council

Network Rail

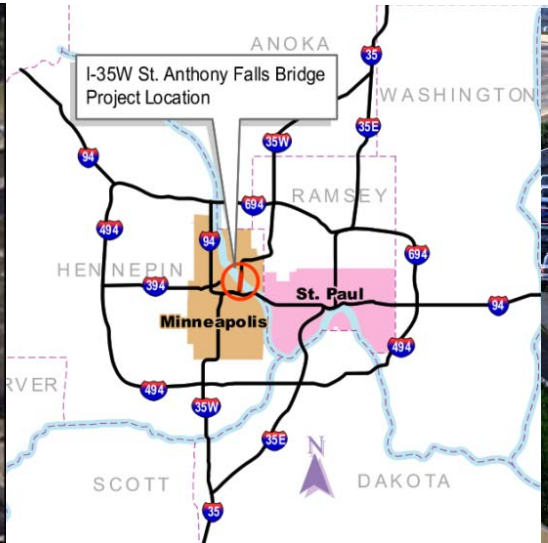
HR Wallingford

TGP

TRL

Risk-based Assessment of Bridge Infrastructure

- Bridge infrastructure resilience to hazards
- Consequence modelling for failures (human, economic, environmental, societal)
- Transportation network analysis
- Traffic delay / re-routing modelling
- Casualty modelling from infrastructure failures



SmartEN: Smart Management of Human Environment

- WP1: Wireless sensors networks
- WP2: Sensor Signal Processing
- WP3: Non-Destructive Evaluation
  - *Optimum Sensor Locations and Requirements for NDE*
  - *Combined Monitoring and Inspection Systems*
  - *Assessment and Long Term Performance Modelling*
  - *Performance Model Updating Based on Sensor Information*
  - *Damage identification*
- WP4: Smart Proactive Management
  - *Proactive Management Strategies*
  - *Life Cycle Design and Assessment*
  - *Multi-objective Optimisation*

EU FP7 Marie Curie

Transmission Tower Collapse

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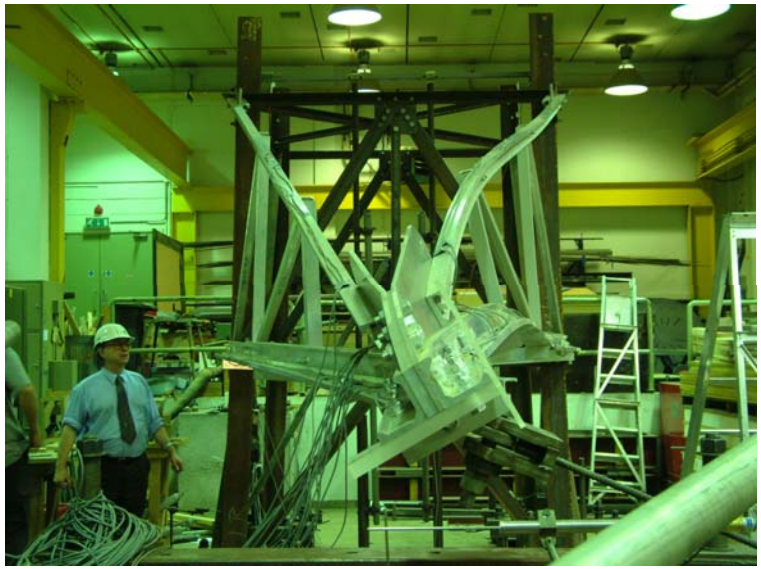
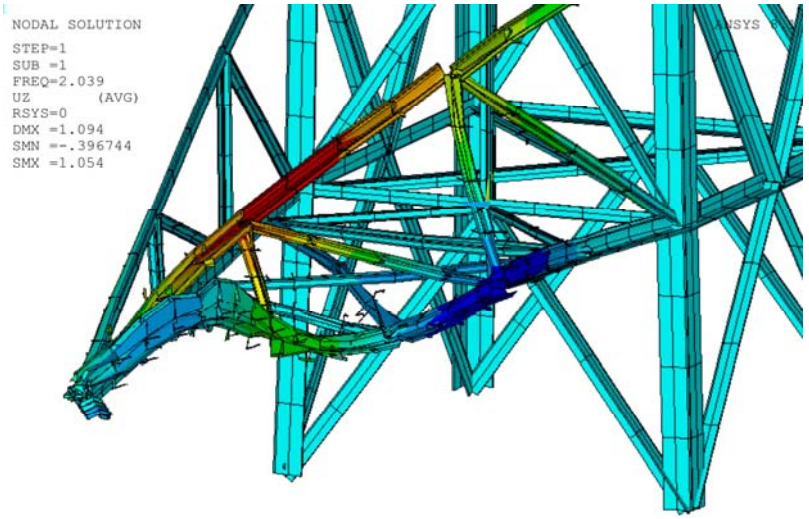
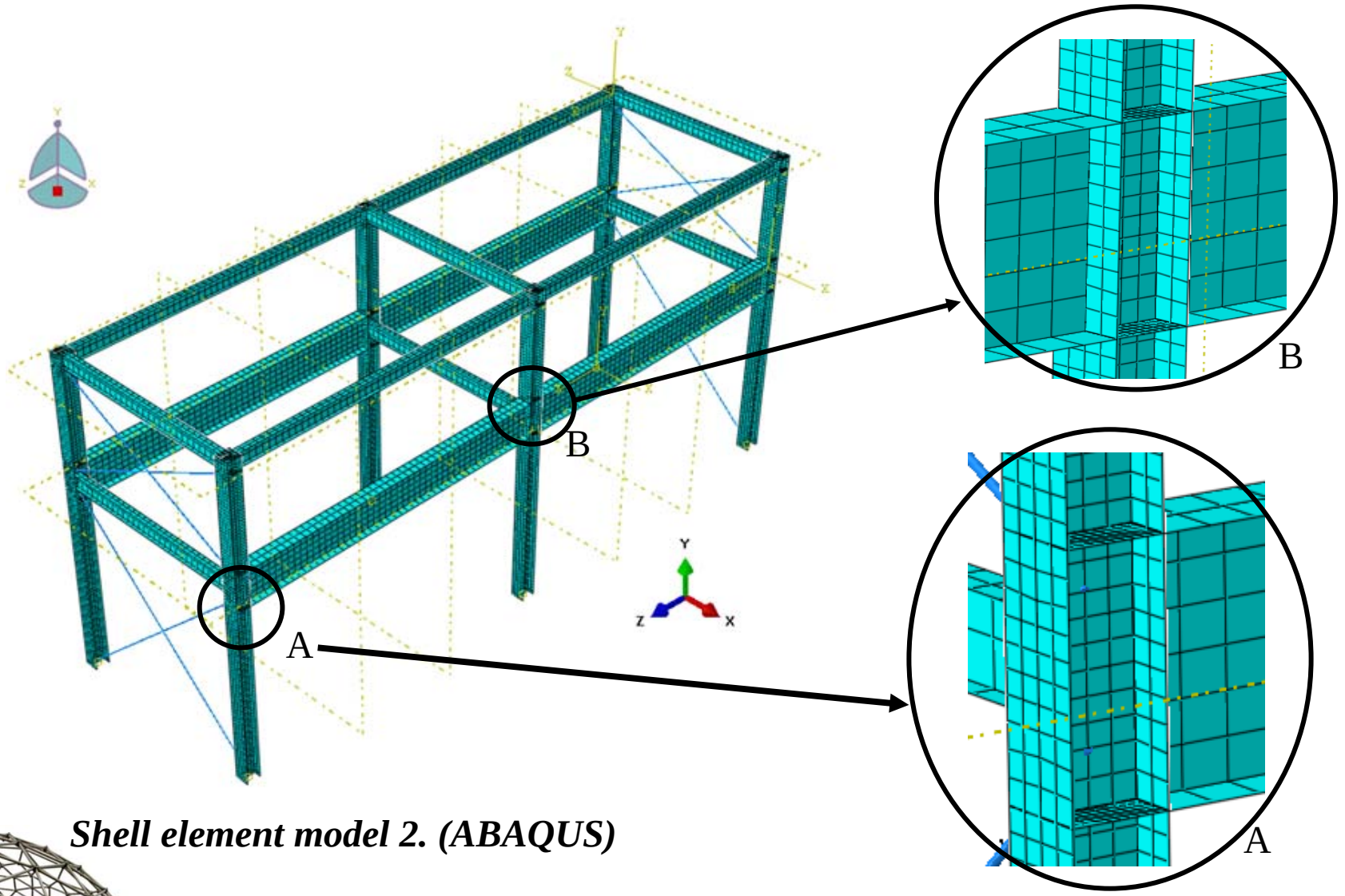
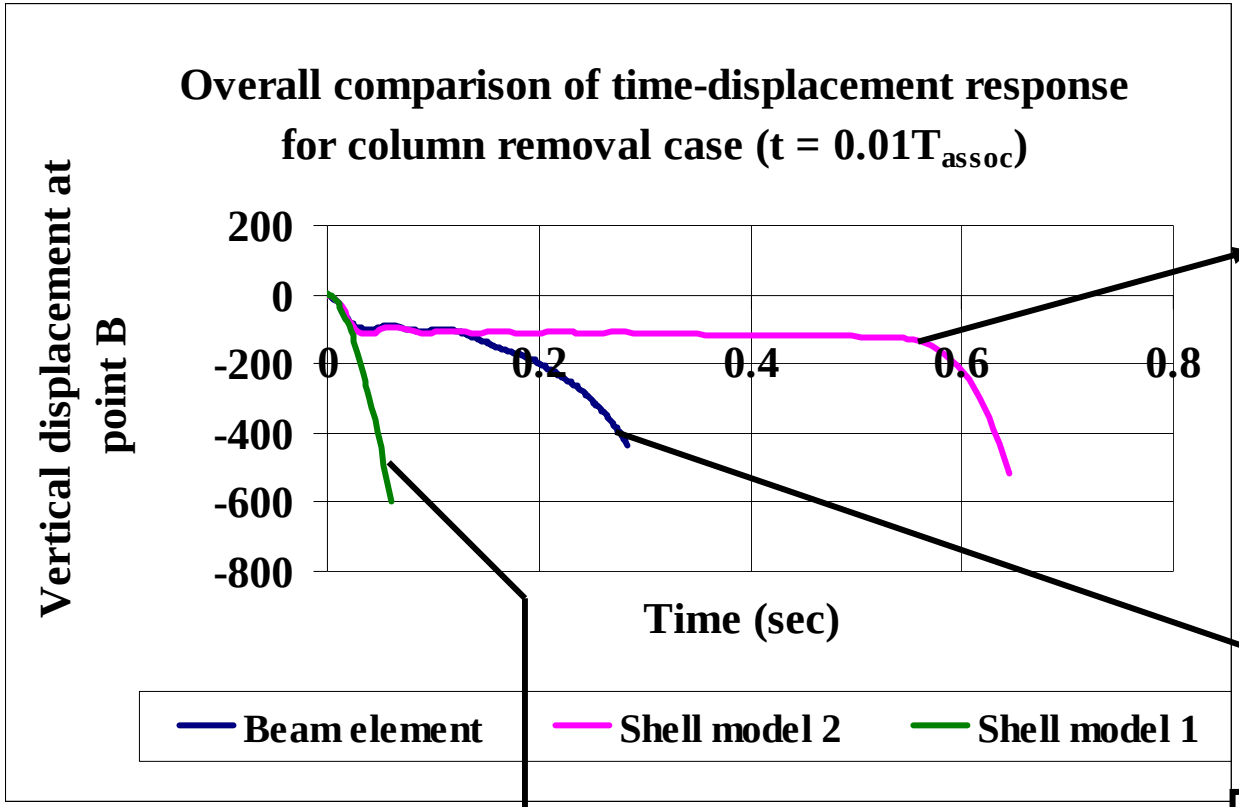


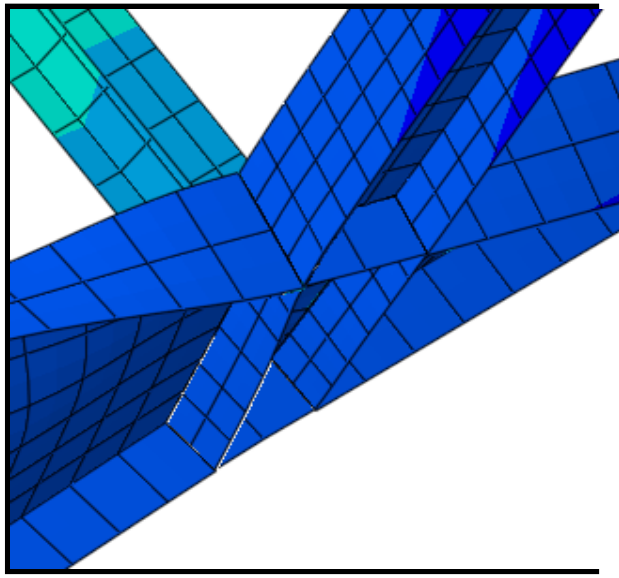


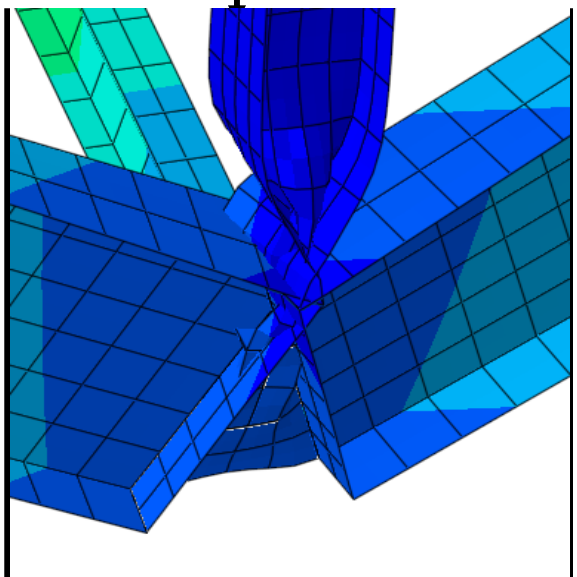
Resilience Response Analysis

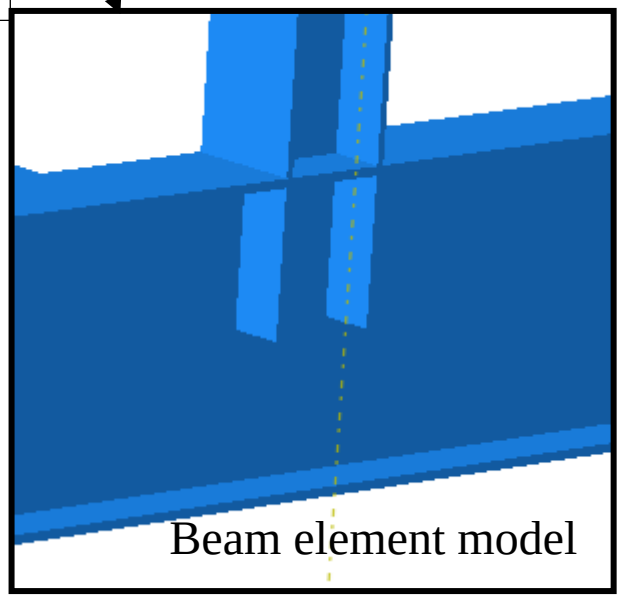


Shell element model 2. (ABAQUS)


Overall comparison of time-displacement response for column removal case (t = 0.01T$_{assoc}$)
Vertical displacement at point B
200
0
-200
-400
-600
-800
0
0.2
0.4
0.6
0.8
Time (sec)
Beam element
Shell model 2
Shell model 1






Beam element model

Summary

- Managing current assets
  - Characterising and modelling deterioration
  - Performance assessment and prediction
  - Structural health monitoring
  - Reliability and consequence modelling
  - Risk-based asset management
  - Infrastructure resilience

- Facing future challenges
  - Impact of climate change
  - Consequence modelling
  - Smart Infrastructure management
  - Multi-scale life cycle analysis