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Bridge Related Research

at the University of Surrey

An Overview
by
Prof Gerry Parke

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Composite Materials & Structures Research

Composites Research at UniS

- Extends from *micro* to *macro* scale
- Involves researchers from several disciplines
  - Chemistry
  - Materials Science
  - Mechanical and Civil Engineering
- Covers processing, characterisation, structural behaviour and durability aspects

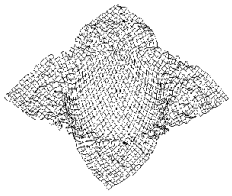
Principal Research Groups

- Polymers, Colloids & Interfaces Laboratory
  based in Physics and Chemistry
- Composite Materials and Structures Group
  based in School of Engineering

Strong interaction between groups manifested through common interests and projects

Polymers, Colloids & Interfaces Laboratory

- Electron and proton-beam processing of thermosetting polymers
- High-performance matrix resins
- Fibre-matrix Interactions
- Composite repair and toughness enhancement



Simulation of the forming of a woven fabric where wrinkling occurs

Composites Research Group

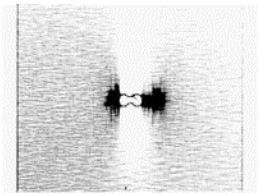
- Fundamental behaviour and properties of individual constituents and simple elements
  - Single fibres, cloths
  - Laminates
  - Notches, Joints
- Damage mechanics, lifetime prediction, process modelling, smart technology are principal research themes
- Excellent facilities for fabrication, mechanical testing and numerical simulation

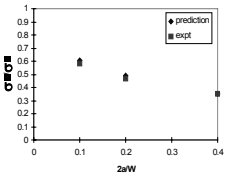
Composites Research Group

- Static, dynamic, fatigue and long-term characteristics of composite systems
  - Concept development
  - Model and prototype testing
  - Numerical analysis and parametric studies
- Strengthening and upgrading in construction
- Development of design guidance
  - Limit State approach
  - Reliability analysis

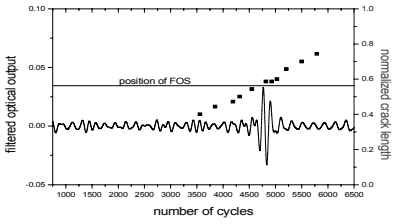
Damage and Fracture in Woven Fabric Composites

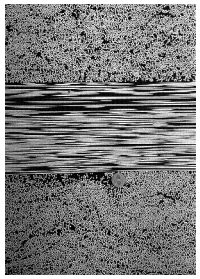
- Experimental and analytical study
- Complex localised damage zone at notch tip



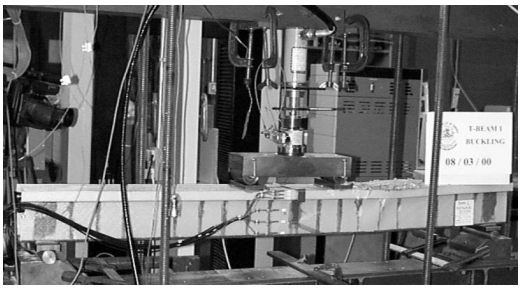


Use of Fibre Optic Sensors to Detect Damage in Composites

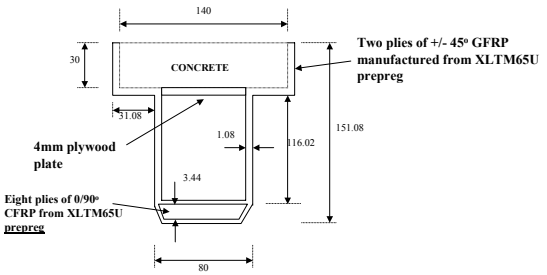




Development of Advanced Composite/Concrete Units



Cross-section of Tee beam of Composite/Concrete Construction



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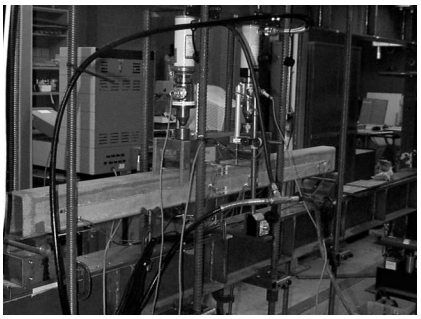

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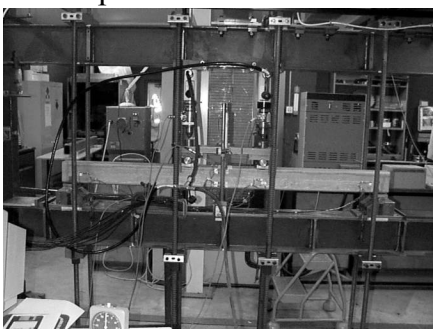
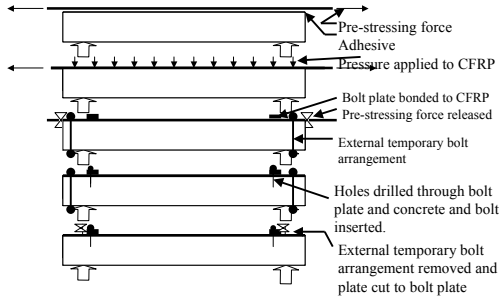
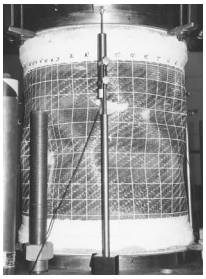
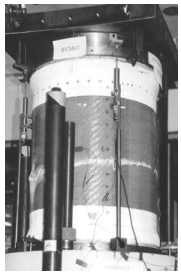


Pre-stressed Composite Plates for Upgrading of RC structures



Design of composite shells



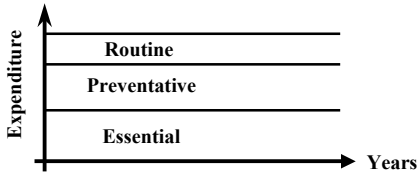


Risk and Reliability Assessment of Bridge Structures and Stocks

Marios Chryssanthopoulos
School of Engineering
University of Surrey

The Problem

- **Deterioration of an aging bridge stock**
- **Increasing traffic loads and frequencies**
- **Limited resources**



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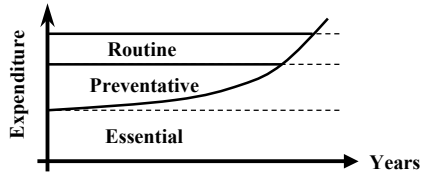
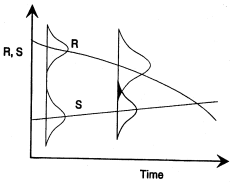


Chloride induced deterioration

Uncertainty and Performance

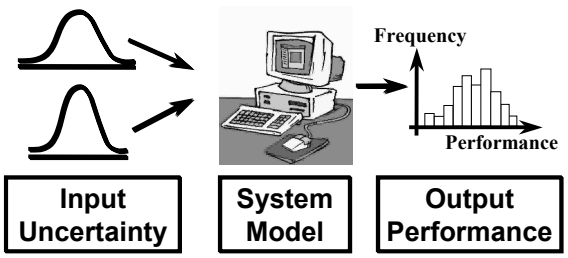
Incomplete knowledge
Future occurrence
Idealised modelling

Causes of Uncertainty



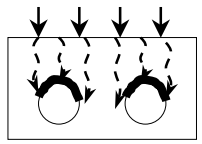
Time-varying performance

Structural Reliability Analysis



Reliability Assessment of RC bridges

- **Cause**
  - **De-icing salt**
- **Deterioration Processes**
  - **Chloride ingress**
  - **Corrosion of reinforcement**
  - **Concrete cover delamination**



Modelling - Spatial - Simulation - Reliability - Case Studies

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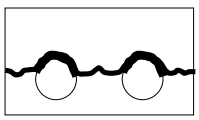


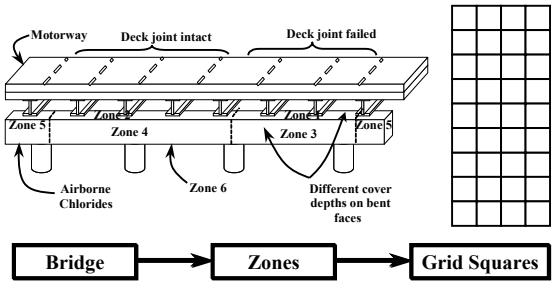
Modelling - Spatial - Simulation - Reliability - Case Studies

Probabilistic Input

- **Deterioration**
  - **Effective diffusivity, chloride quantity, critical chloride corrosion threshold, corrosion rate**
- **Materials & Geometry**
  - **concrete compressive and reinforcement yield strength, section dimensions**
- **Loading**
  - **Dead and Superimposed Dead**
  - **Live (static + dynamic amplification factor)**

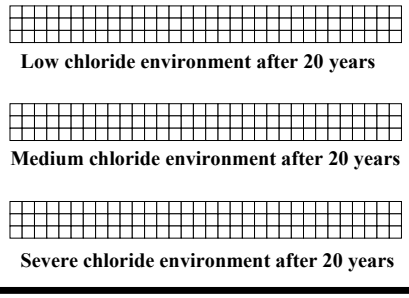
Modelling - Spatial - Simulation - Reliability - Case Studies

Spatial Analysis



Bridge → **Zones** → **Grid Squares**

Typical Simulation Output



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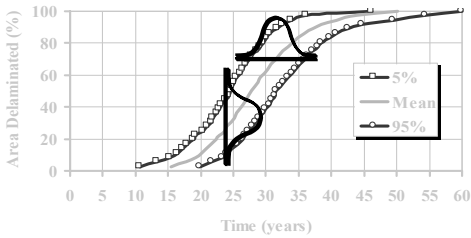


•Deterioration profile for an identified zone

Time-Varying Reliability Analysis

- Failure margins

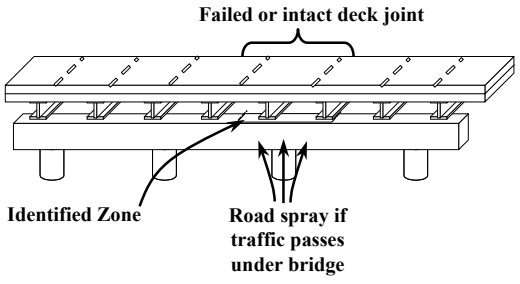
$$\text{Margin} = (\text{Bond or Yield Capacity}) - \left(\frac{M}{z} + \frac{V}{2}\cot\theta\right)$$

Evaluation of Reliability

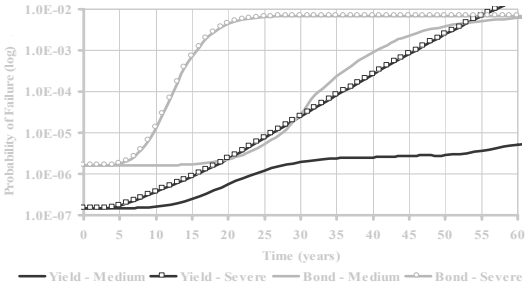
•Monte Carlo Simulation

$$\text{Probability of failure} = \frac{\text{Number of failures}}{\text{Sample Size}}$$

Case Study - Zone from a RC Bridge



Time-Varying Reliability Profile



Conclusions

- Spatial approach can improve deterioration prediction capability
- Spatial deterioration can be integrated with limit state reliability analysis
- Members/structures may be compared through time-varying reliability profiles
- Further work on deterioration models/data

Spatial Deterioration Modelling

The Pros:

- Improved knowledge of current condition
- Improved modelling of future condition
- Predict future inspection and maintenance requirements (preventative?)
  - Produce long term financial/work plans
- Remove a degree of subjectivity/uncertainty

Spatial Deterioration Modelling

The Cons:

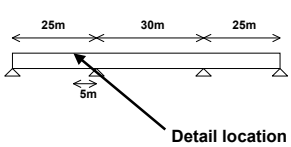
- Increased (upfront) expenditure on:
  - Data collection (traffic management, possessions etc)
  - Spatial analysis
  - Develop supporting Bridge Management Systems
- Black Box management:
  - Ensure that experience and judgement play a role
  - Danger of overlooking local unforeseen phenomenon through the use of generic models

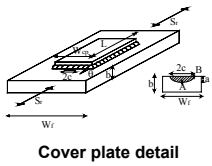
Fatigue Assessment of Steel Bridges

- **S-N approach**
- **Fracture Mechanics approach**
- **Fatigue Loading**
  - **Semi-analytical pdf's**
  - **cycle counting methods**
- **Typical limit states**
- **Material uncertainties**
- **Model uncertainties**
- **Correlation effects**

Example application: Fatigue life assessment after inspection and repair

- Fatigue treatment based on Fracture Mechanics
- Probabilistic models from JCSS-PMC
- NDE and different types of invasive action (load truncation and/or weld toe grinding)

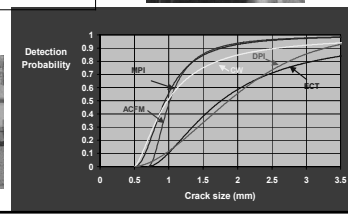




Fatigue assessment: Random Variables (2)

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

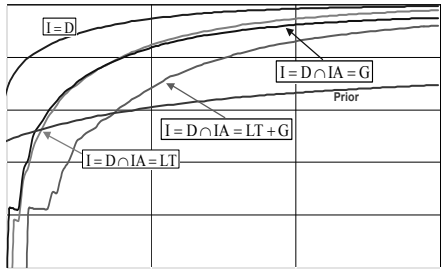
*** POD for MPI used in case study**



Fatigue assessment: scenarios

- **Inspection and crack detection at T=30y**
- **Alternatives considered:**
  1. **Load truncation (LT)**
  2. **Weld toe grinding (G)**
  3. **Load truncation + weld toe grinding (LT+G)**

Fatigue assessment: typical results

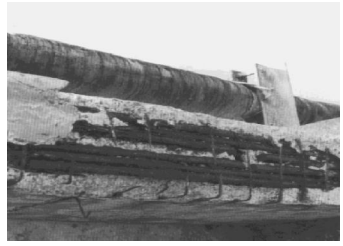


I: Inspection, D=Detection
IA: Invasive Action, LT=Load Truncation, G=Weld Toe Grinding

Future Research

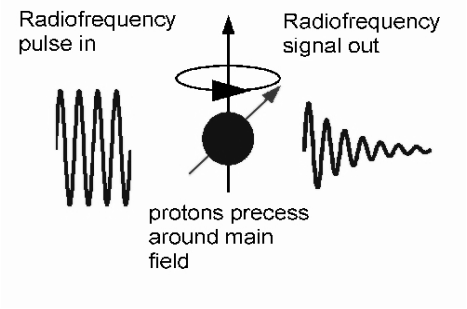
- Can we justify **Managed Deterioration** within Bridge Management?
- Integrate with **Inspection and Monitoring**
- Develop **Bridge Management Systems** to support improved modelling and inspection updating
- Use within an **Asset Management** Regime taking into account WLC, LCA and Social Aspects
- Integrate into **Asset Value** of Structures

The Deterioration of Reinforced Concrete: A Trillion Dollar Problem



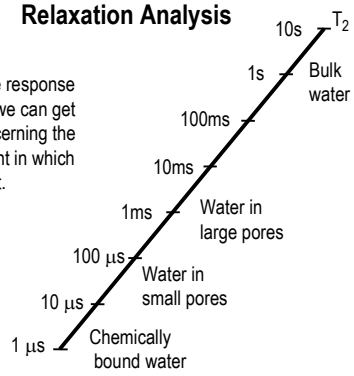
Dr Mike Mulheron, School of Engineering

Nuclear Magnetic Resonance

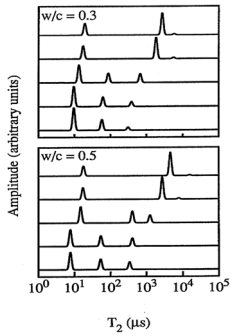


Relaxation Analysis

By analyzing the response decay time, T_2, we can get information concerning the local environment in which the protons exist.



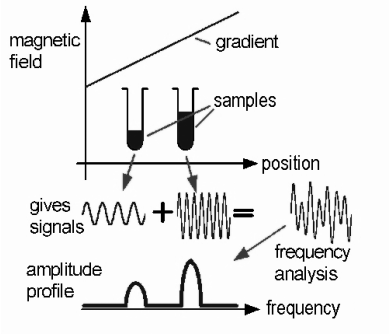
Relaxation Analysis



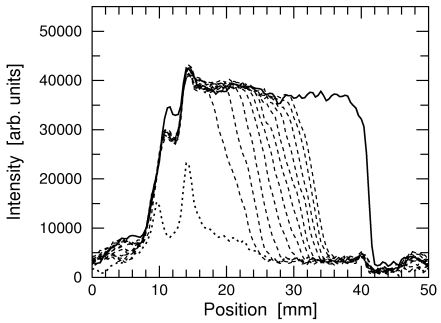
1 hr.	NMR T_2 analysis
4 hr.	used to follow the
1 day	development of
8 day	cement paste pore
28 day	structures…

Peak position ∝ pore size.
Peak height ∝ relative proportion.

Gradient Echo MRI



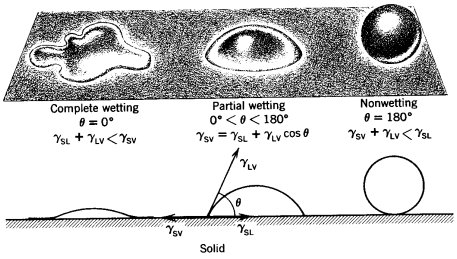
Water ingress into cement



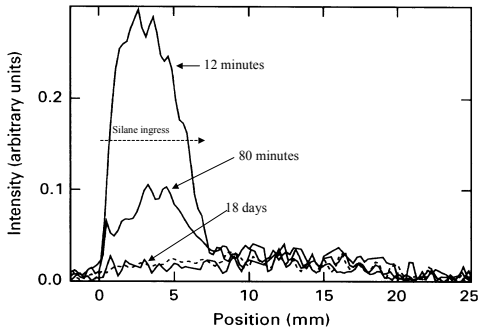
4 slices per mm ∴ positional accuracy ≈ 250μm.

Hydrophobic Surface Treatments

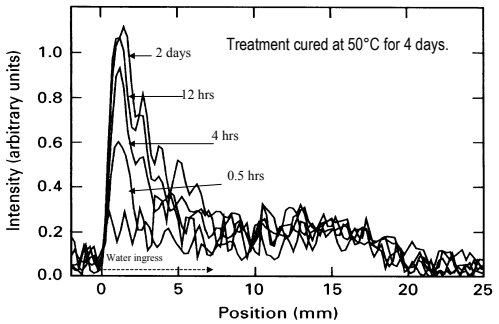
Concrete surfaces are generally easily wetted and so have a tendency to absorb water into the pores of poorly cured cement pastes.



Uptake Dynamics of Silane



Post-treatment Effectiveness



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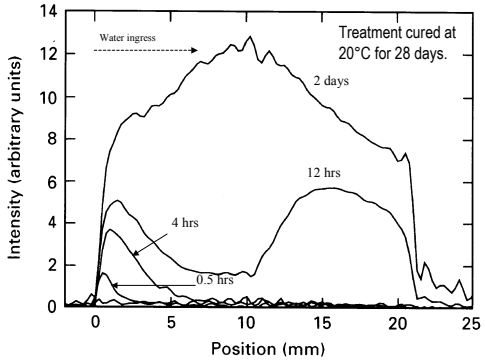
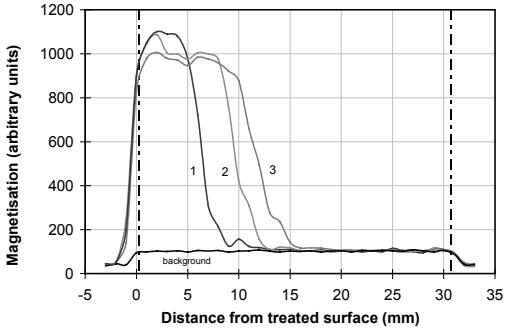
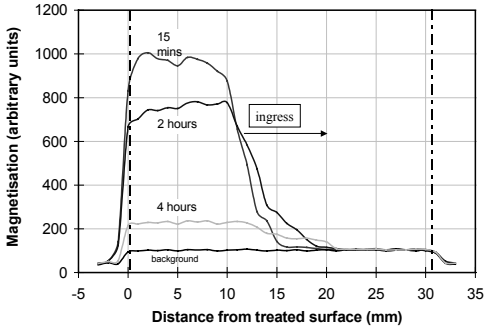
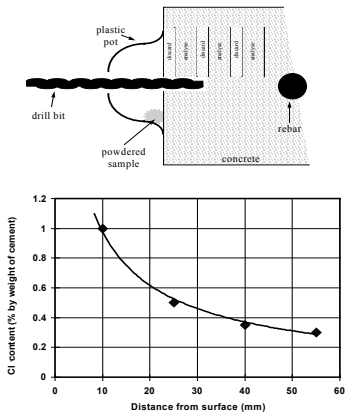


Surface Applied Corrosion Inhibitor

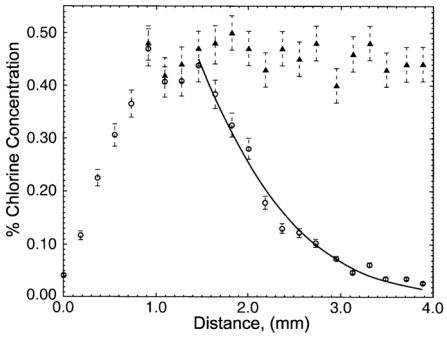


Subsequent Redistribution with Time





Chloride ion Profiles in Cement



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Other Bridge Related Research at the University of Surrey

- Assessment of riveted bridges.
- Technology transfer study from offshore to bridge sector on system reliability assessment.

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Other Bridge Related Research at the University of Surrey

- Development of system reliability methodology for bridges.
- Damage tolerance assessment of bridges using system reliability methods (Korean Government).

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Other Bridge Related Research at the University of Surrey

- Integration of proactive health monitoring data into reliability based management of bridges (University of Surrey Scholarship).
- Contributing to the development of educational and training packages on risk and reliability for industry and universities.

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Thank you all for listening

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