Characterising engineering materials under extreme dynamic load conditions

Dr Chanel Fallon

The Vice-Chancellor's Research Day

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Introduction

Dr Chanel Fallon

- Joined Bath as Lecturer in Mechanical Engineering in Aug ’21
- Previously at Oxford, working with Rolls-Royce – shooting ice at titanium blades
- MEng and PhD at Cambridge in mechanics of materials – shooting steel projectiles at concrete

Research: **Dynamic behaviour of materials and structures**

Extreme loads: explosive blast, impact, crash

Extreme conditions: very low and high temperature

Why?

- Materials and structures can behave in **unexpected**, unpredictable ways under extreme conditions
- **Catastrophic** consequences – important for **safety-critical** design
- Experiments and modelling in these regimes are challenging!

Dynamic behaviour of materials and structures

Integrated experimental-numerical-analytical approach; applications in mechanics, structures, aerospace

Materials testing

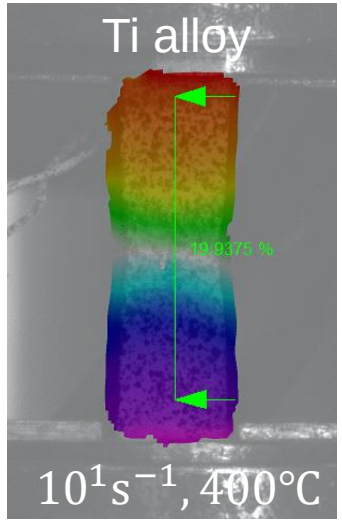
- Concrete, ice, titanium, polymer, CFRP
- Digital image correlation
- Spanning strain rates and temperatures

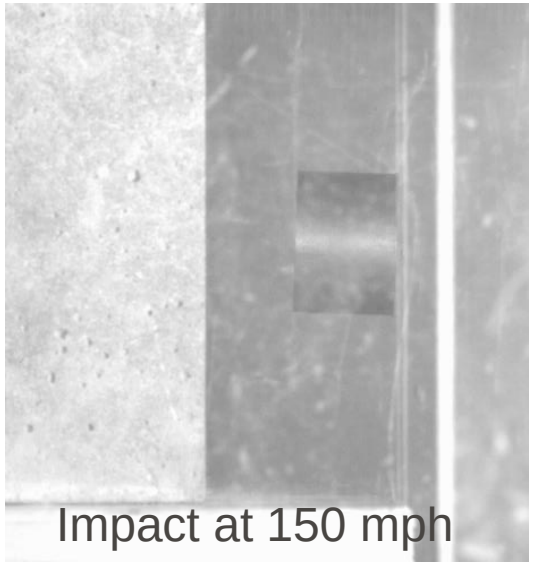
Experimental design and diagnostics

- Impact testing using drop-tower, gas guns, SHPB
- High speed imaging
- Force sensor
- Photon Doppler Velocimetry

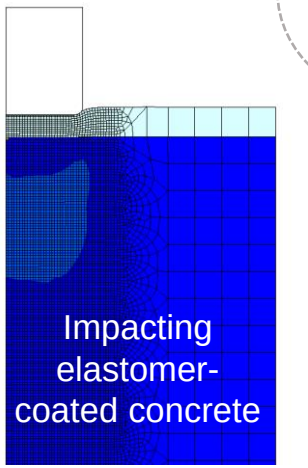
Numerical modelling

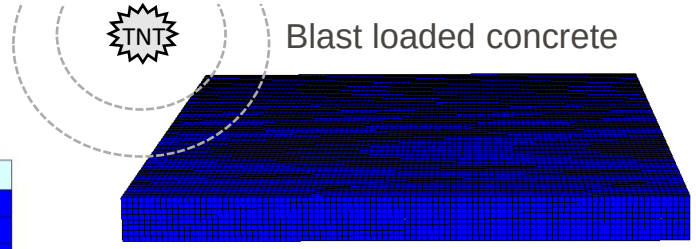
- Air blast and impact
- Dynamic finite element analysis in Abaqus/CAE and LS-DYNA
- Concrete, elastomer, ice, CFRP
- Coupled Eulerian-Lagrangian techniques

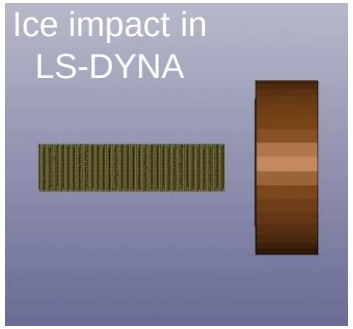




Concrete impacted at 150mph







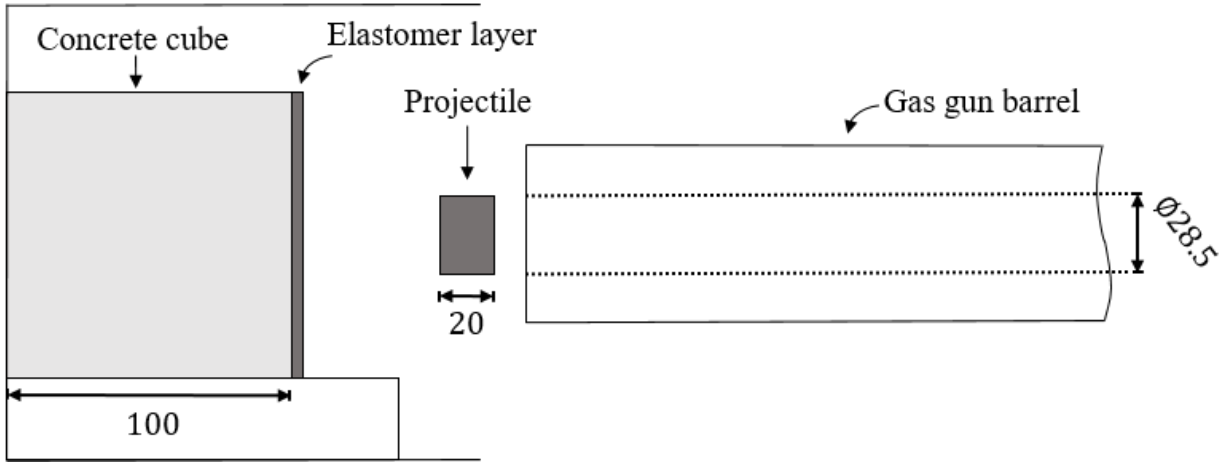
Case study:
Protecting concrete from fragment impact

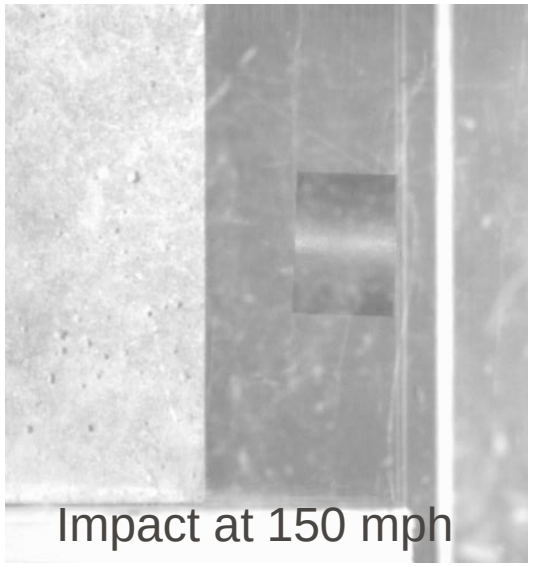
Case study: Protecting concrete from fragment impact

How to protect ageing, vulnerable infrastructure?

- When a bomb explodes in an urban environment, the resulting debris and structural fragmentation cause serious human injury
- **Low cost retrofit** for the **protection** of **concrete** from blast and **impact**:

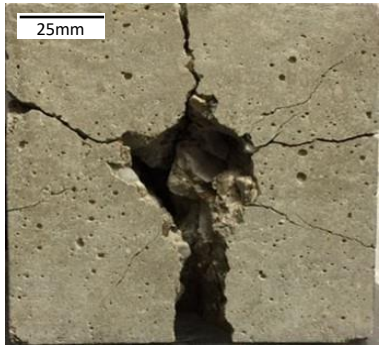
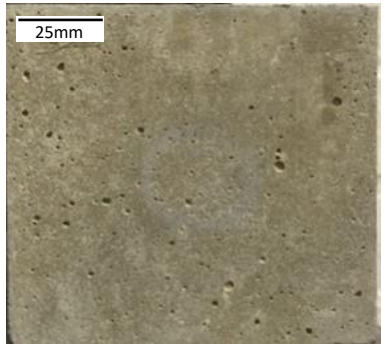
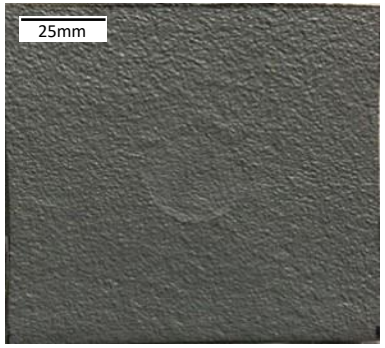
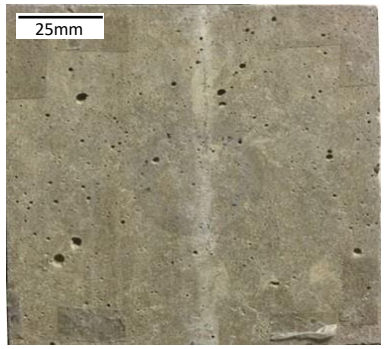
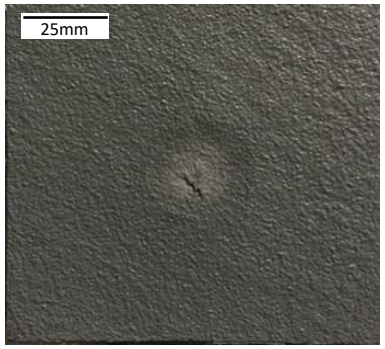
spray-on elastomer coating





[1] Fallon, C. and McShane, G. J., Impact mitigating capabilities of a spray-on elastomer coating applied to concrete, *International Journal of Impact Engineering*, Volume 128, June 2019, Pages 72-85

Case study: Protecting concrete from fragment impact

Impact velocity	Concrete when uncoated	Concrete when coated	Elastomer, 5mm impacted face
150 mph			
225 mph			

Key finding: coatings are effective in some response regimes (e.g. local **impact**), but they offer limited benefit in others (e.g. during dynamic flexure of slabs)[1-3]

Key question: How and why? What are the protective mechanisms at play?

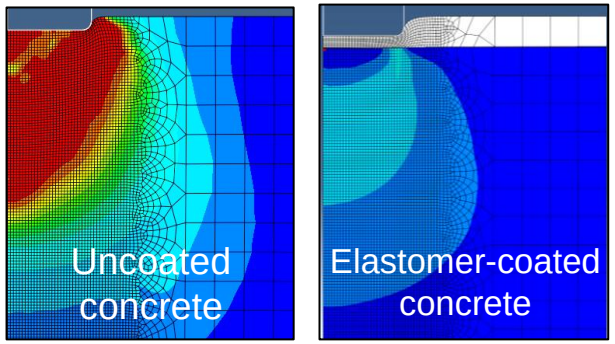
[2] Fallon, C. and McShane, G. J., Impact damage protection mechanisms for elastomer-coated concrete, *International Journal of Protective Structures*, January 2021

[3] Fallon, C. and McShane, G. J., Fluid-structure interactions for the air blast loading of elastomer-coated concrete, *International Journal of Solids and Structures*, Volume 168, August 2019, Pages 138-152

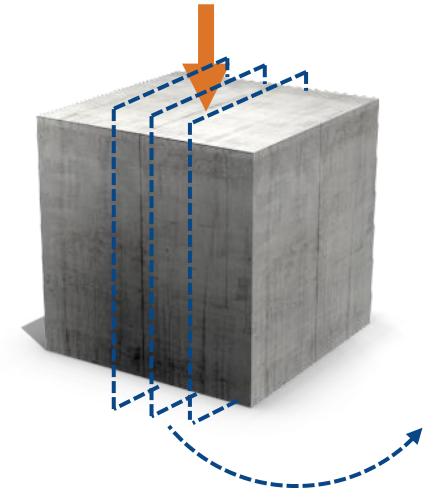
Case study: Protecting concrete from fragment impact

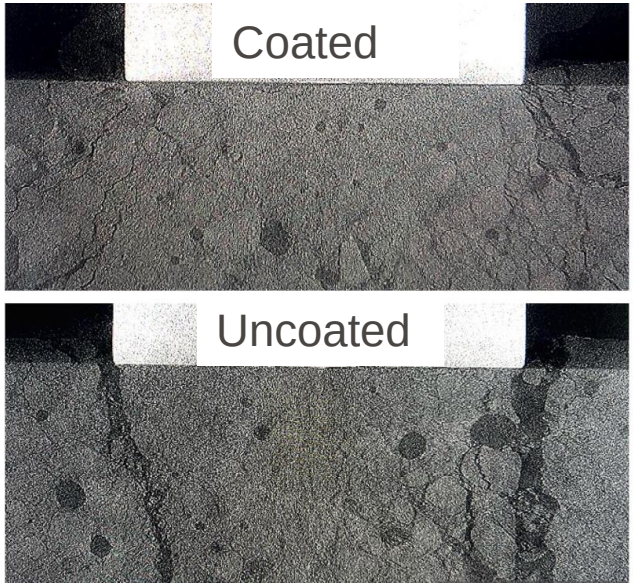
Modelling can give insights; but can we validate these models experimentally?

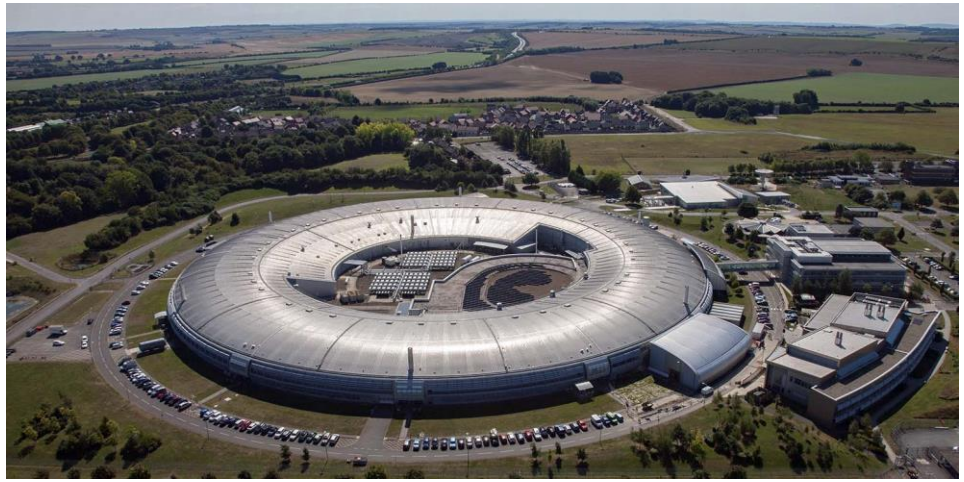
Need to **“see through”** the **concrete** to understand how cracking and failure mechanisms develop



- A synchrotron accelerates electrons so they give off light 10 billion times brighter than the sun
- Enables very high resolution, real-time, in-situ, 3D X-ray imaging of concrete







Diamond Light Source: UK’s national synchrotron

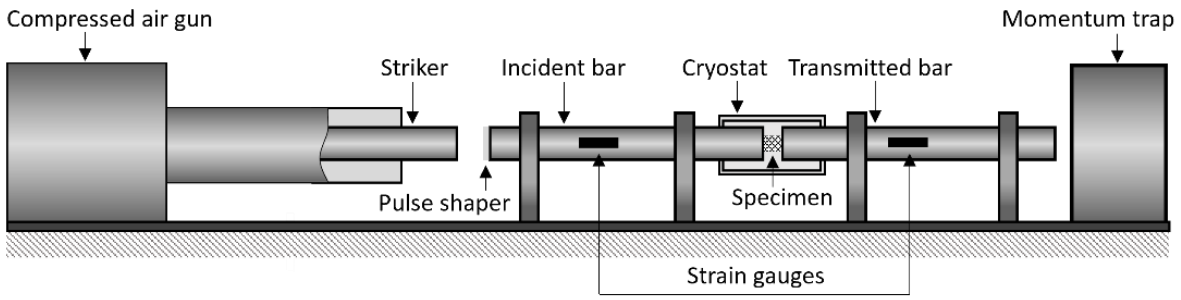
Next steps: Validate numerical models and interrogate the protective mechanisms at play

Case study:
Impact at LH_2 temperatures

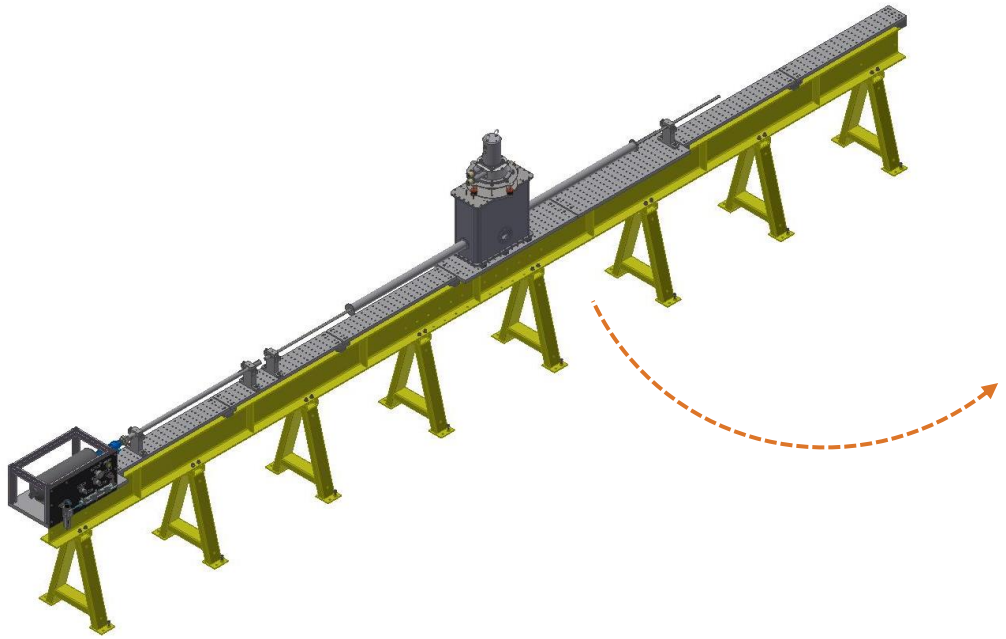
Case study: Impact at LH_2 temperatures

Building a cryogenically-cooled gas gun

- Bath's first piece of high-speed dynamic testing apparatus: split-Hopkinson pressure bar
- Achieves strain rates x10,000,000 faster than typical (Instron) testing machines
- Cooled to -253℃



Cryogenically-cooled split-Hopkinson pressure bar



Next steps: Investigate dynamic material behaviour at LH_2 temperatures

Thank you for listening.
Any questions?

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