BRE Institute of Sustainable Engineering

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

7 Academics

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Vision = to pave way to new generation of digital buildings with

lifelong resilience and
adaptability to their environment,
usage and
occupancy,

enabled by

smart materials and products,
integrated design and manufacturing systems,
total lifecycle approaches.

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2 research challenges underpinning the vision:

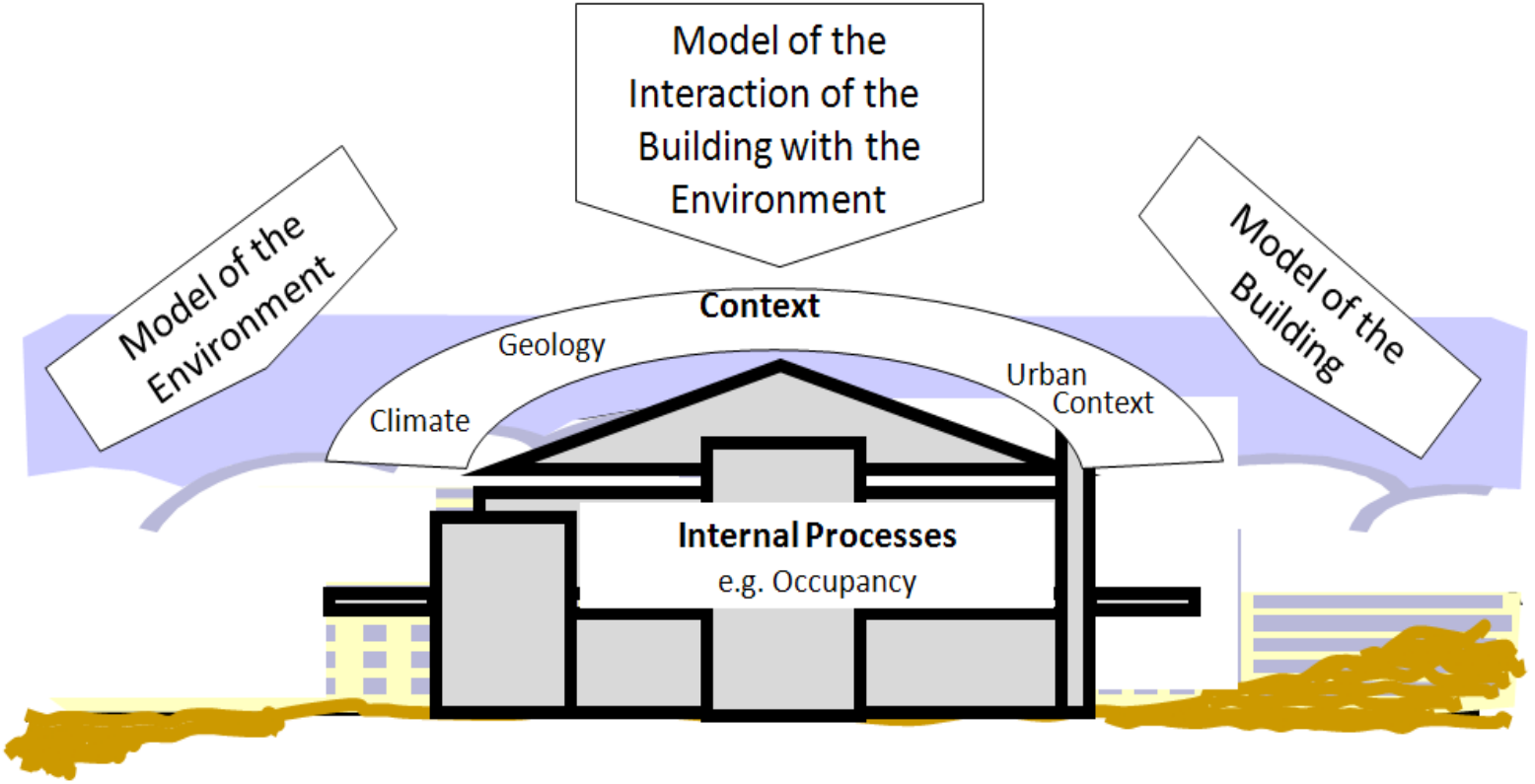
How confer optimum resilience,
sustainability and
continual fitness for purpose
on existing building stock?

How deliver new or retrofit human-centric buildings
address lifetime requirements and
capable of performing optimally
in constraints of unknown future scenarios?

adaptability & resilience

Key Research challenges

- Design and simulation models simplify building physical phenomena, assuming **linear relationship** based on **Newtonian mechanistic view of the world.**
- Design approaches based on **serviceability requirements**.



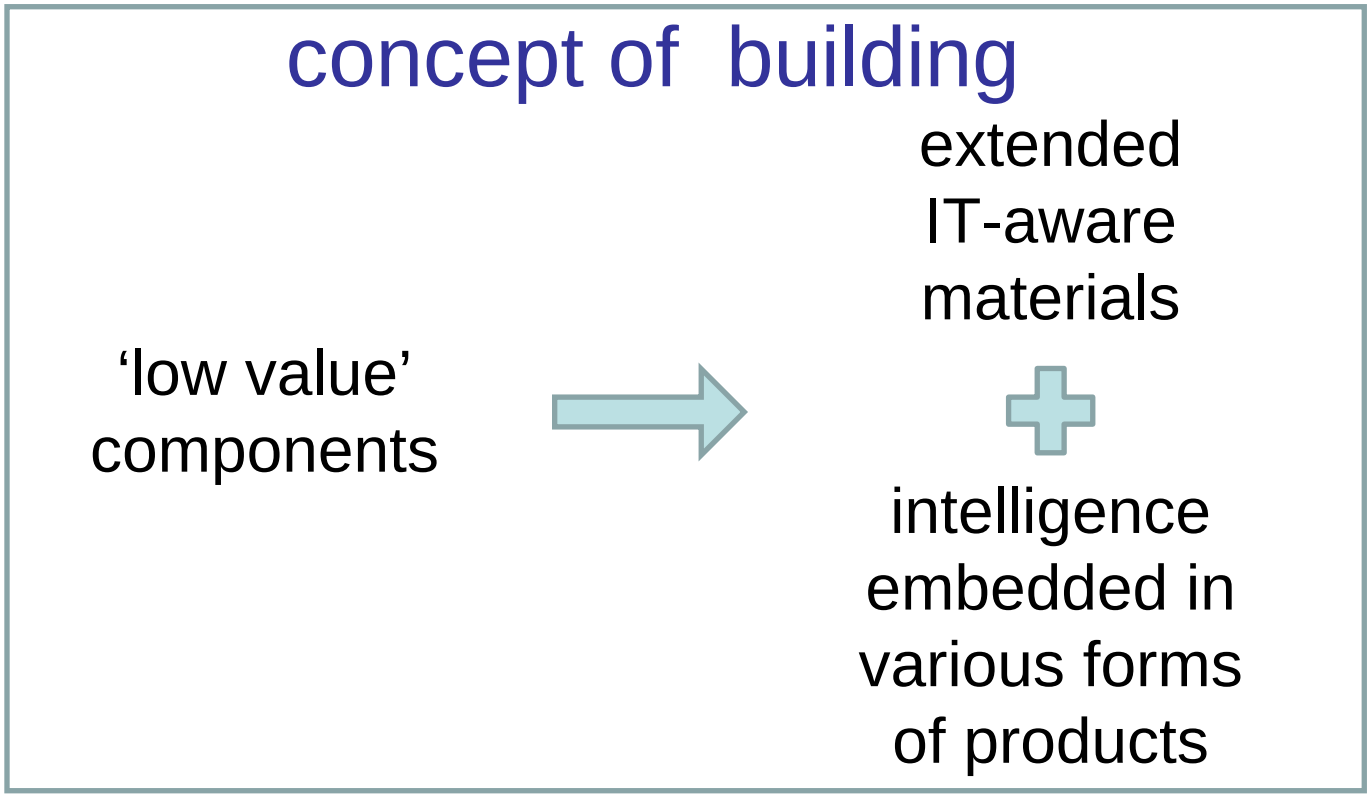
- Buildings and infrastructures are **highly complex** composed of **dynamically nonlinear** interacting systems and components.

Approach to resilience

- Resilience should be embedded within
  materials, components and systems,
  thereby enabling the capability to adjust to any potential state change induced by
  environmental or
  technological stimuli or
  adverse event.
- Building components should have the capability to collaboratively respond through a “modulated response”
- Thus state of the building can be defined at
  the moment of the stimuli and
  resilience and emergency response can be optimized
  on the basis of the building state change.

Approach to resilience – “hardware to liveware”

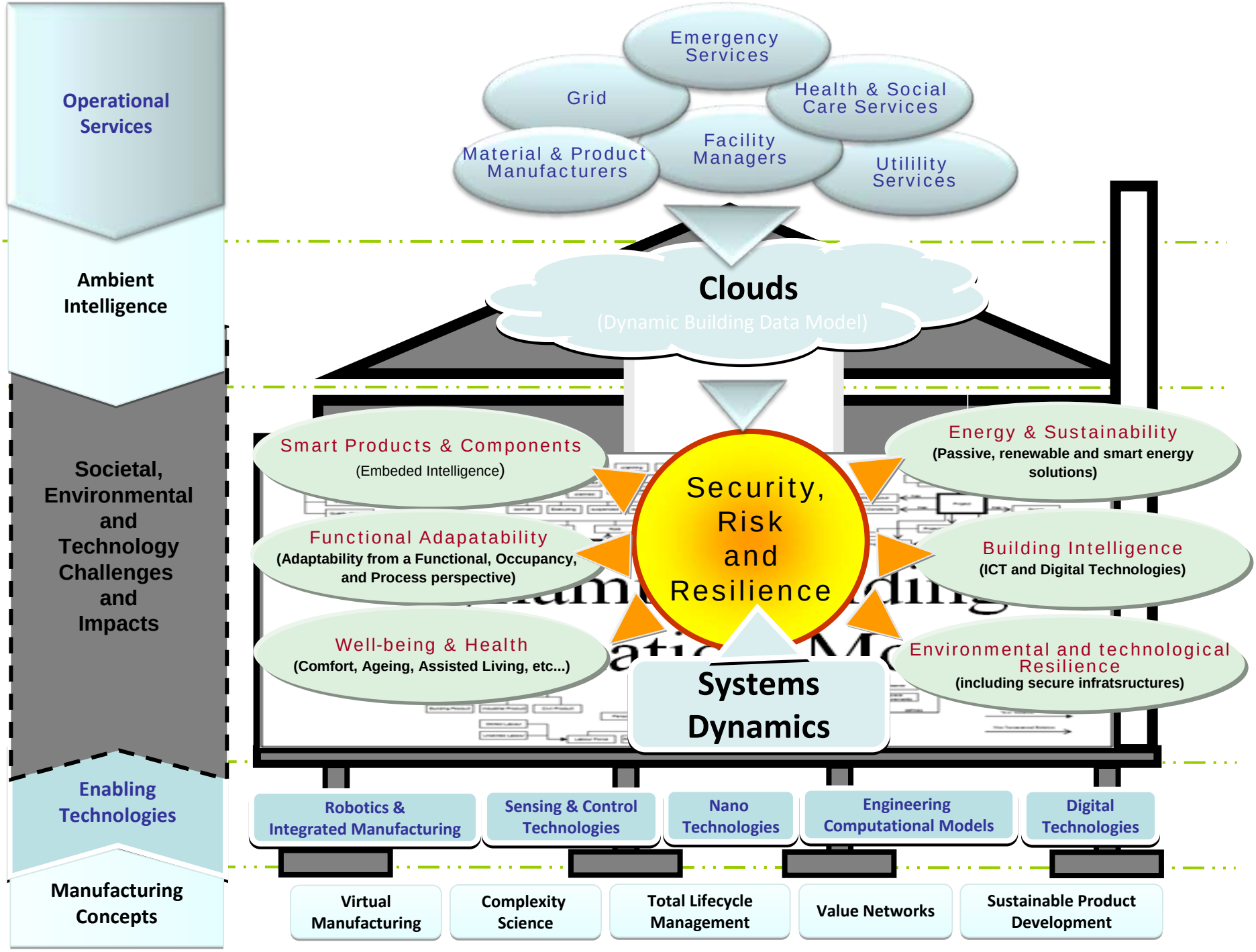
Buildings should have ability to be context-aware environmental and occupancy aspects thus be adaptive to change.



Approach to resilience – “hardware to liveware”

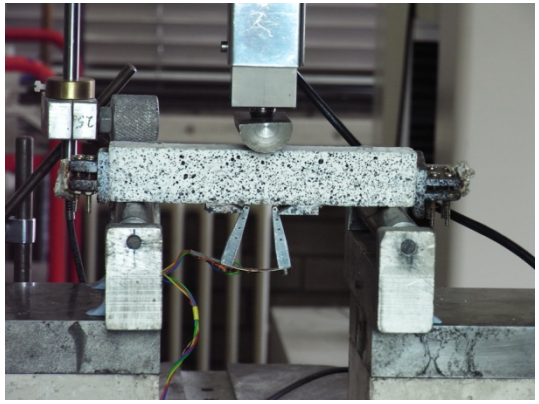
concept of building being
dynamic and
self-updatable digitalised
fully exploits latest ICT, inc pervasive sensing tech

Digital technologies allow
dynamic representation of a building
provide real-time building performance
(including energy consumptions)
and ensure lifelong adaptability to its usage and environment.


Operational Services
Ambient Intelligence
Societal, Environmental and Technology Challenges and Impacts
Enabling Technologies
Manufacturing Concepts
Emergency Services
Grid
Health & Social Care Services
Material & Product Manufacturers
Facility Managers
Utilility Services
Clouds
(Dynamic Building Data Model)
Smart Products & Components
(Embeded Intelligence)
Energy & Sustainability
(Passive, renewable and smart energy solutions)
Functional Adapatability
(Adaptability from a Functional, Occupancy, and Process perspective)
Security, Risk and Resilience
Building Intelligence
(ICT and Digital Technologies)
Well-being & Health
(Comfort, Ageing, Assisted Living, etc...)
Environmental and technological Resilience
(including secure infratsructures)
Systems Dynamics
Robotics & Integrated Manufacturing
Sensing & Control Technologies
Nano Technologies
Engineering Computational Models
Digital Technologies
Virtual Manufacturing
Complexity Science
Total Lifecycle Management
Value Networks
Sustainable Product Development

Underpinning research themes

- **Smart materials and products**
  with embedded resilience & enhanced structural performance subject to combinations of influence/impact
- **Functional adaptability**
  continuous fitness for purpose and adaptability to building function, occupancy and activities
- **Building intelligence**
  design and deployment of digital interventions that confer enhanced resilience across the building lifecycle
- **Environmental and technological resilience**
  embedding risk and resilience management into design and manufacturing processes.
- **Energy and sustainability**
  management of energy in buildings with a view of delivering lifelong sustainable and secure facilities
- **Comfort, health and well-being (socio-technical)**
  human-centric digital-interfaced buildings that support healthy living



Cementitious, Self-**H**ealing, **I**ntelligent, **C**onstruction Materials

research and development of design,
analysis and
simulation of
innovative, smart and sustainable composites
for building and construction industry

Self Healing materials

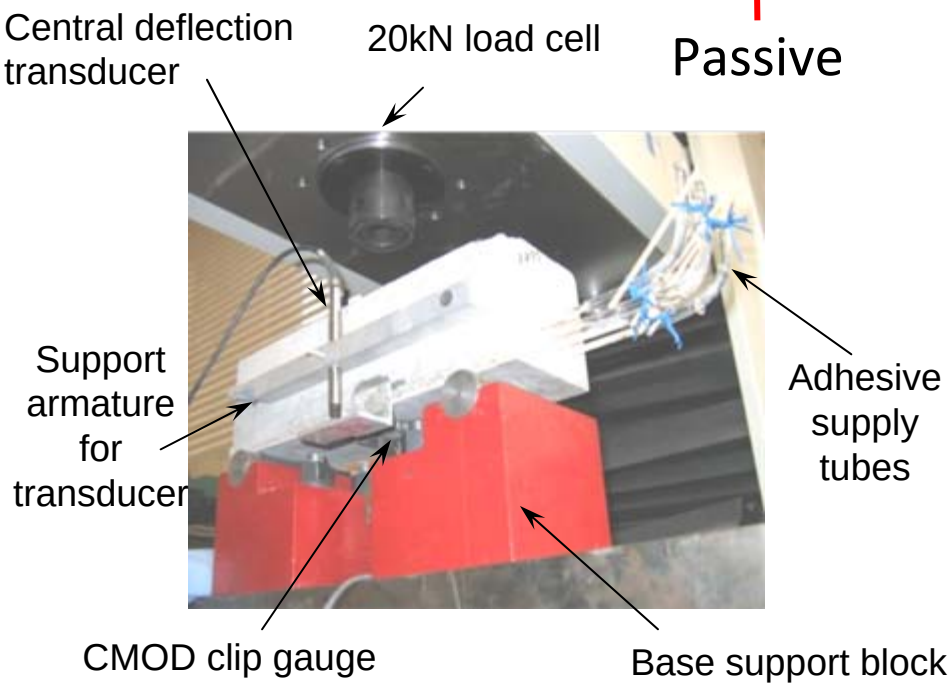
New Composite Materials

Intelligent Materials | Smart Materials | Smart Structures | Sensory Structures

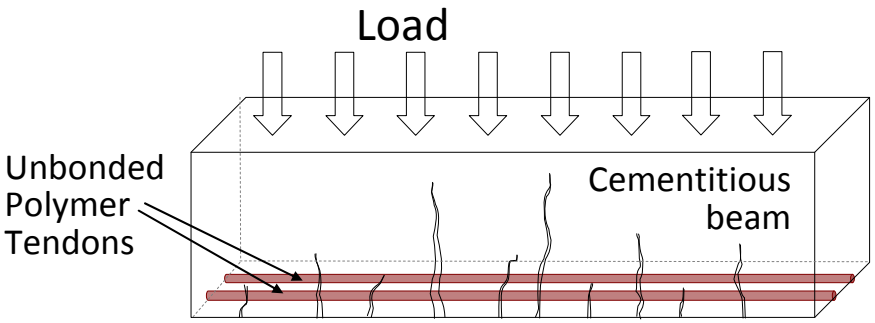
Self-Healing Materials

Autonomic Healing | Autogenous Healing

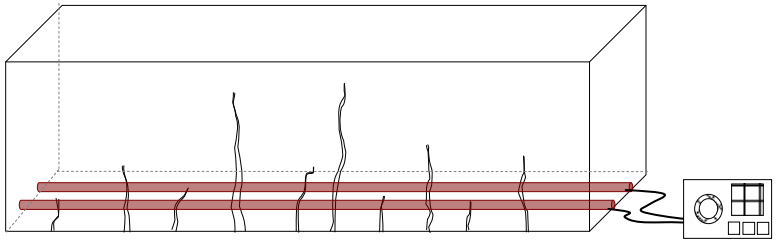
Passive | Active | Passive | Active



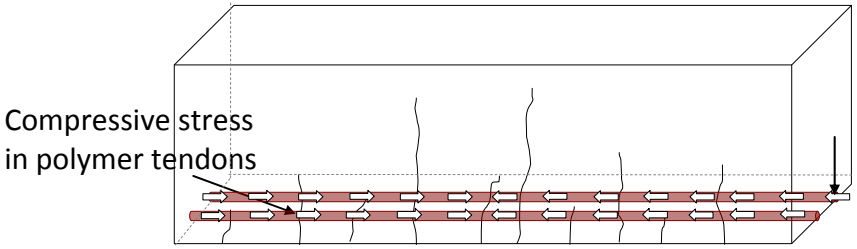
Enhancing Self Healing – shape memory polymers



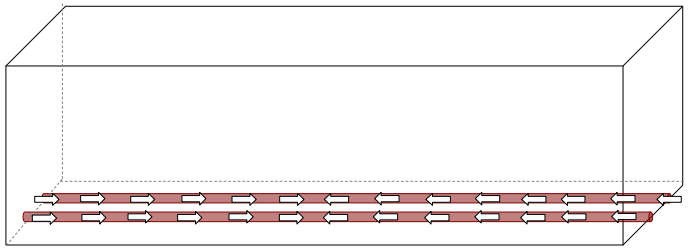
1 Cracking induced due to applied load/shrinkage



2 Activation of polymer tendons by heat/electrical supply (post-tensioning)



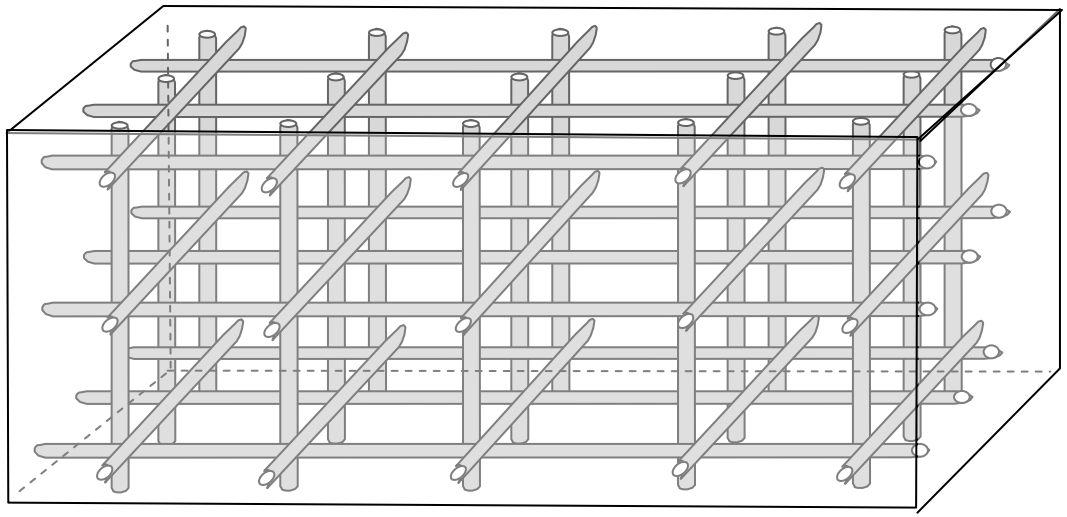
3 Crack closure effect of activated polymer tendons



4 Healed beam with post- tensioned polymer tendons

Schematic representation of 4 stages of enhanced autogenic healing procedure

Enhancing Self Healing – shape memory polymers



Schematic representation of tendon arrangement in cementitious beam to achieve full triaxial confinement

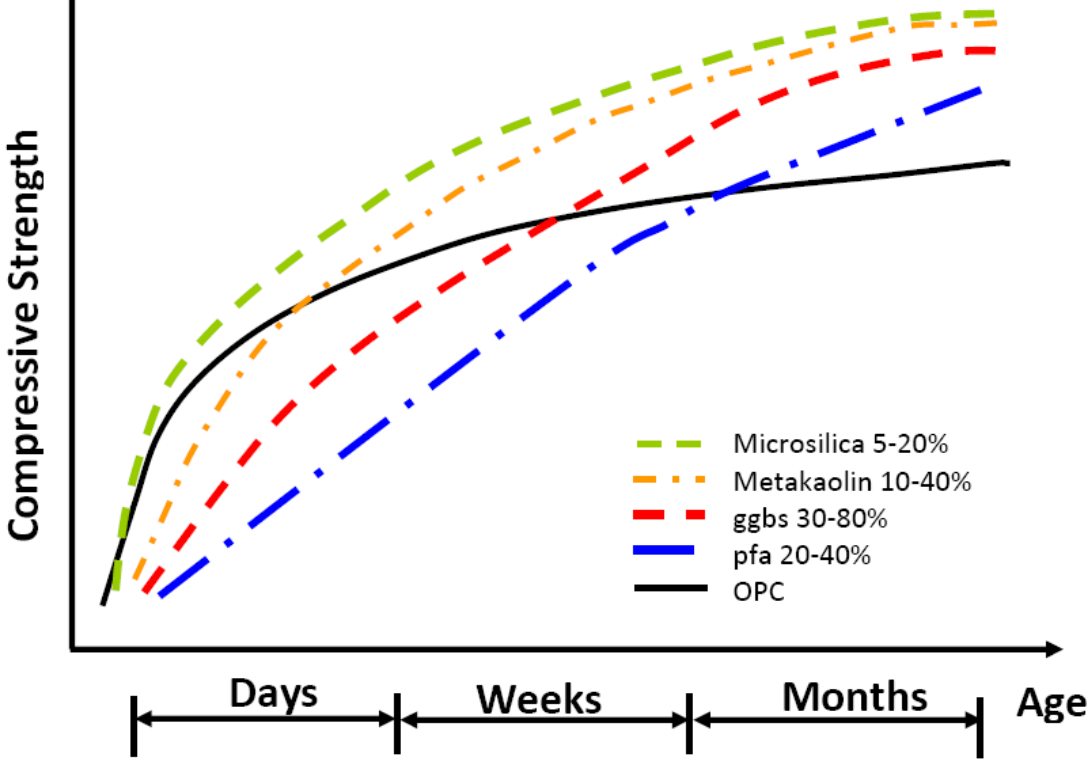
Not only a self healing material …

Possibility of *matrix* of shape memory polymer tendons to provide sufficient prestress force to allow full triaxial confinement of the material

Green binders

- Strength and durability popular cement replacement materials (CRMs, e.g. PFA and GGBS) are well known.
- Self healing properties … less so.

Comparison of the compressive strength gain over time for various green binders and OPC



- So what is the basis of replacement levels?
- Alternative binders:

  Magnesium oxide cement

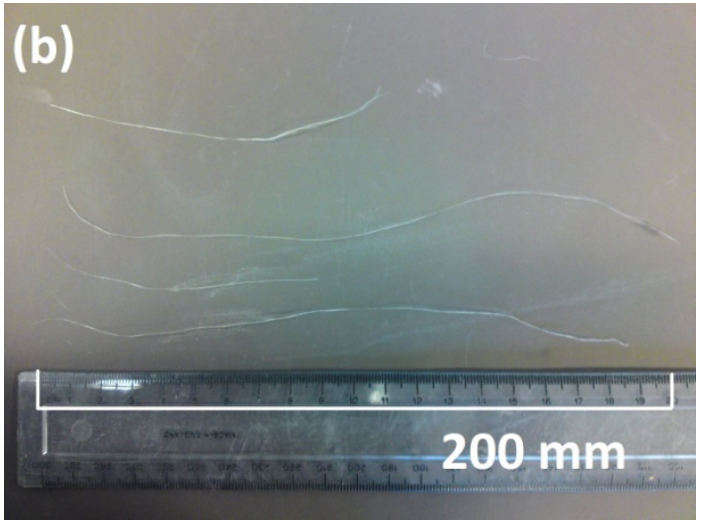
  Alkali-activated cement

  Geopolymer cement

Green fibres

- Fibres afford ductility and abate crack growth and propagation.
- Possible use of green fibres in a cementitious matrix.
  - Hair
  - Hemp
    - High yield
    - Relatively cheap
    - Tensile strength 500-900MPa
    - Wet and dry properties vary greatly
    - High alkali resistance
  - Straw
  - Feather
  - Recycled plastics

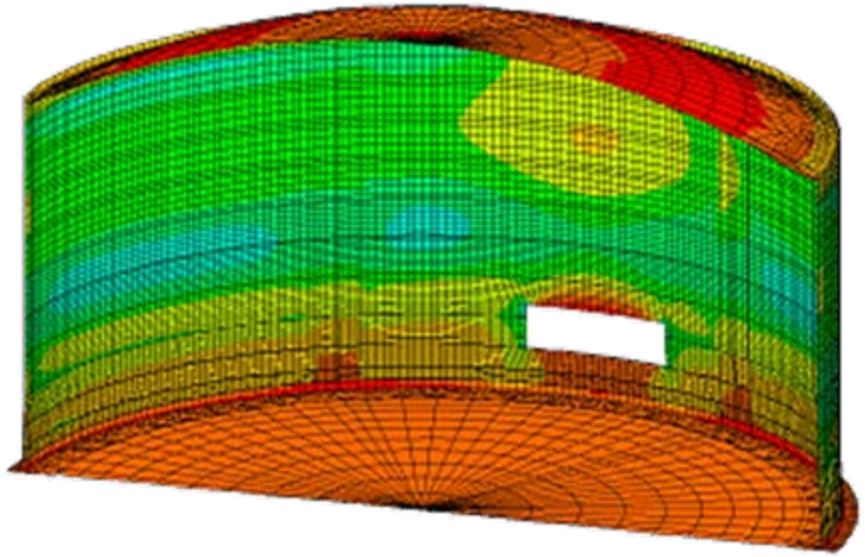
(a) Fibre bundle in its original state



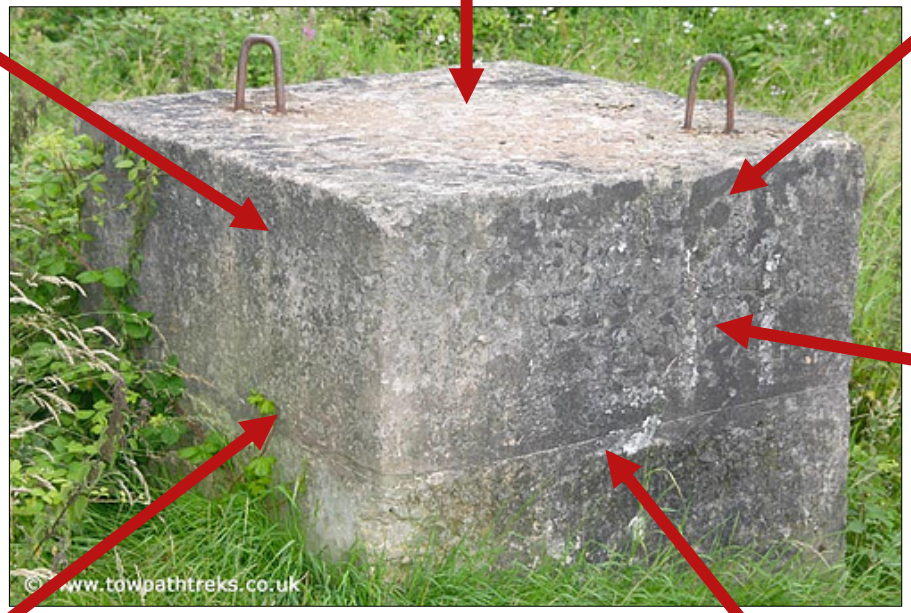
(b) varying lengths of fibres.

Numerical research

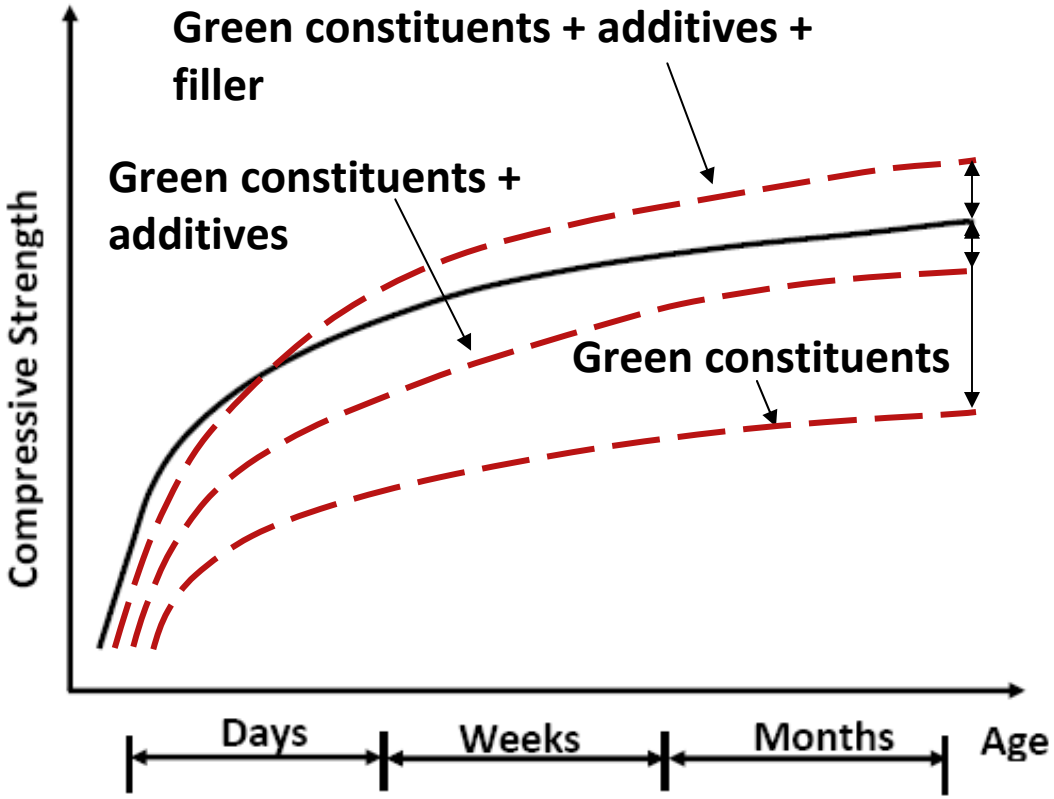
- Finite element Company LUSAS Sponsored Readership at Cardiff + 2 researchers + KTP Associate
- Past work. Models now in commercial version of code
  - Plastic-Damage-Contact constitutive model . (The Craft model) (*IJSS 2003., IJNMAG 2007, Engng Comp 2008*)
  - Interface models (*ASCE J Engng Mech, 2002*)
  - Soil models based on critical state soil mechanics
  - Modelling gas flow through concrete *(Cem & Conc Res. 2008)*



A sustainable system



How do they all work?



Enhancing compressive strength sustainably

simultaneous contribution to the material performance from all constituents

- Reduce cement content
- Include additional admixtures to generate further hydration products/liberate reactive products from fine aggregates

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Virtual Building - Life Long BIM

e-Collaborative Design, FTF, CMC, NVC

Preparedness for disaster

adoption of e-Gov services

Adoption for e-serives in utilities

Future adapatability of buildings

CardiffGA

bonding of reinforced concrete

Couples chemical-theromo-hydro-mechanical analysis (cementitious)

Low-c composites

Digital Building - from conceptual design through to life-long management

manufactured sand in concrete

corrosion control on the bond strength in high yield reinforcing steels.

Renewable Energy Solutions in the Domestic Sector

strength of brickwork walls subject to flooding.

Flow Properties of Self-Healing Agents In Damaged Zones

BIM based Sustainable Design and Development/Architectural Engineering "

Ductility and Bond of Reinforcement

"Building Physics - Passivhaus and Zero Carbon Buildings

"Total Quality Management in Public Research and Technology Organisations to Develop National Impacted Innovations "

Micro-Mechanically Based Fi Models For Cementations Materials.

Deployable Structures

Applications of waste quarry dust

Computational Imagination

Home centred healthcare (assisted living)

m-Gov in Oman