Smart Materials for Smart Cities

Sept. 17th –20th 2017
SHCC 4: Strain-Hardening Cement-Based Composites, Dresden, Germany

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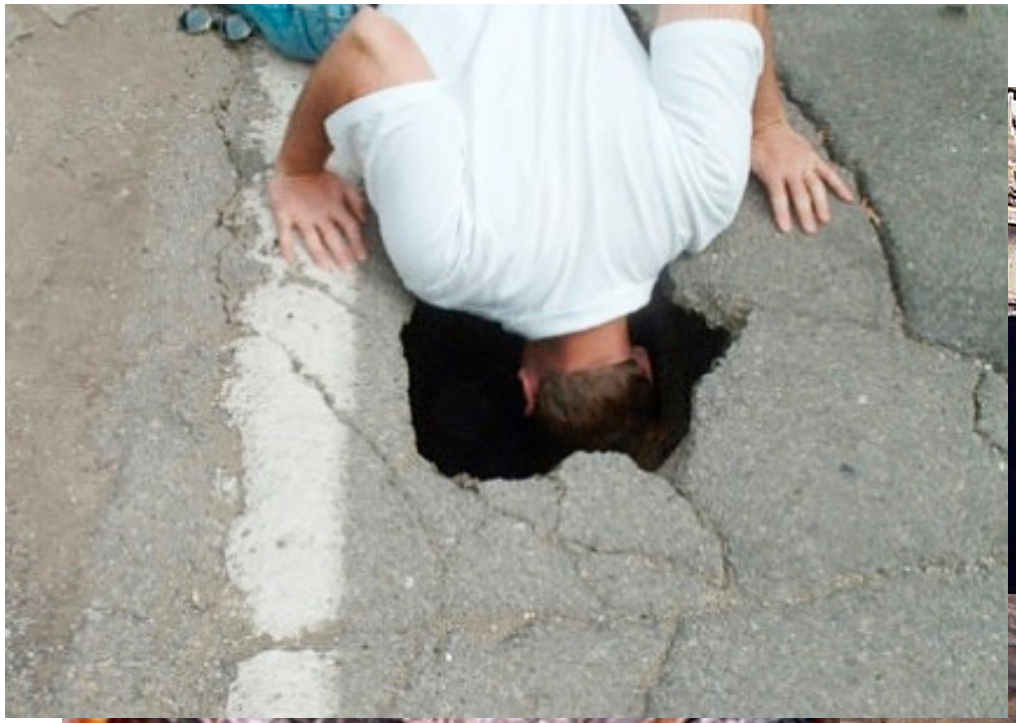
Smart cities deserve smart materials

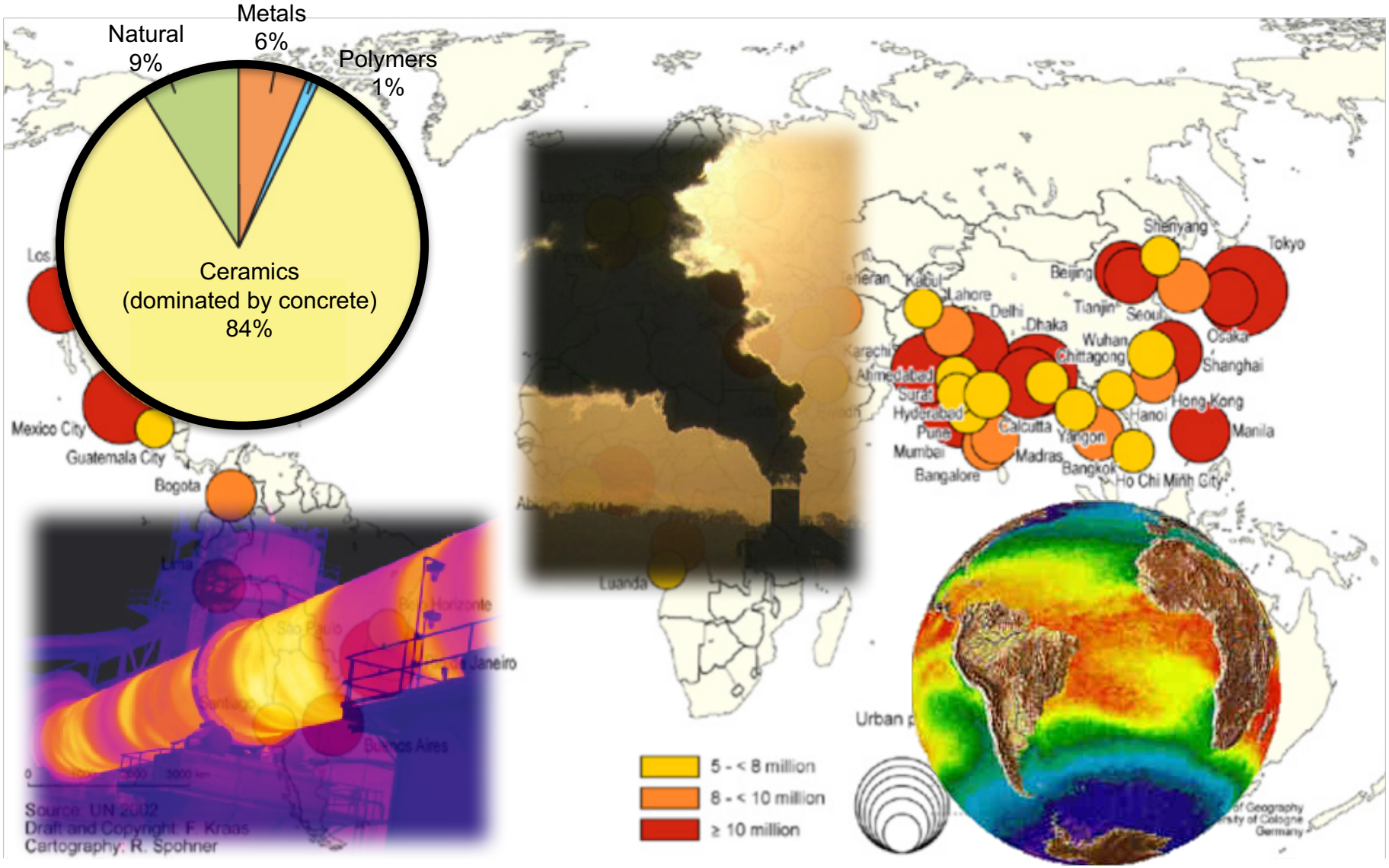
Civil infrastructure is vulnerable to natural hazards

Aftermath of 2008 Sichuan Earthquake

Concrete infrastructure lacks durability



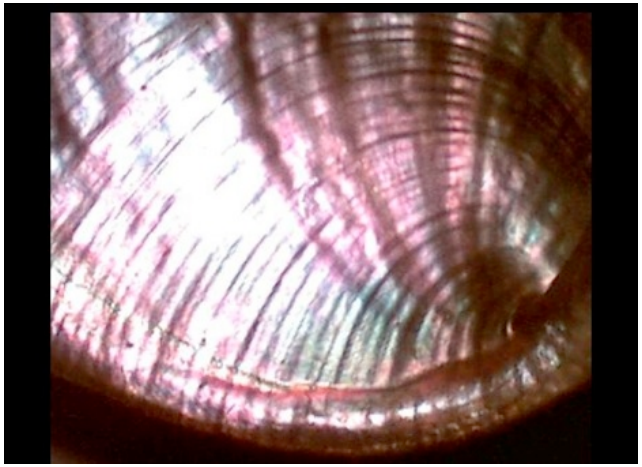
Civil infrastructure has large environmental impacts

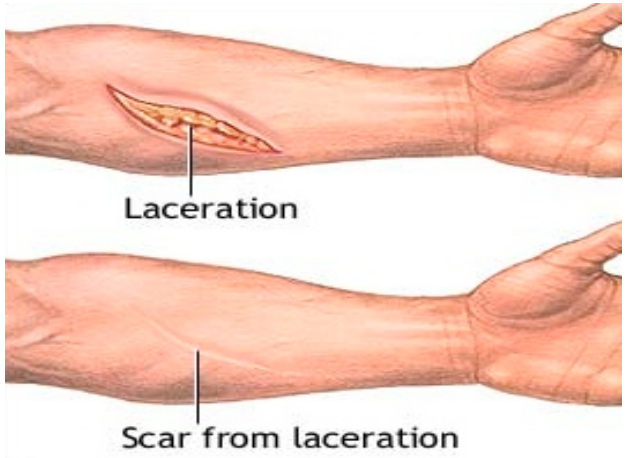


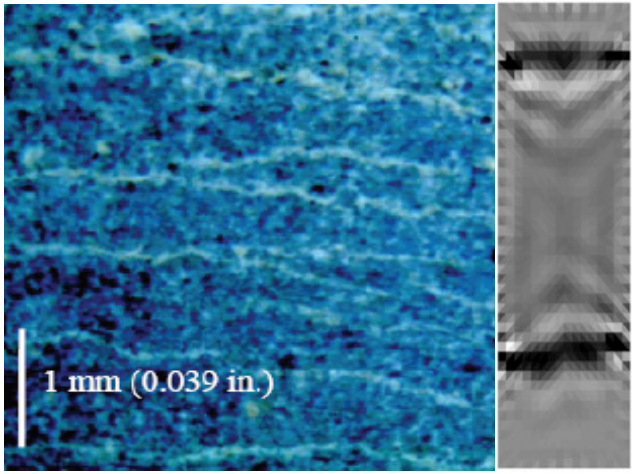
Concrete bears load only, & nothing else

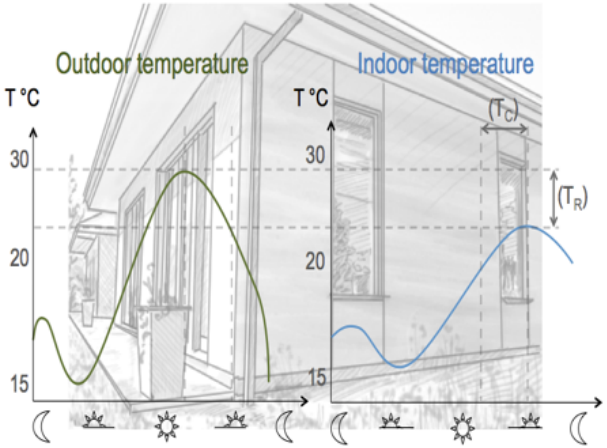
Smart materials inspired by nature

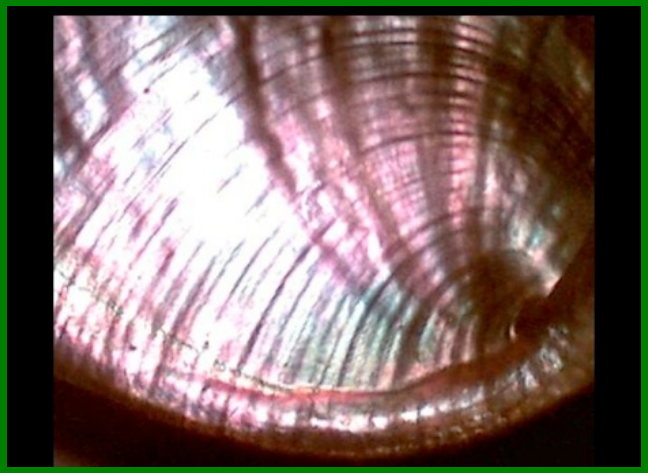
Biological system possesses multifunctionality:
Super strong and ductile, Self-sensing, Self-healing, Self-thermal adaptive



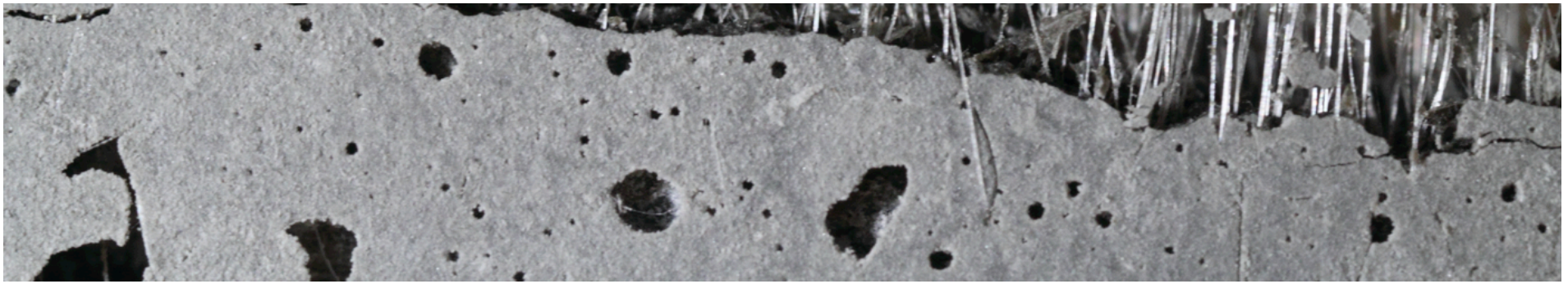




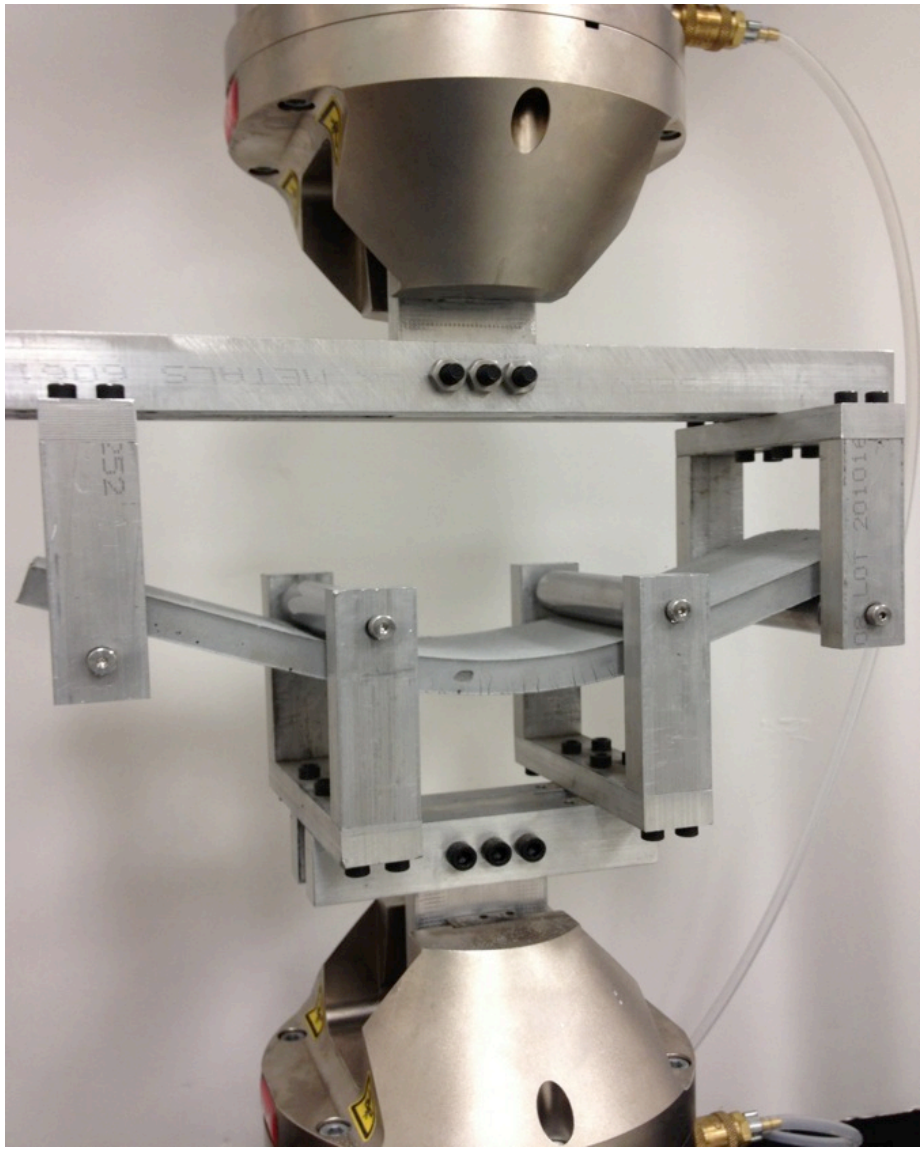




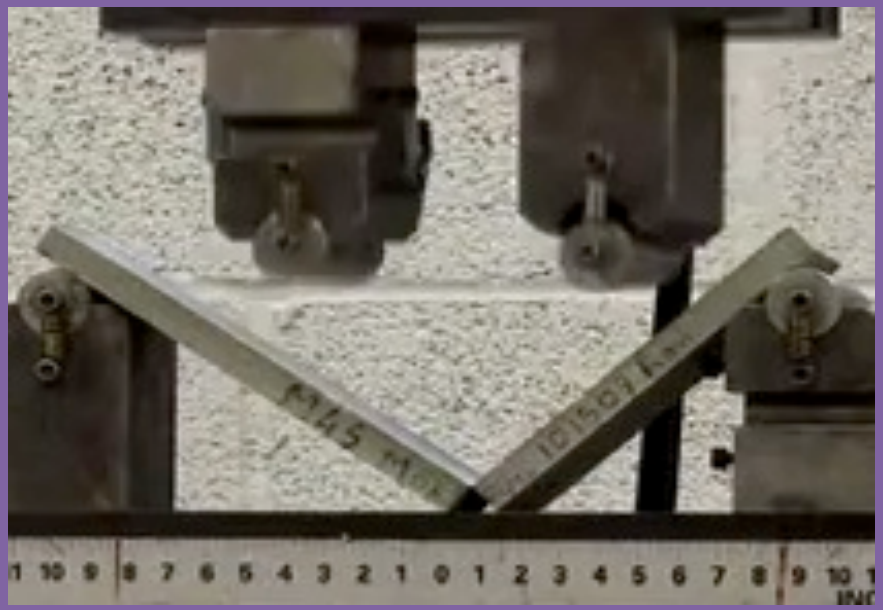
Extreme damage tolerance



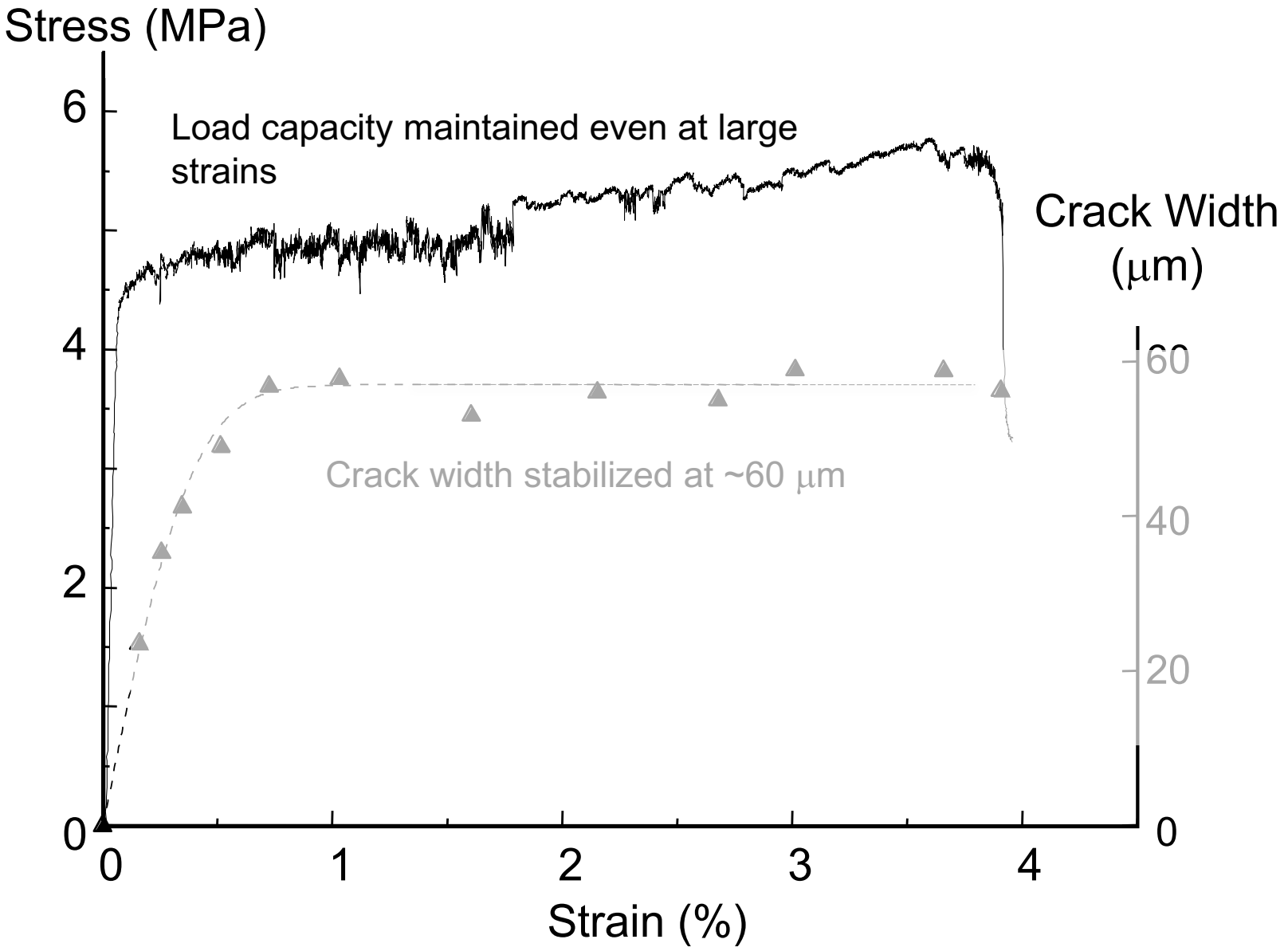
ECC suppresses brittle fracture and crack induced infrastructure deterioration



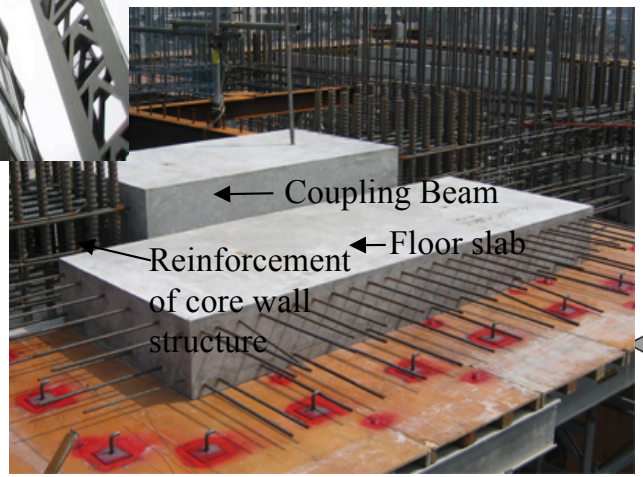
High compressive strength but brittle

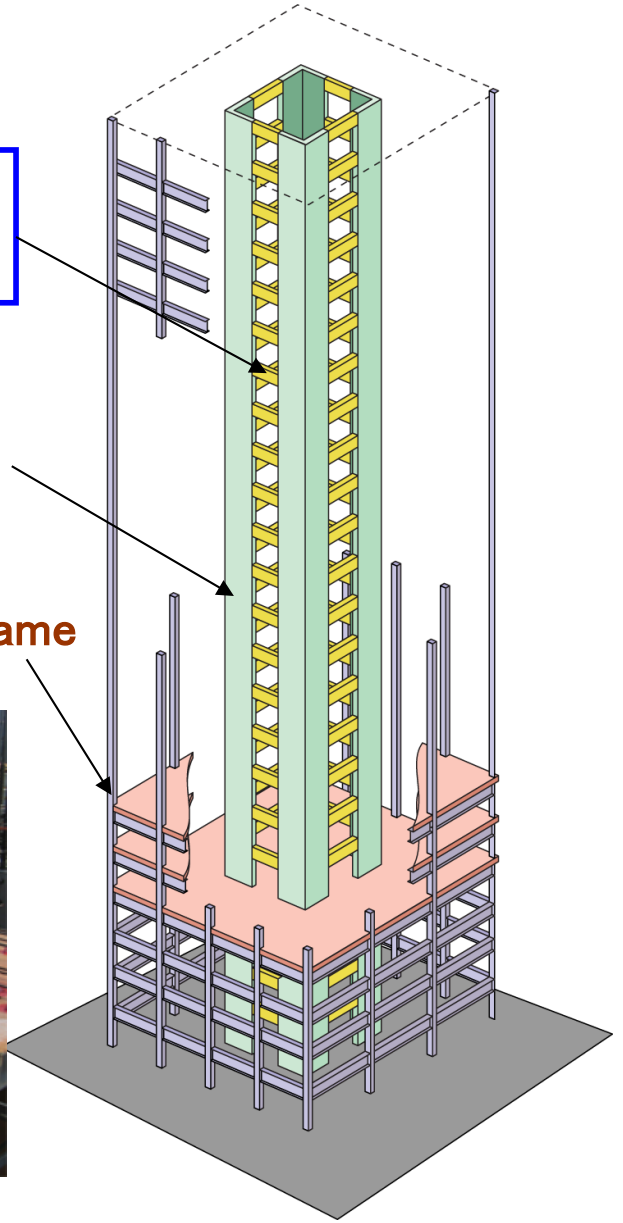


ECC is most ductile concrete material in use



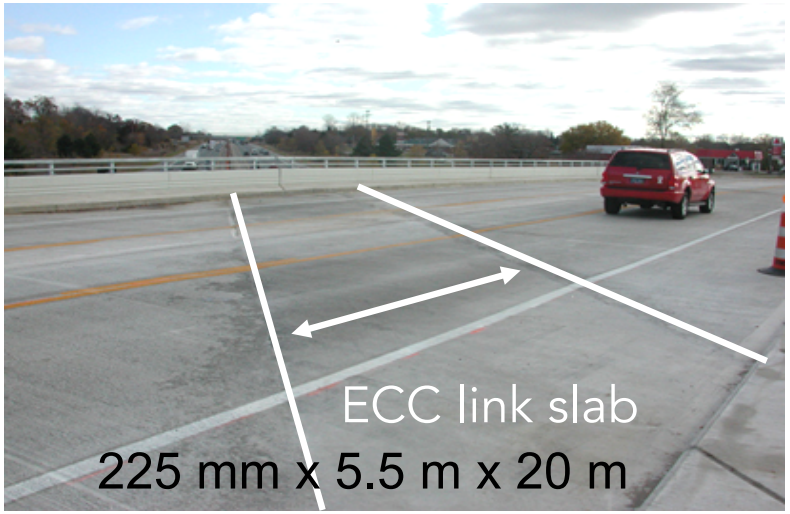
Resilient buildings in Japan



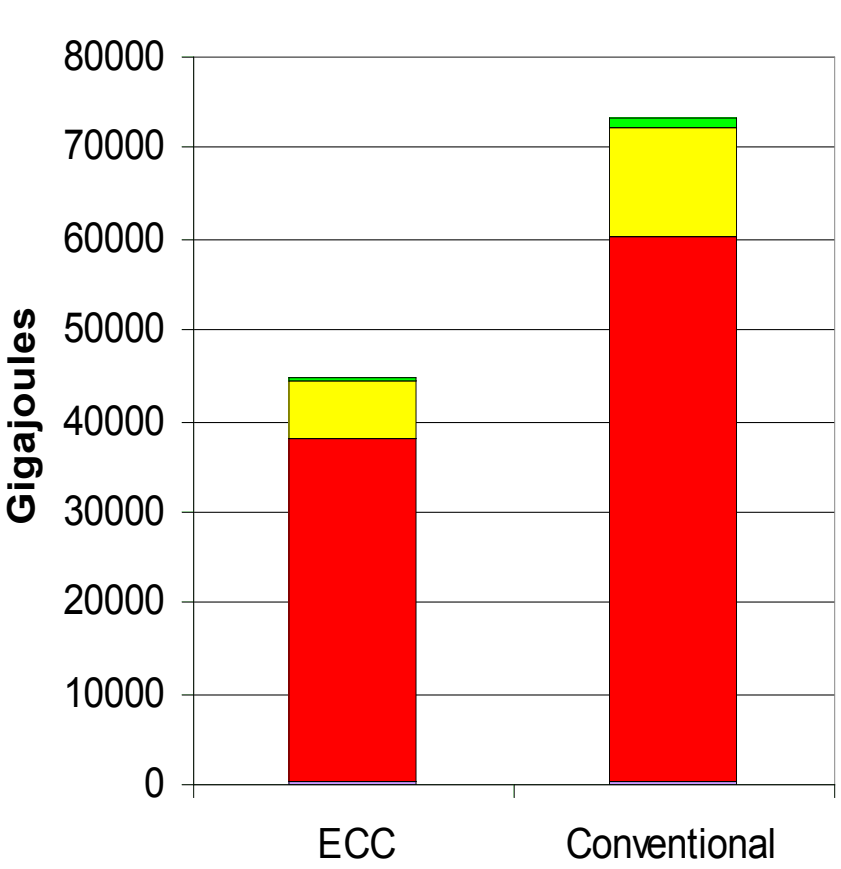


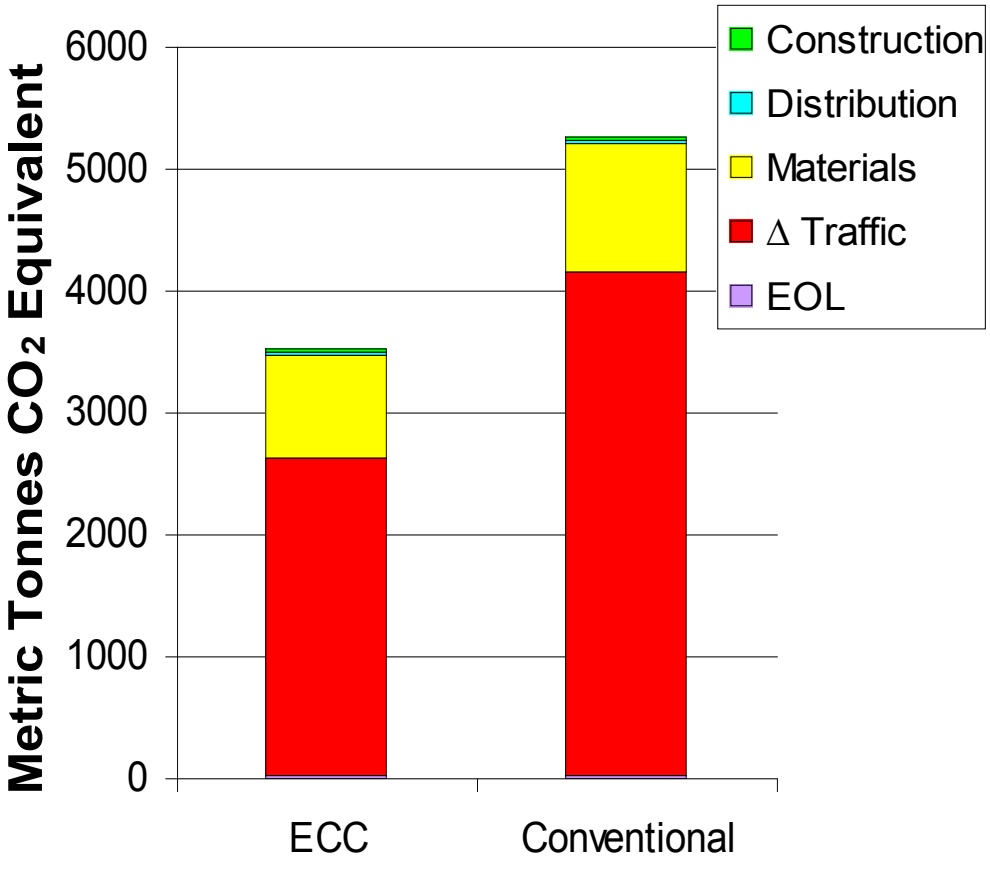
Designed by Mitsubishi Jisho Sekkei Inc. & Kajima Corp.; Constructed by Kajima Corp.

Durable ECC link-slab in the US



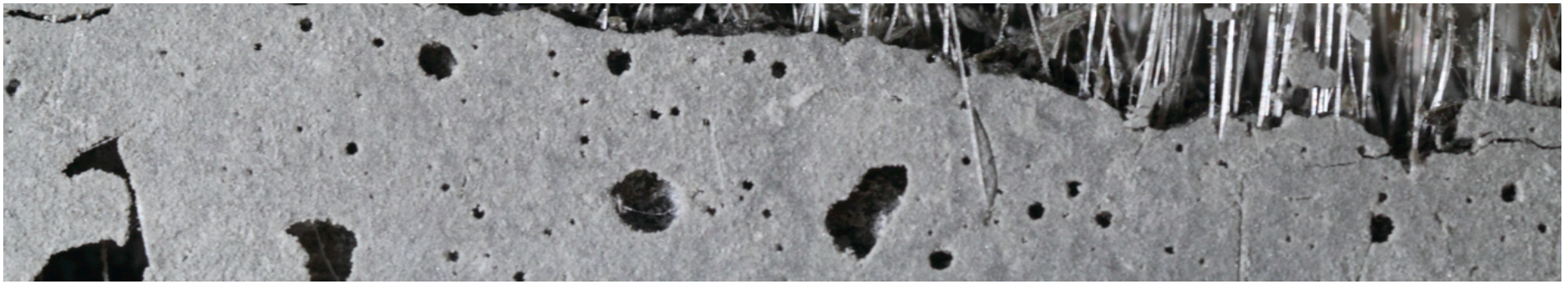
Ductility and durability of ECC leads to infrastructure sustainability



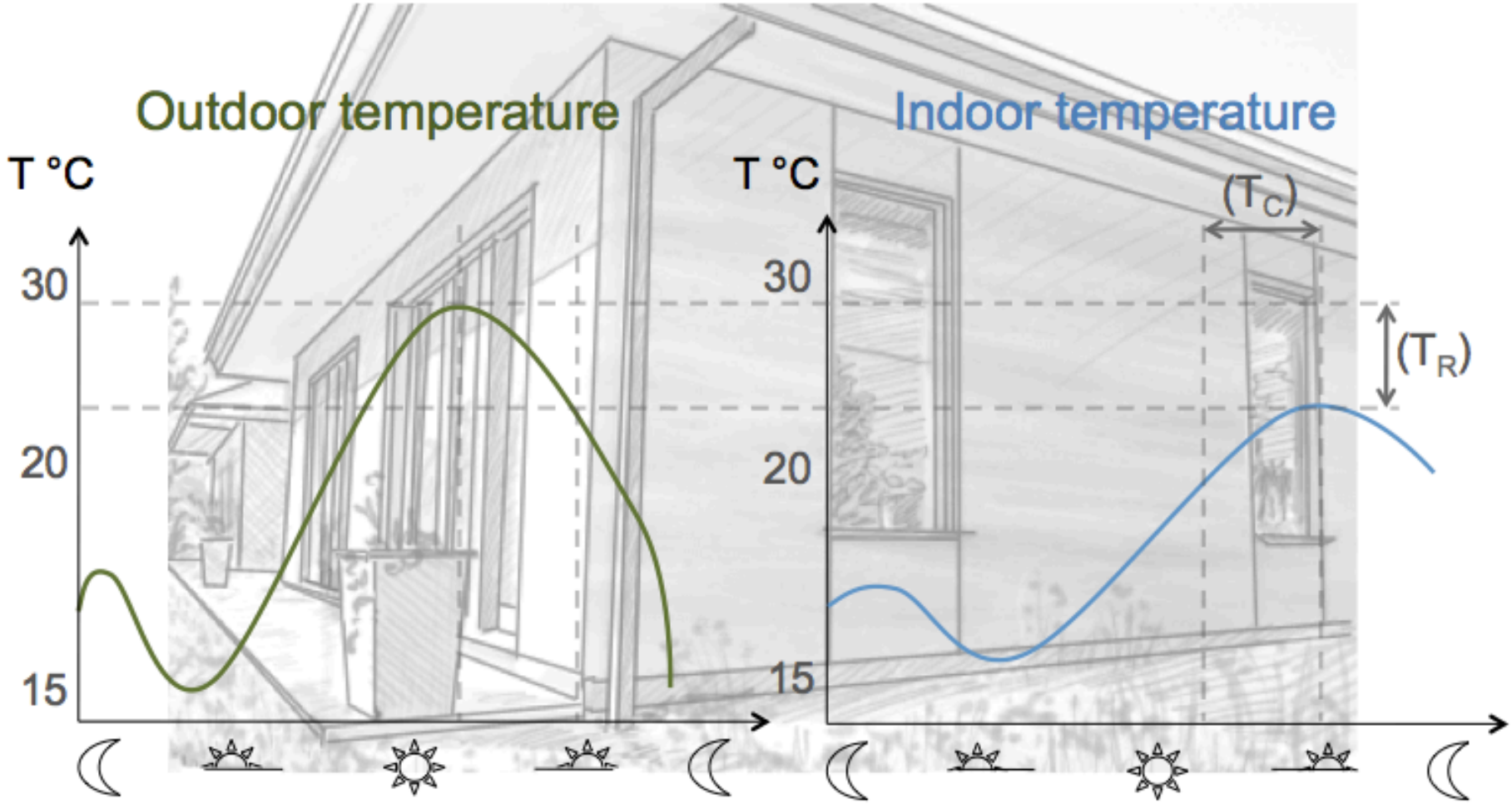


~40% reduction in primary energy consumption and CO_2 emissions

Thermal Adaptive functionality

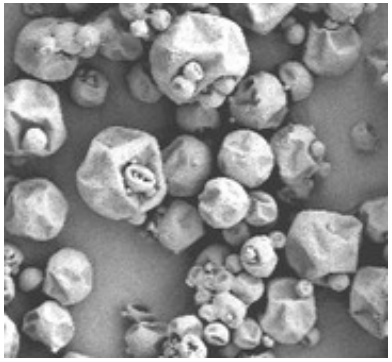


Thermal resistance and thermal capacitance reduces and delays peak temperature

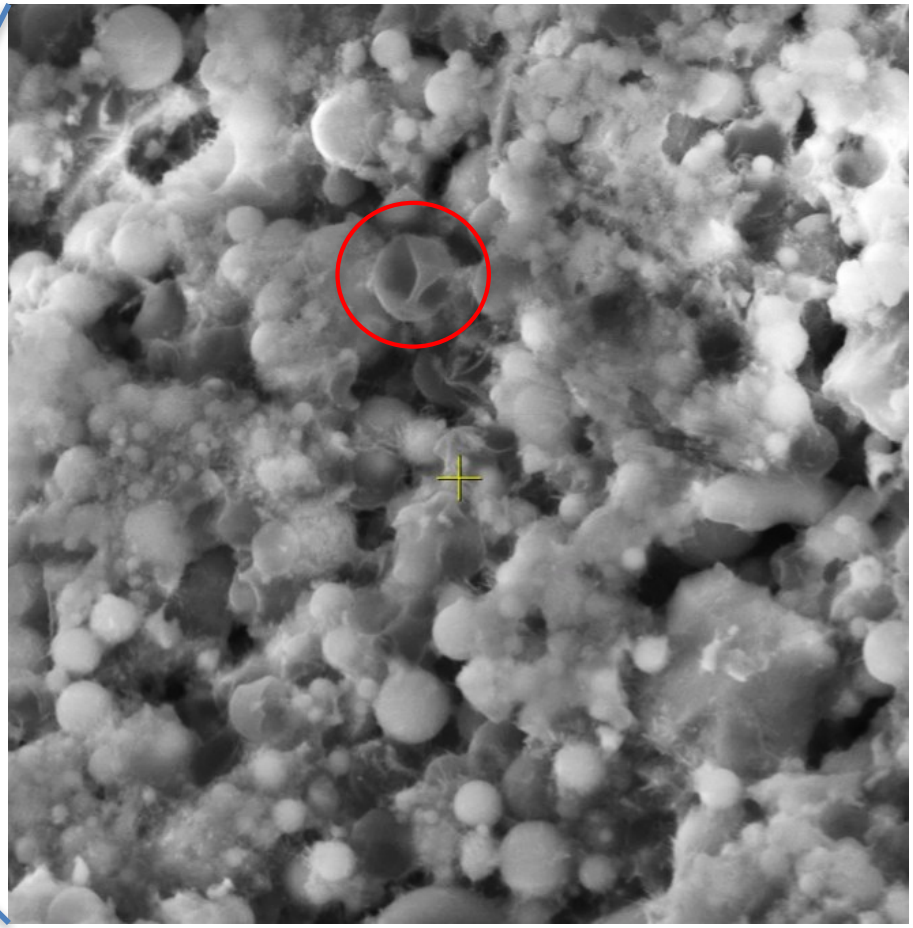


40% of home energy use is devoted to space heating and cooling

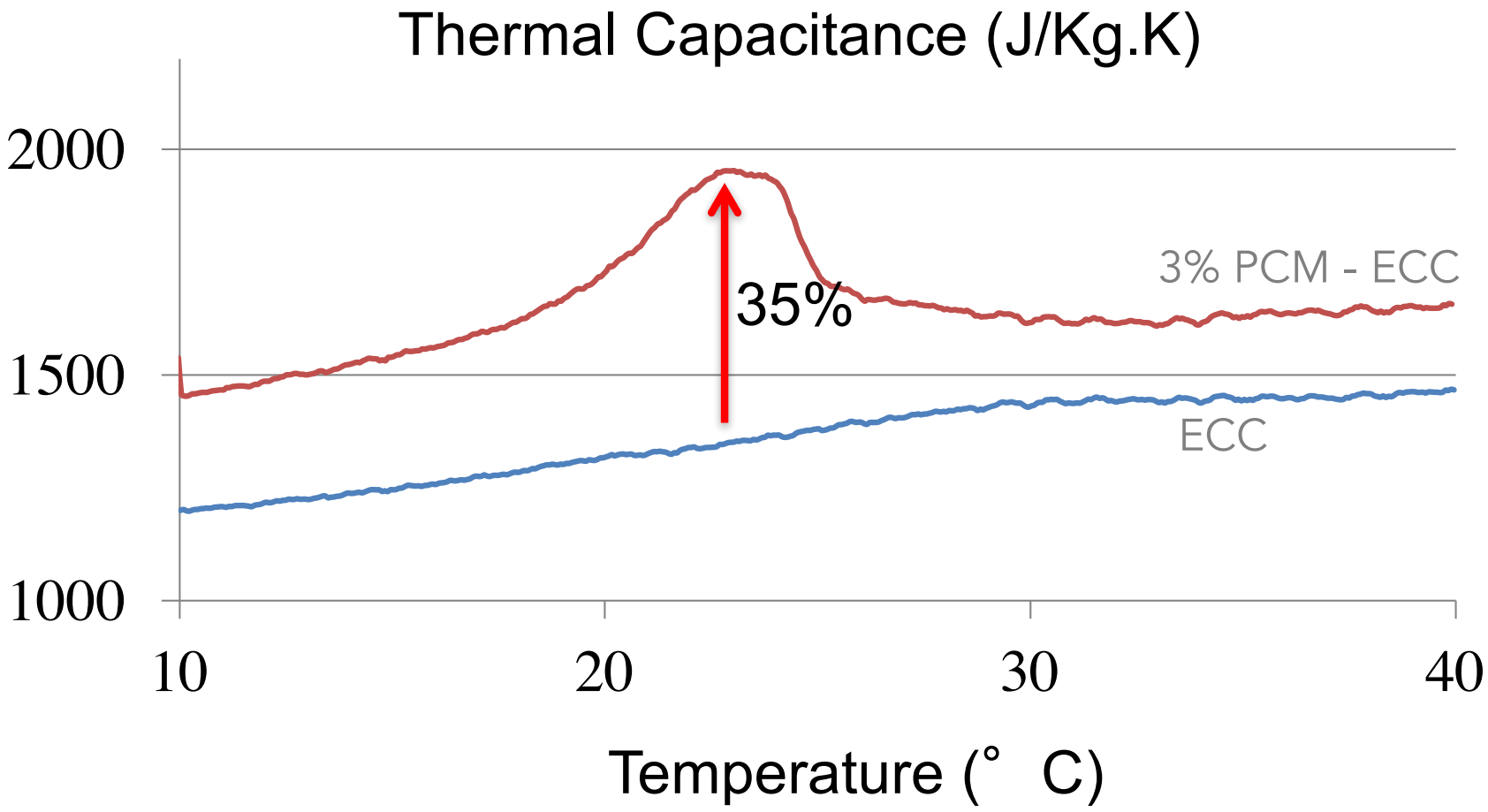
Increasing thermal capacitance with phase-change materials



Paraffin micro-encapsulated in PMMA.
Melting temp: 73° F



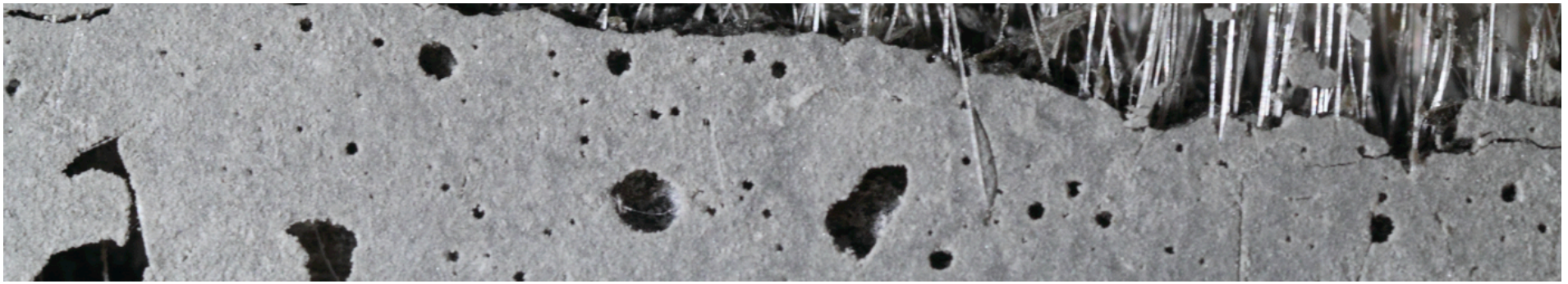
Increasing ECC thermal capacitance with phase-change materials



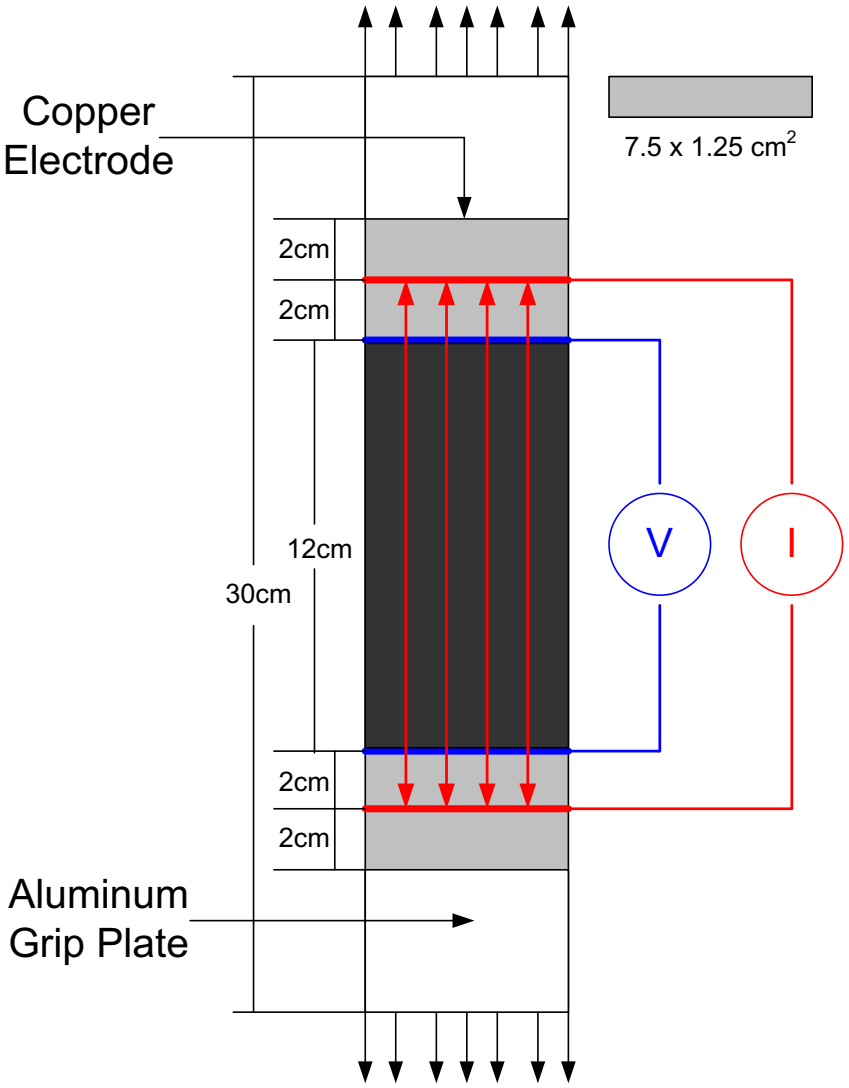
Estimated 1-2° C and 2 hour delay of peak temperature is feasible

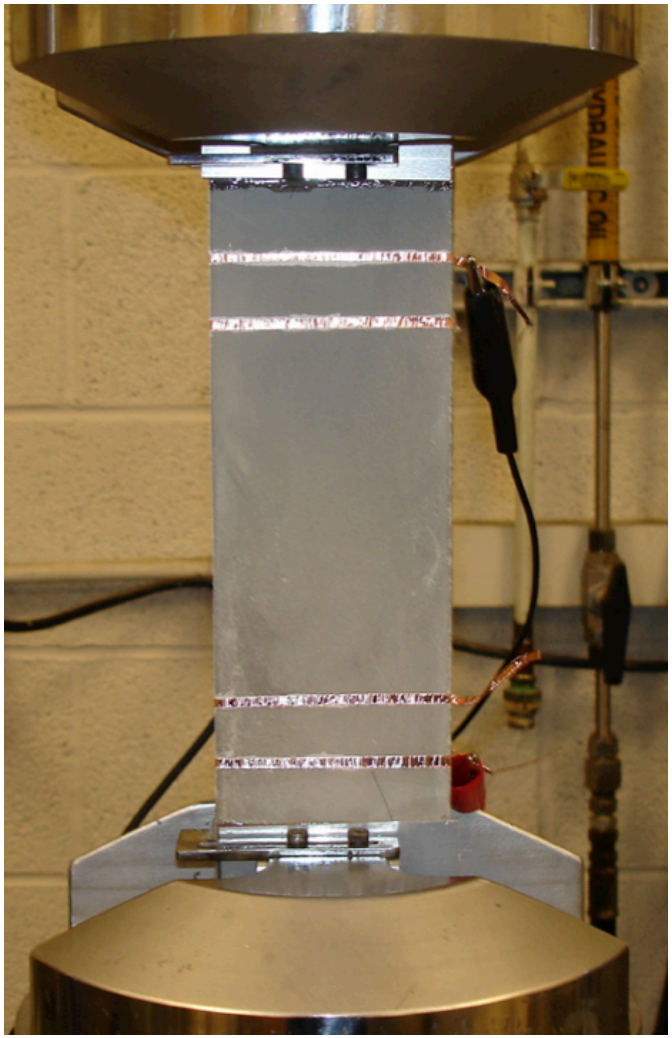
Desai et al, 2013

Self-sensing functionality



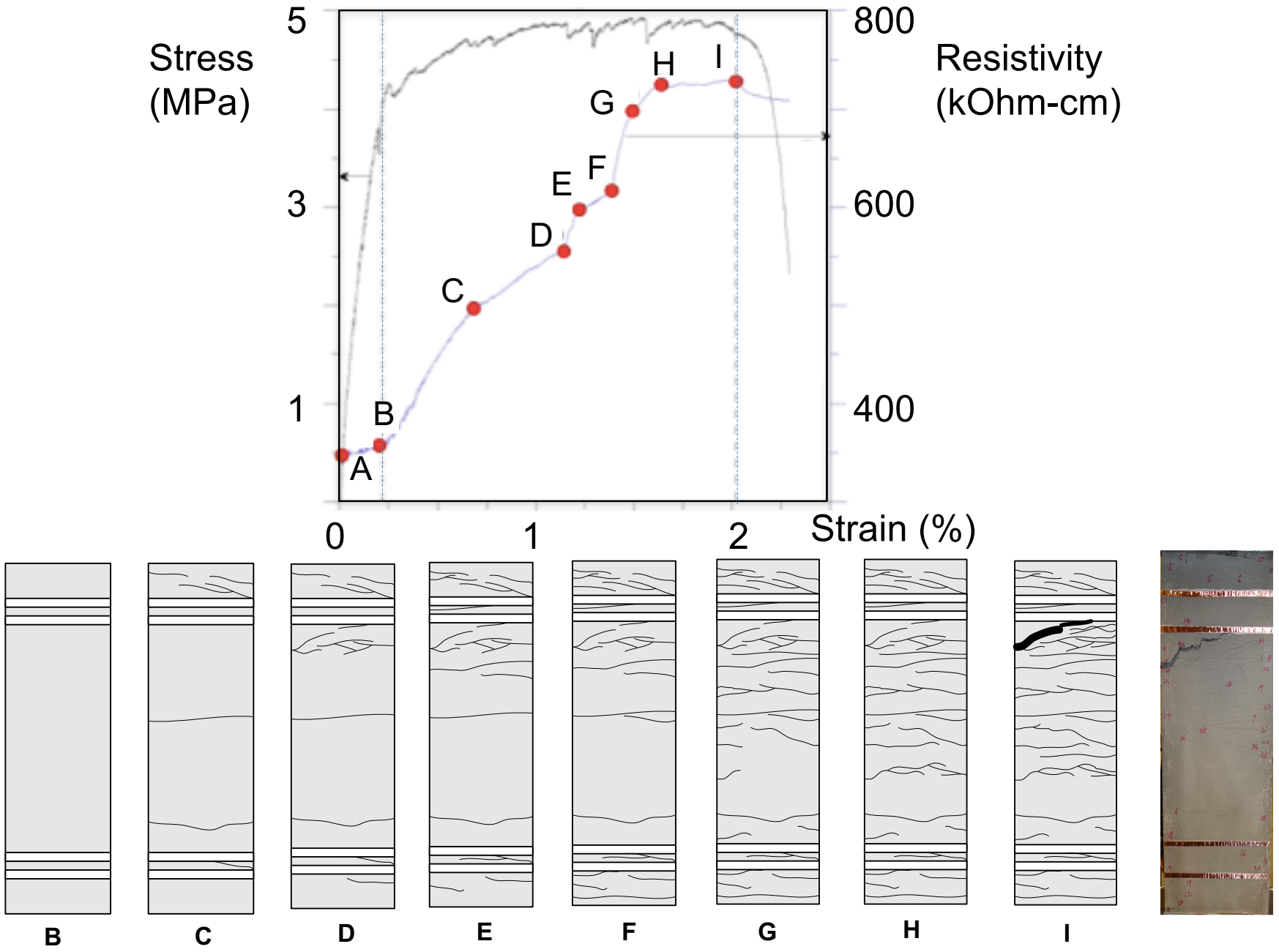
ECC serves as a structural material and as sensors for health monitoring



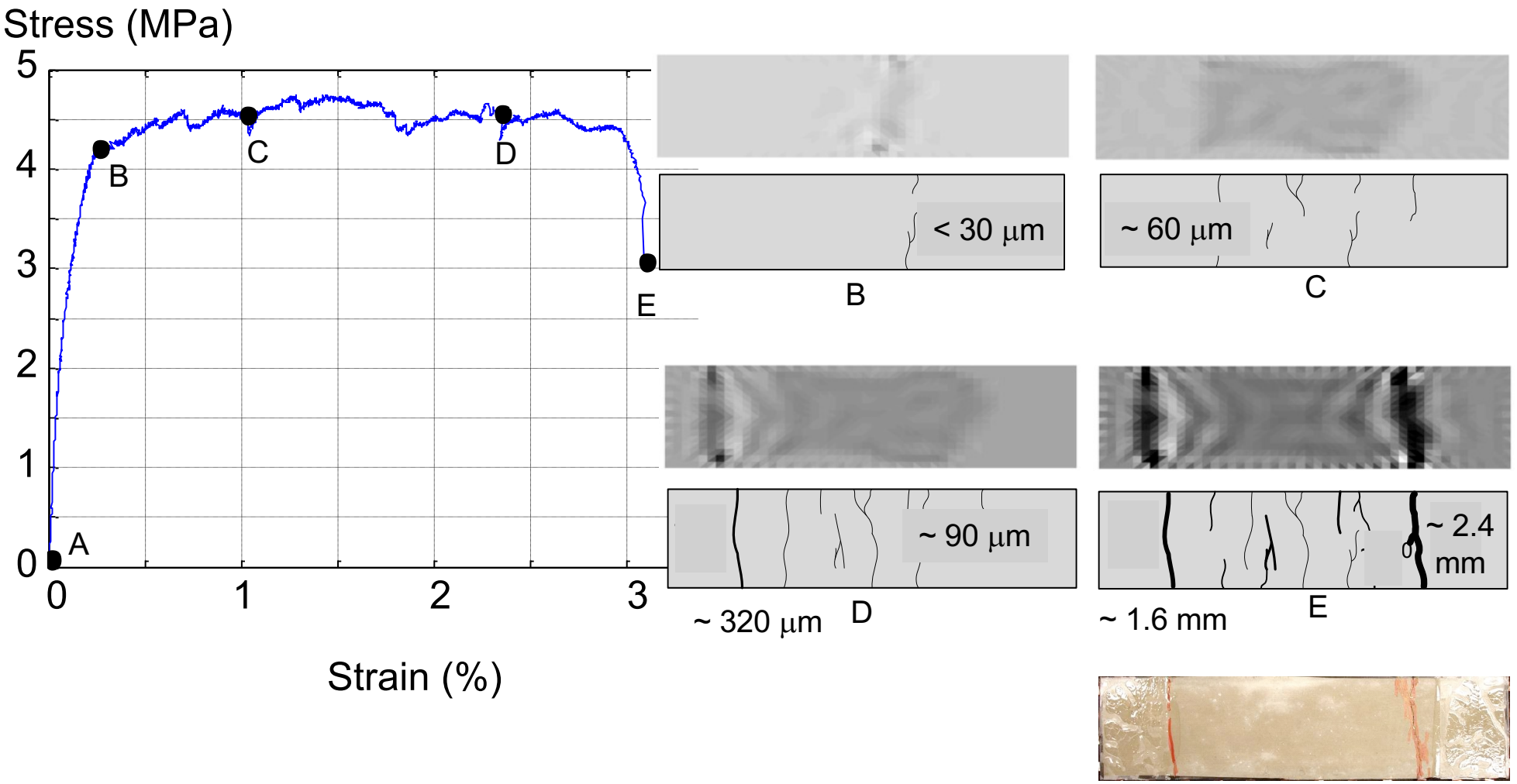


Piezoresistivity allows correlation between resistivity and cracking/strain

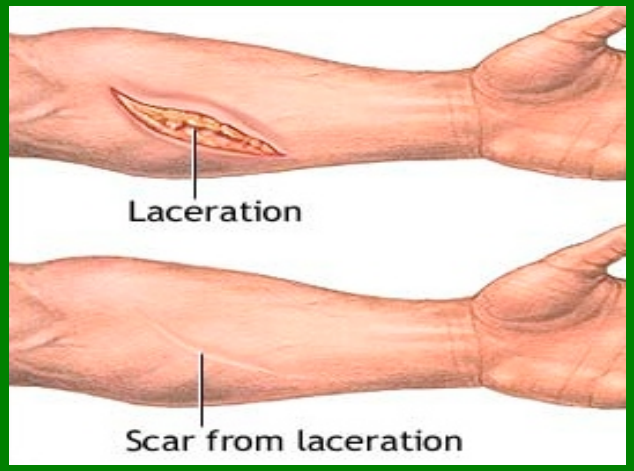
Resistivity increase with strain/damage



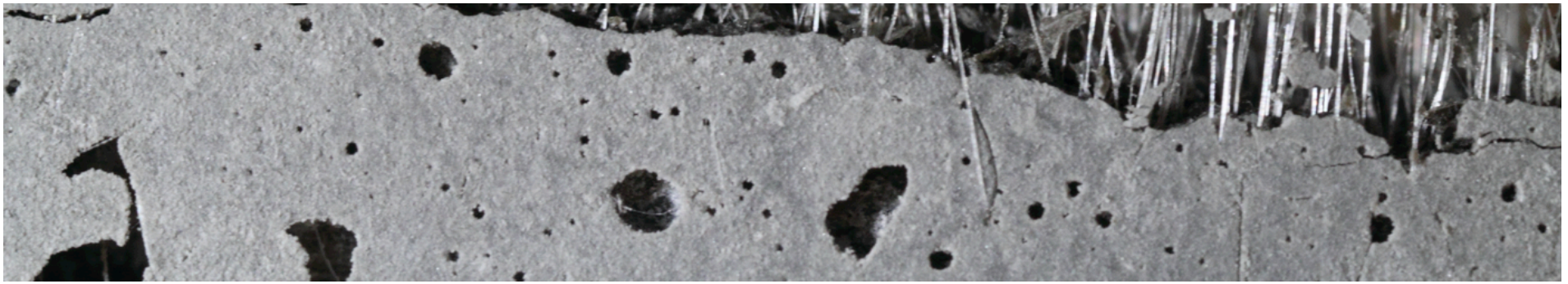
Direct reading of damage evolution during strain hardening



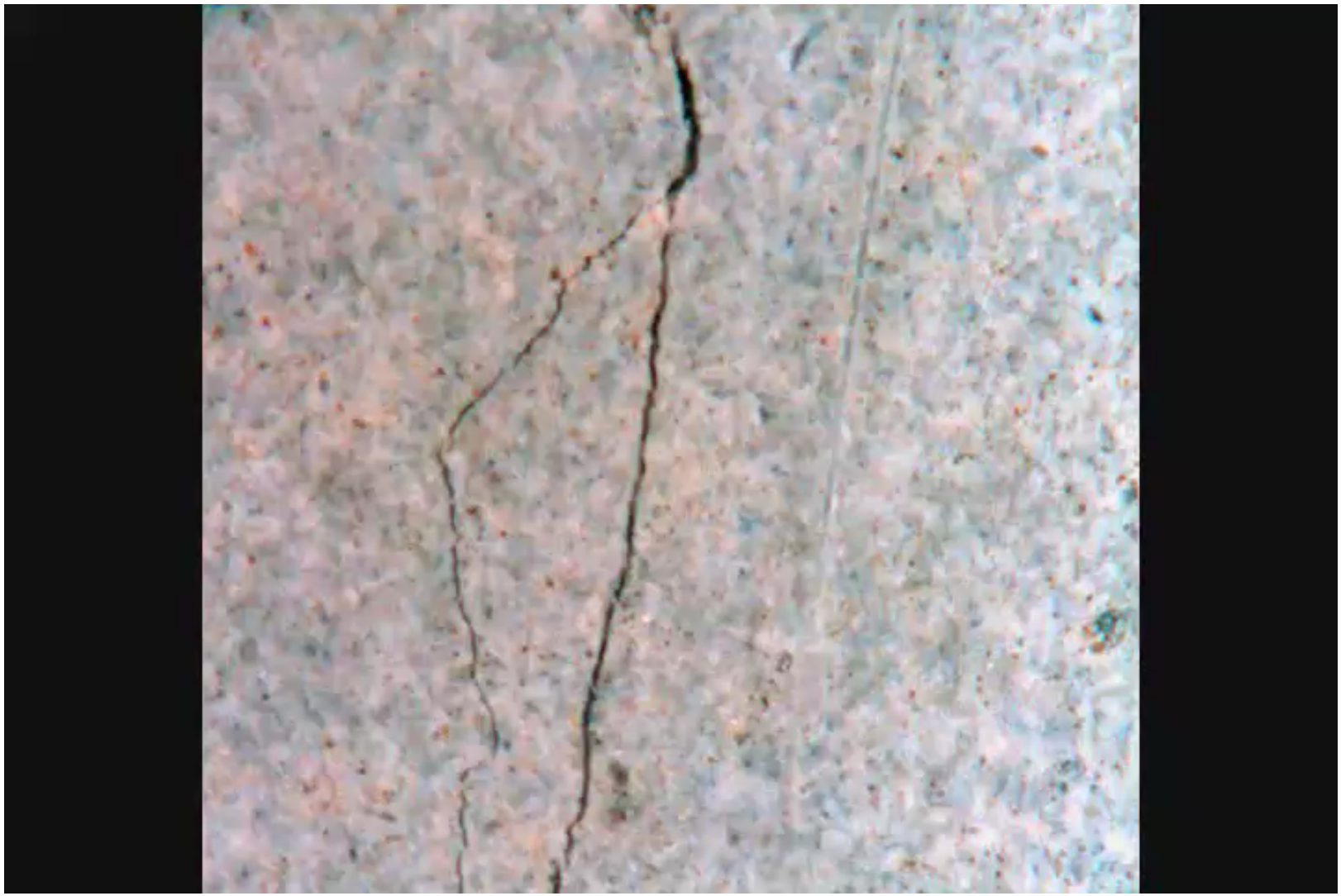
Lynch et al, 2009



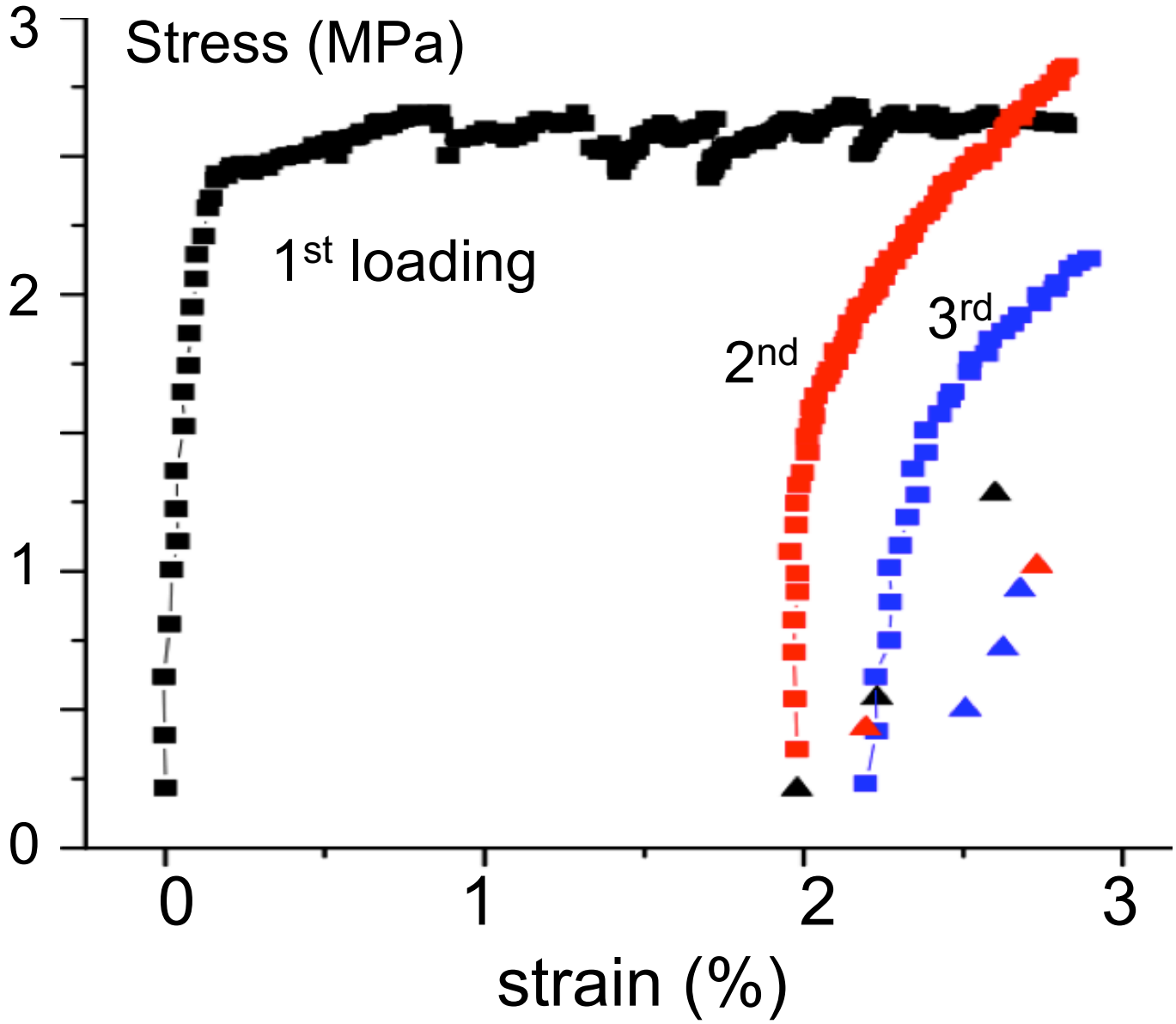
Self-healing Functionality



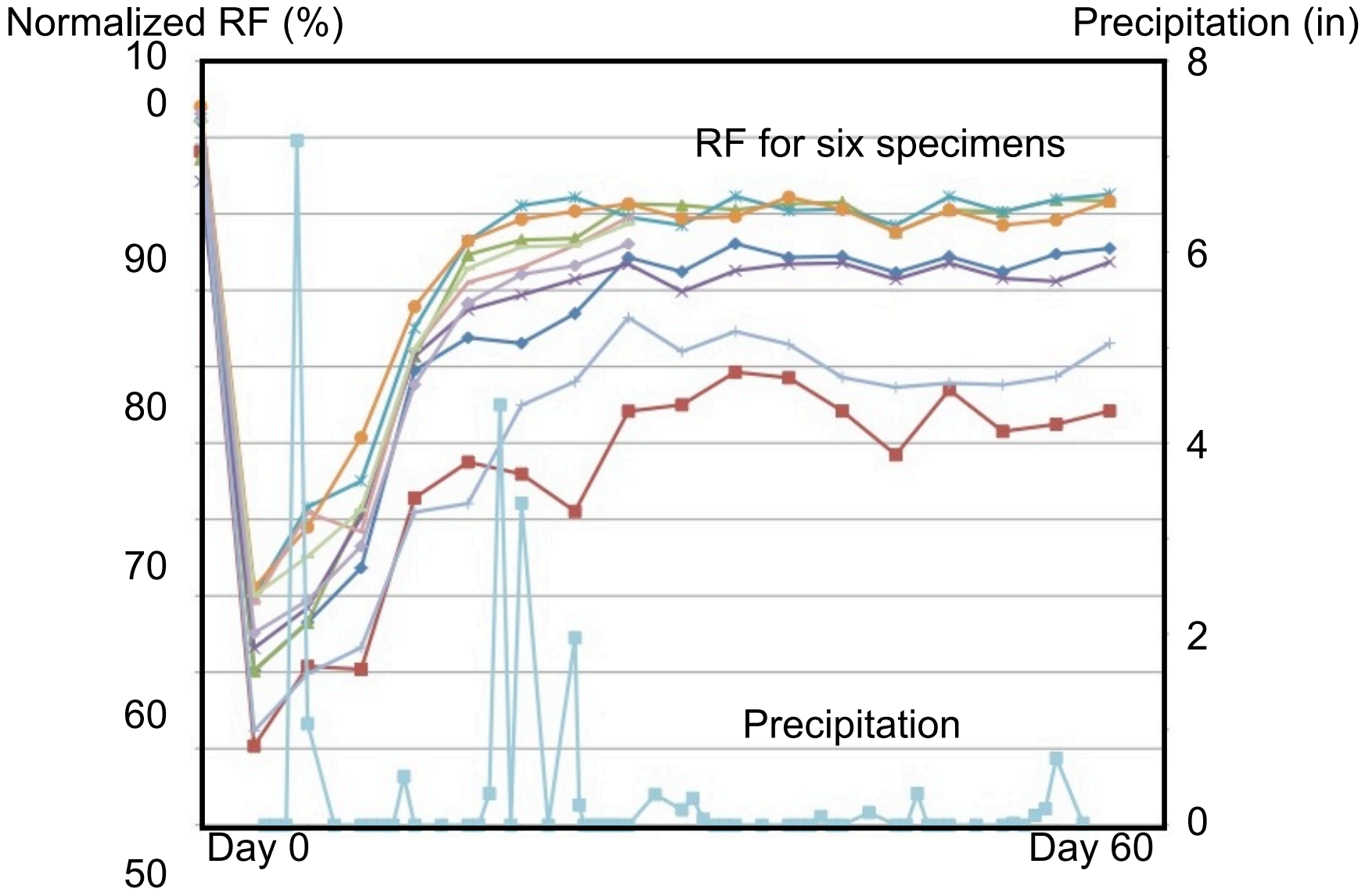
ECC self-heals – just let it rain



Rehealing function maintained after repeated damage cycles



Self-healing robustness – natural environment



Herbert and Li, 2013

Conclusions

- Smart cities demand smart infrastructure with dramatically enhanced resiliency, durability, sustainability, and intelligence
- Inspired by nature, ECC provides a materials design platform to meet these needs
- ECC can embody multi-functionalities, including thermal adaptability, self-healing and self-sensing in a single material

Harmonious
built and natural environment