



Combining multi-scale healing techniques in cementitious materials

Dr Robert Davies (Cardiff University)

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Co-Authors: Dr Martins Pilegis (Cardiff University), Dr Trupti Sharma (University of Bath),
Dr Antonios Kanellopoulos (University of Cambridge)

Encapsulation:

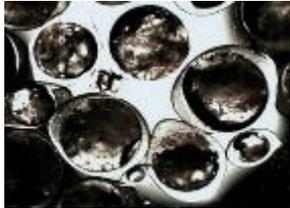


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- Interfacial Polymerisation
- Microfluidics
- Hydrogels
- **Glass capsules**
- Pellets

WP1 Nano/ Micro scale Micro/Macro capsules

(Dr Antonis Kapellonoules)



- Novel vascular **network 1D** and 2D
- 2D network in slabs
- Combining WPs
- Site trials



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- Characterisation
- Spore germ. trigger
- Long term survival
- Crack repair
- **Bacillus cohnii**,
B. pseudofirmus,
B. halodurans

WP2 Micro /Meso scale Bacteria

(Dr Trupti Sharma)



WP3 Meso/Macro scale Crack Prevention SMP

(Dr Martins Pilegis)

- **SMP-PET strips**
- SMP-PET filaments
- Anchorage
- Crack closure
- Scaling-up



Can these be combined?



Combination matrix

Work Packages	WP1 Microcap.	WP1 Macrocap.	WP2 Bacteria	WP3 SMP	WP4 Flow Net.
WP1 Microcap.					
WP1 Macrocap.					
WP2 Bacteria					
WP3 SMP					
WP4 Flow Net.					

Combination matrix

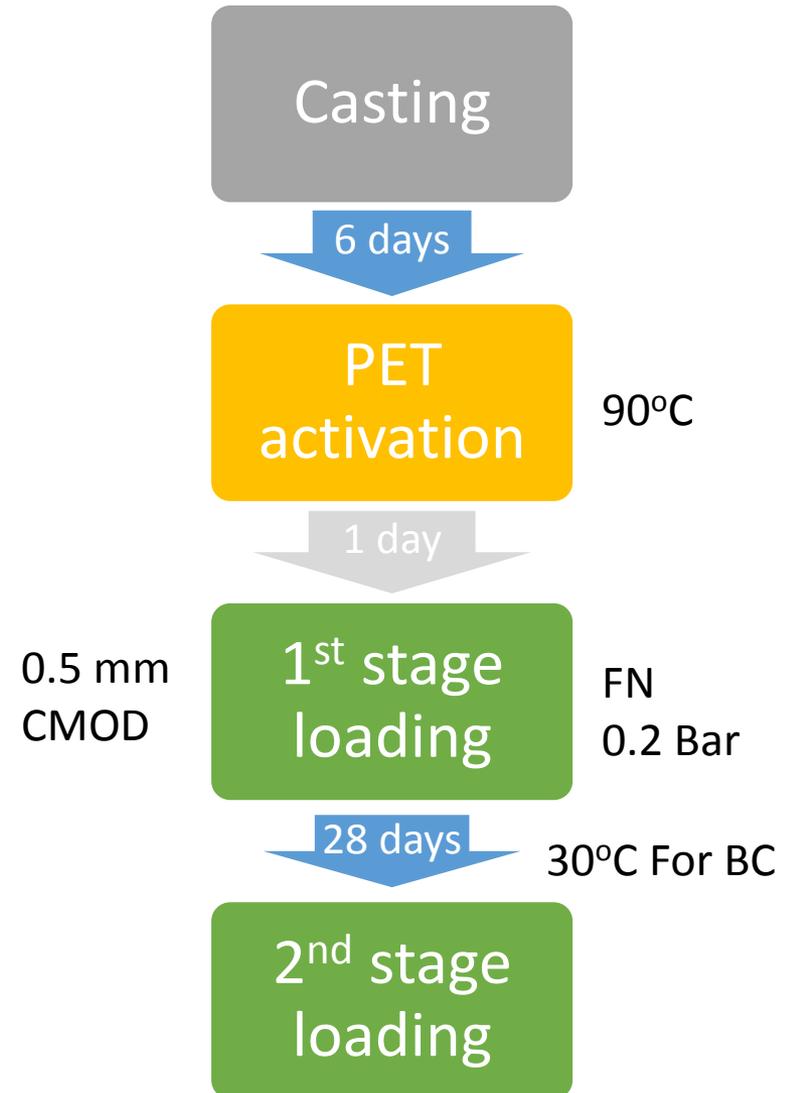
Work Packages	WP1 Microcap.	WP1 Macrocap.	WP2 Bacteria	WP3 SMP	WP4 Flow Net.
WP1 Microcap.					
WP1 Macrocap.			✓	✓	
WP2 Bacteria		✓			
WP3 SMP		✓			✓
WP4 Flow Net.				✓	

Combination matrix

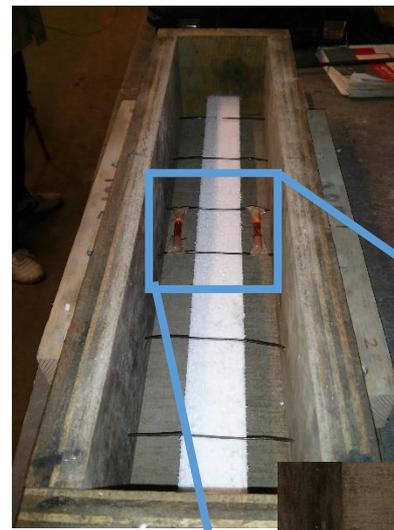
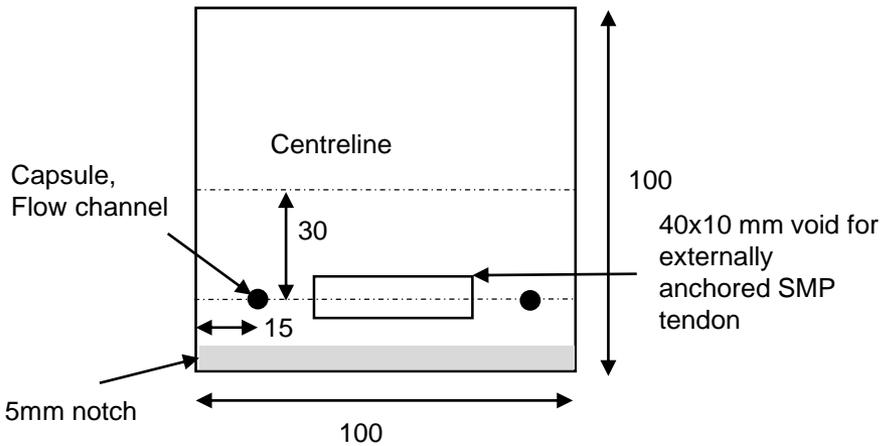
Work Packages	WP1 Microcap.	WP1 Macrocap.	WP2 Bacteria	WP3 SMP	WP4 Flow Net.
WP1 Microcap.			Started	?	
WP1 Macrocap.			✓	✓	
WP2 Bacteria	Started	✓		?	Started
WP3 SMP	?	✓	?		✓
WP4 Flow Net.			Started	✓	

Summary of experiments

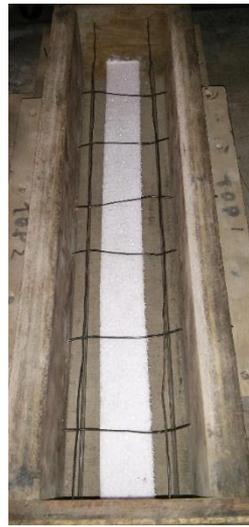
- Glass capsules + Sodium Silicate
- Glass capsules + Colloidal Silica
- Flow network + Sodium Silicate
- Bacteria (*Bacillus Cohnii*) and nutrients in separate macrocap.
- **All with and without PET strips**
 - X no. of PET strips externally anchored with expected force generated 1MPa
 - 3 x 500 beams for each



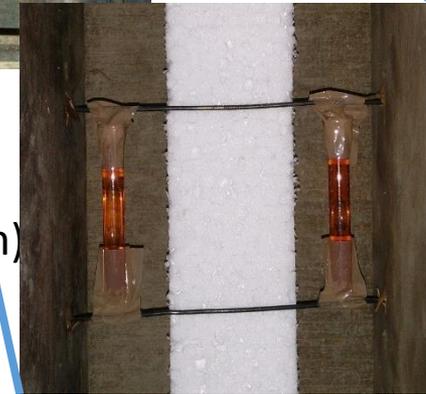
Cross-section, placement and testing



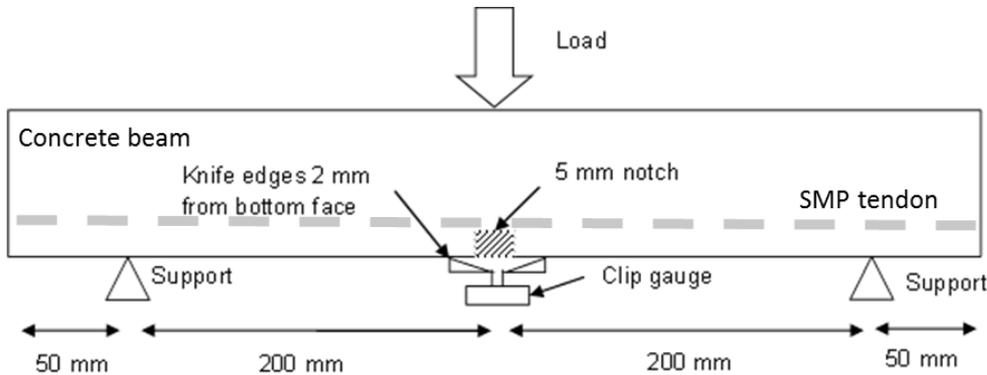
Capsule Placement
(6mm x 60mm)



Flow network



Centre cross-section



PET anchor



Test setup

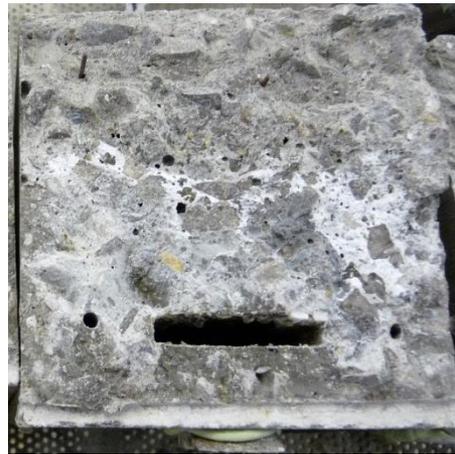
Typical final fractured faces



Control



Control cross-section



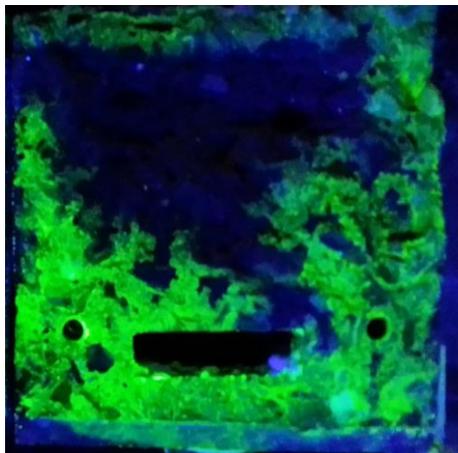
**Flow network
sodium silicate (SS)**



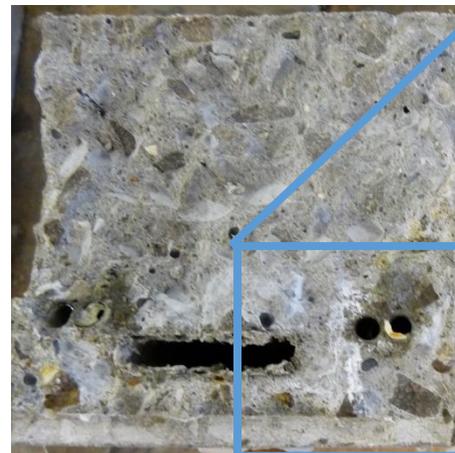
**PETr + Flow network
sodium silicate**



**PET + glass capsule
sodium silicate**



**Glass capsule SS
UV light**



Bacteria



Bacteria capsule

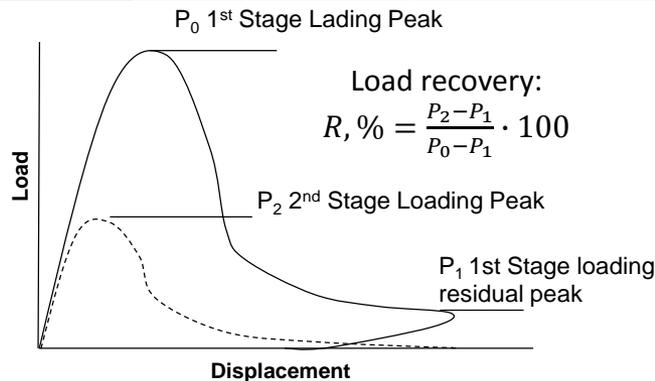
Combination results

	Control	WP1 Macrocap. Sodium Silicate	WP1 Macrocap. Colloidal Silica	WP2 Macrocap. Bacteria and food	WP4 Flow net. Sodium Silicate
Load recovery (%)	1.4	1.3	0	0.9	5.4
Load recovery (%) with SMP WP3	14	34	12	-	31

Ageing Material Prop.

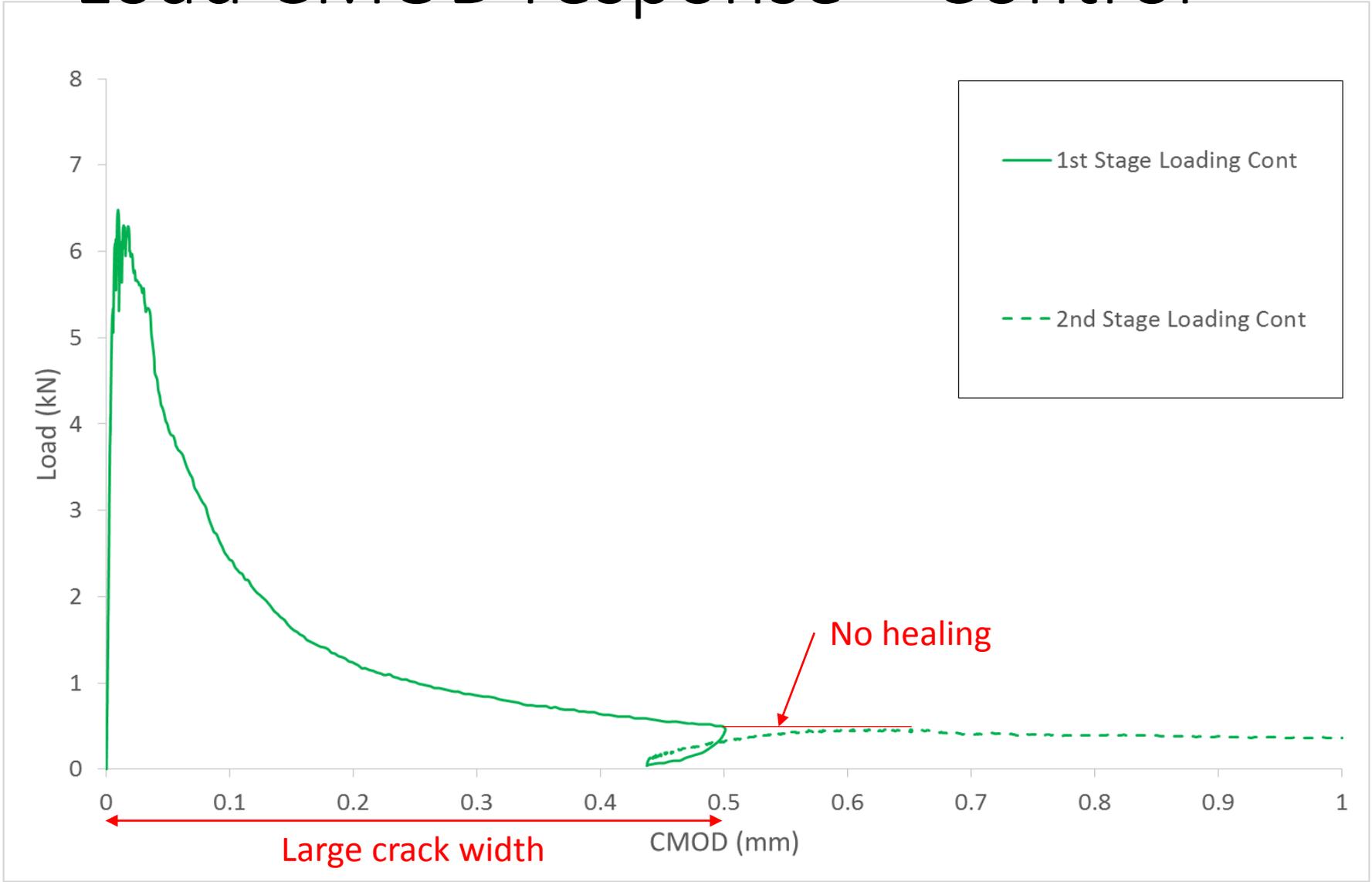
Autogenous Healing

Improved Healing

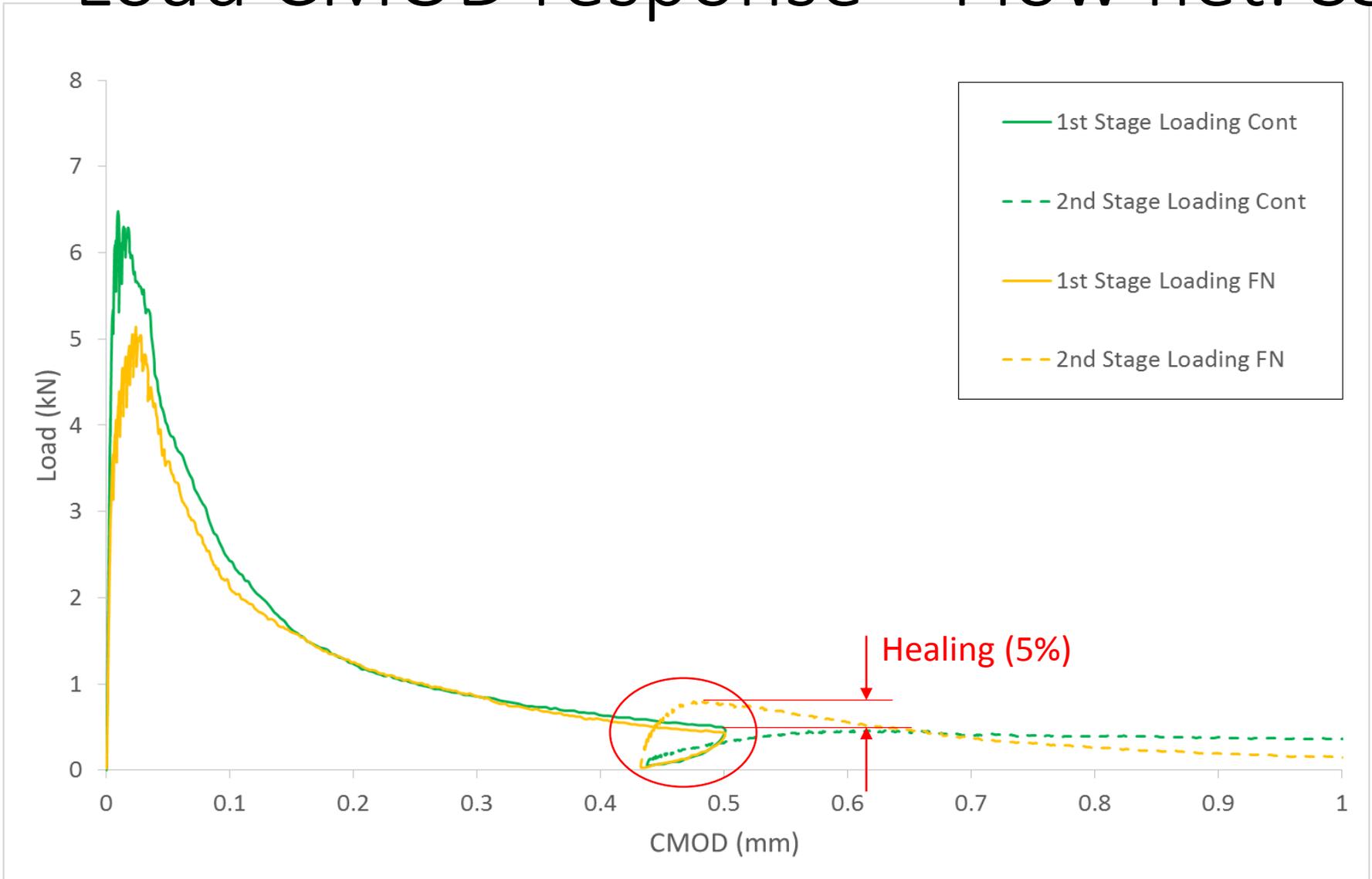


Note. Efficiency calculated using average of Control samples for initial peak and residual strength

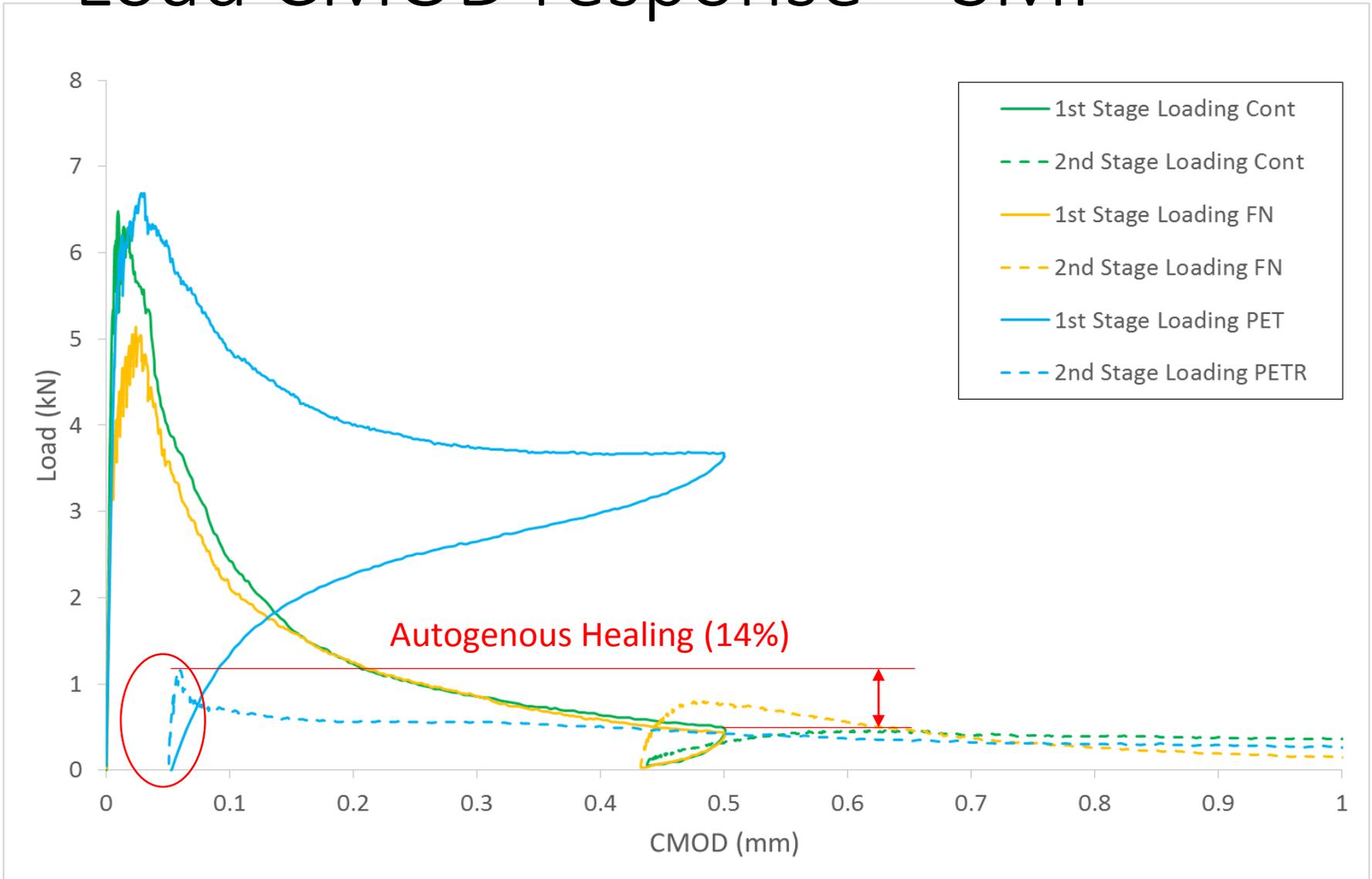
Load CMOD response – Control



Load CMOD response – Flow net. SS



Load CMOD response – SMP

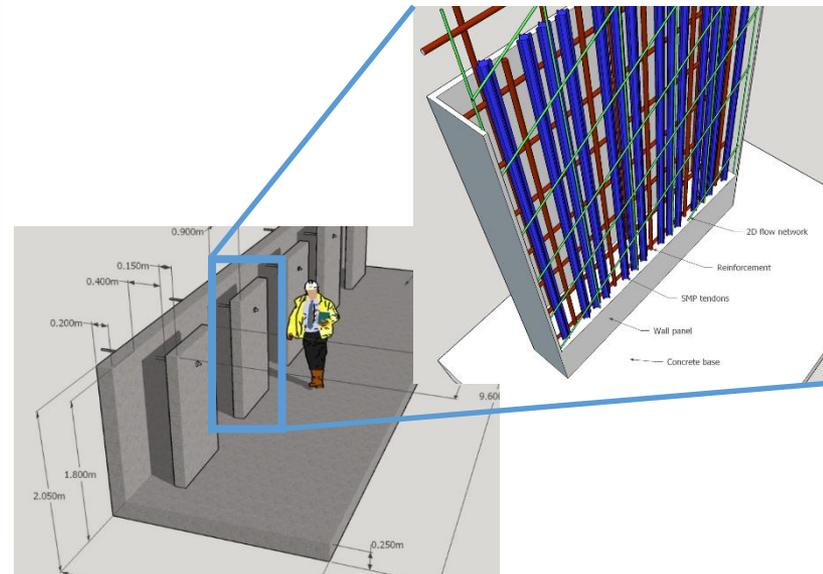
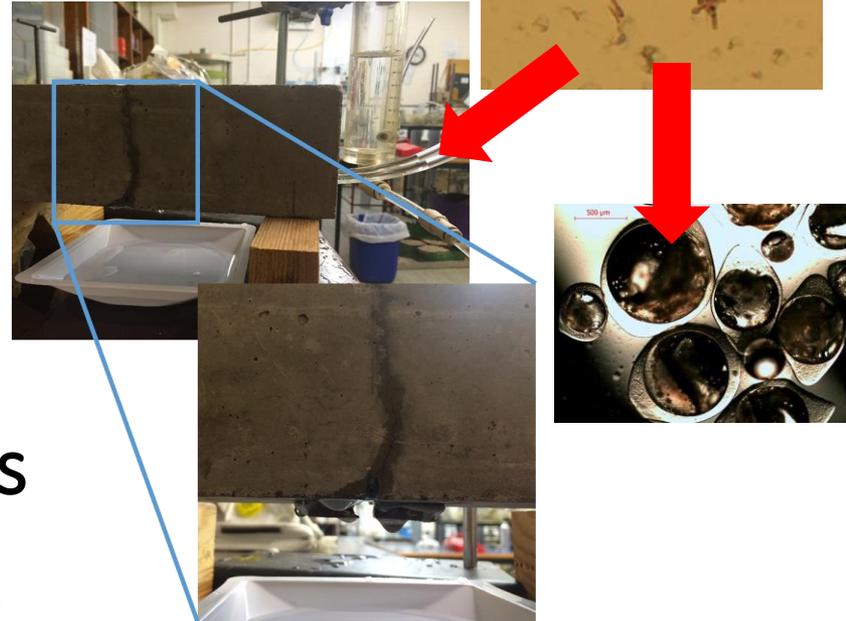


Summary

- Introduction to M4L
- Investigated **combination** of WPs
- **Doubled load recovery** with SMP

Future work and challenges

- Continue to investigate combinations
 - Using flow networks to **deliver** bacteria/nutrient
 - Bacteria spores **encapsulated** within microcapsules
- Application of combinations
 - **Steel** reinforcement and 2D slabs
 - **Site trial** scale-up





Thank you

Further information:

[www. m4l.engineering.cf.ac.uk/](http://www.m4l.engineering.cf.ac.uk/)

twitter @materials4life

Dr Robert Davies (DaviesRE11@cf.ac.uk)

twitter @DrREDavies

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