ÖZYEĞİN UNIVERSITY

IMMOBILIZATION OF BACTERIAL CELLS ON NATURAL MINERAL FOR DEVELOPING SELF-HEALING CEMENT-BASED MORTARS

Ilgin Sandalci, Mustafa Mert Tezer, Assistant Prof. Zeynep Basaran Bundur

Department of Civil Engineering, Ozyegin University

BIO-BASED SELF-HEALING

SUSTAINABILITY

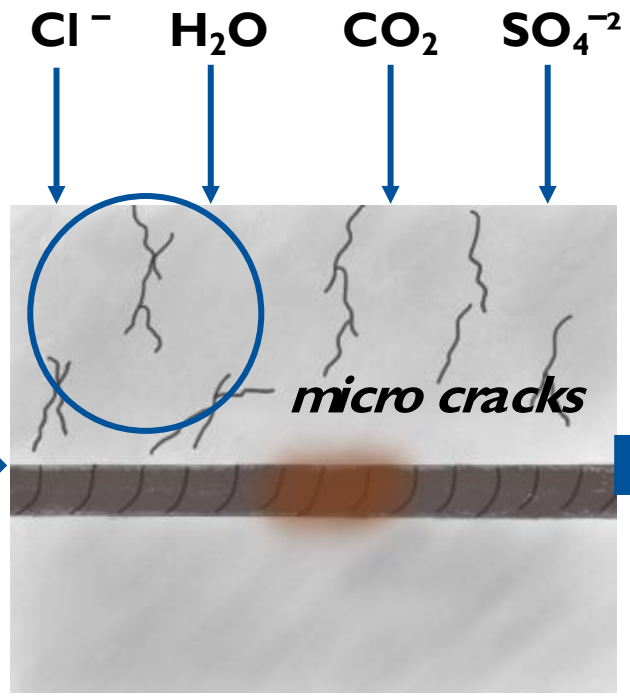
extending service life

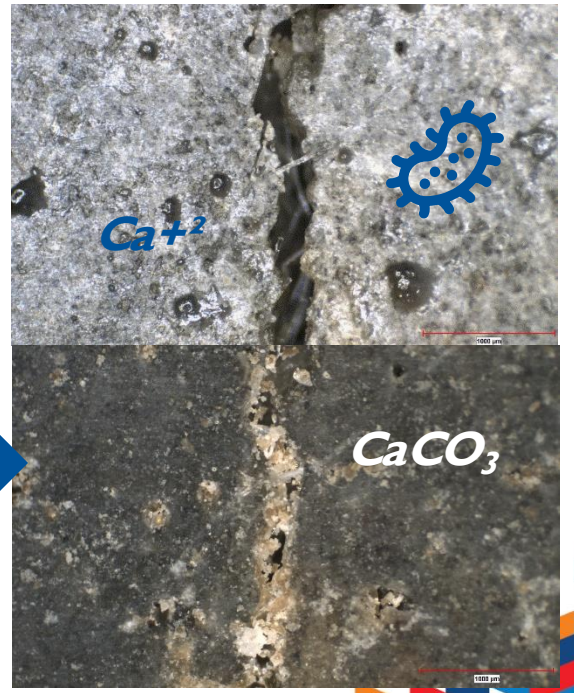
DURABILITY

decrease the ingress of degrading agents

SELF-HEALING

microbial induced calcite precipitation

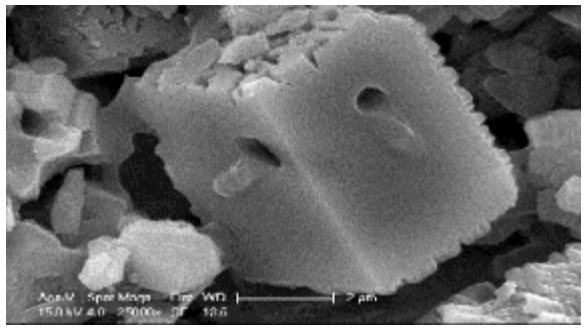




BACTERIAL SELF-HEALING AGENT

- Tolerate highly alkaline conditions
- Survive the mixing process
- Remain viable with limited access to nutrients

Self-healing Agent
Sporosarcina pasteurii



$$CO(NH_2)_2 + H_2O \xrightarrow{urease} CO_3^{-2} + 2NH^{+4} + 2H_2O$$

urea — *carbonate*

$$Ca^{+2} + CO_3^{-2} \rightarrow CaCO_3(s)$$

- Bacteria cells were found to be **viable up to 330 days.** (Bundur et al. 2017a)
- **Corn Steep Liquour (CSL)** was sound alternative to replace yeast extract in self-healing applications. (Amiri et al. 2018)

IMMOBILIZATION BACTERIA CELLS

Natural Mineral
Bentonite
Zeolite

+

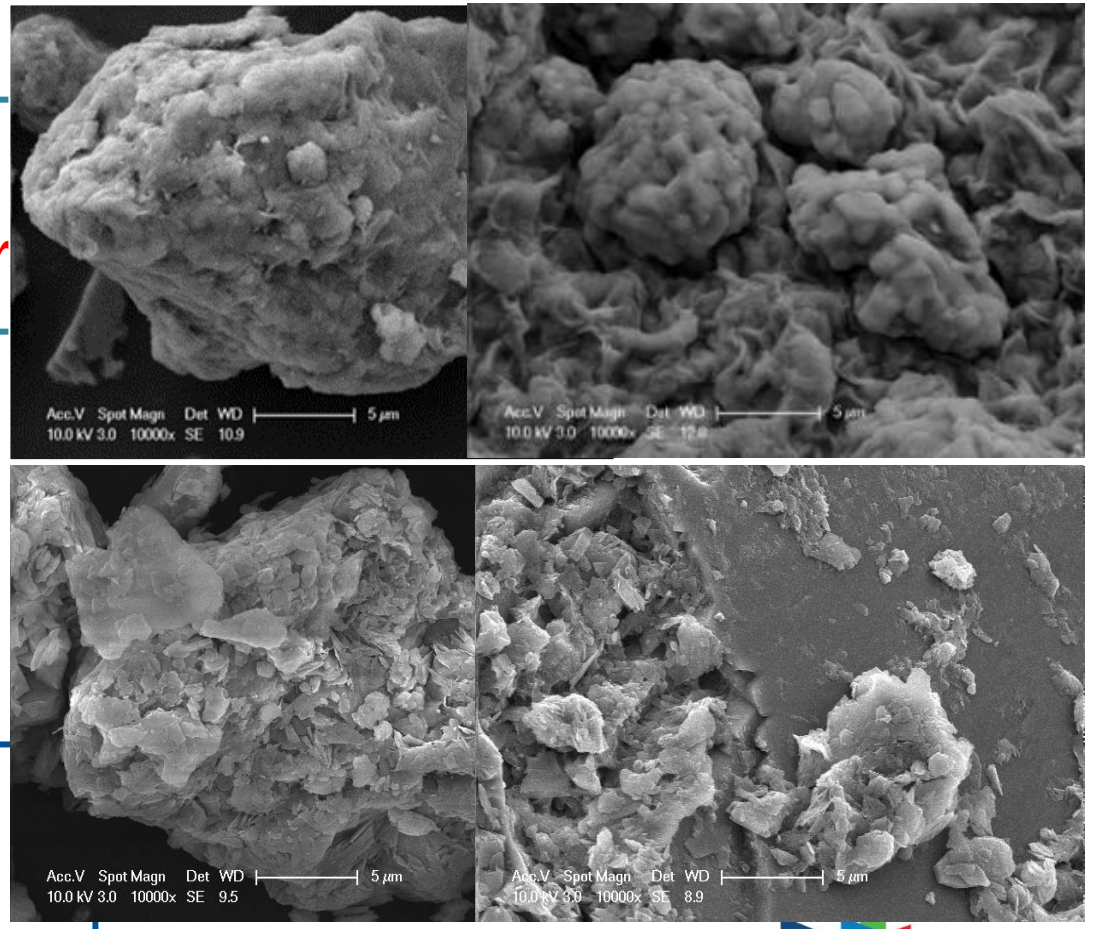
Bacteria Cell + PBS
Bentonite

- Average Particle Size 20-200µm
- Absorption Capacity 300-25%

Natural Mineral
Bentonite
Zeolite

+

Zeolite
Nutrient Medium
UCSLC



Before Immobilizatio *After Immobilization*

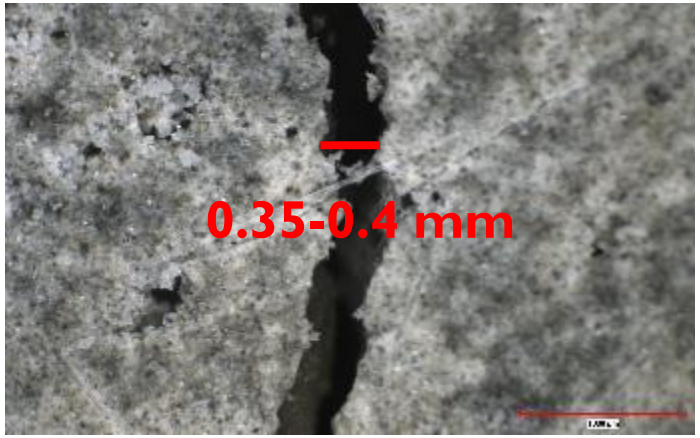
METHODOLOGY

Immobilizing viable *S. pasteurii* cells **(2P)**

Without any bacterial cells **(C)**

after 28 day

cracked under a 3-point flexural loading

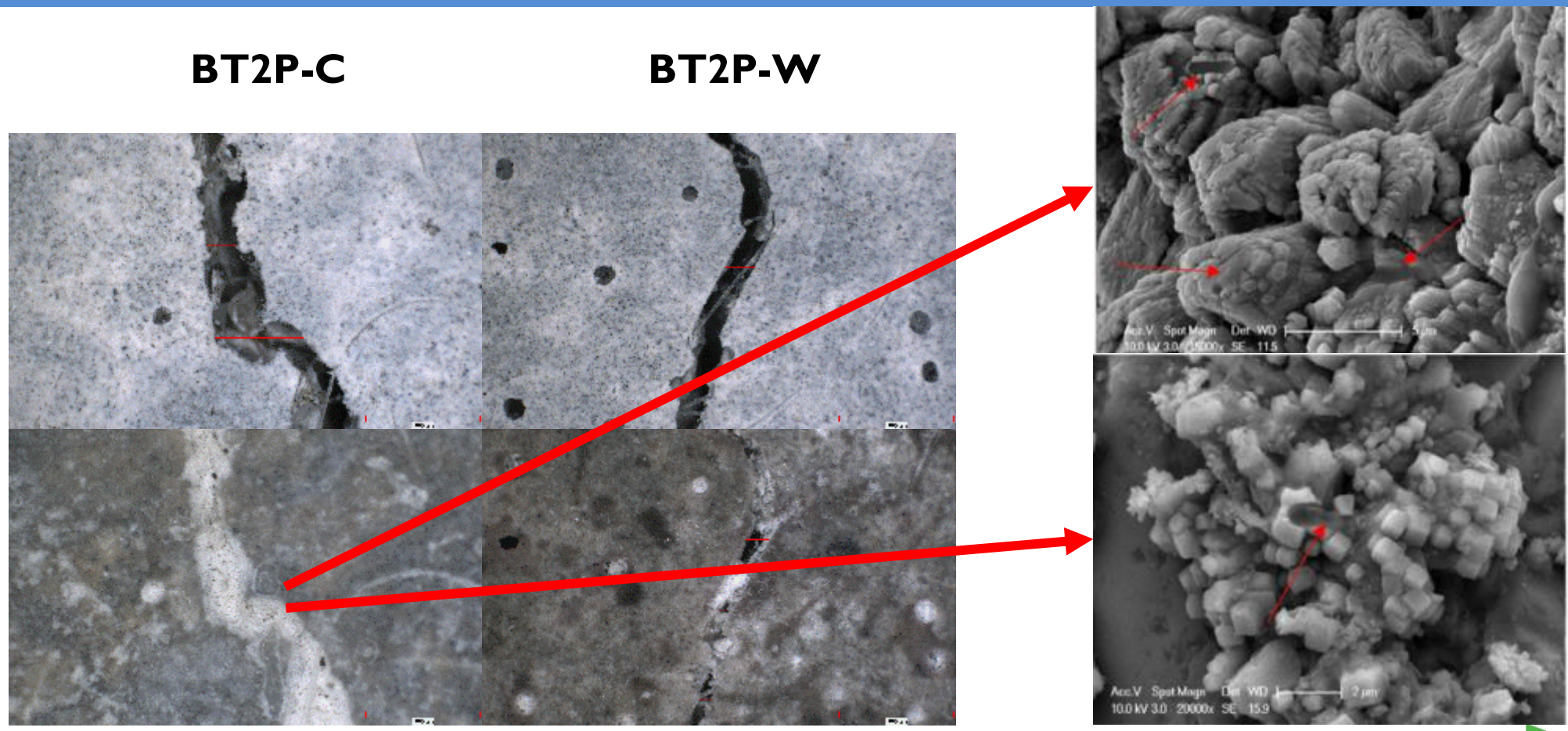


Cured in UCSLC nutrient medium **(C)**

'2 Days Period' Treatment Process

Cured in water **(W)**

VISUAL CRACK HEALING - BENTONITE

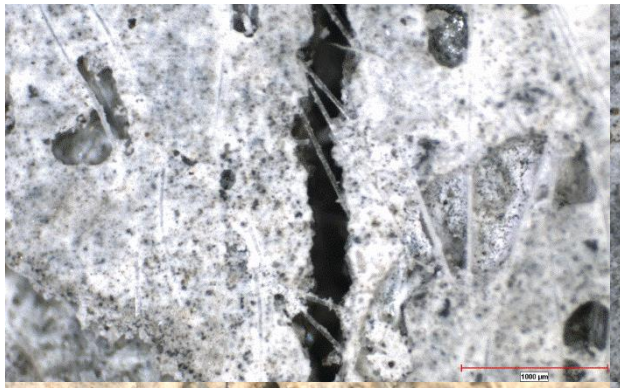
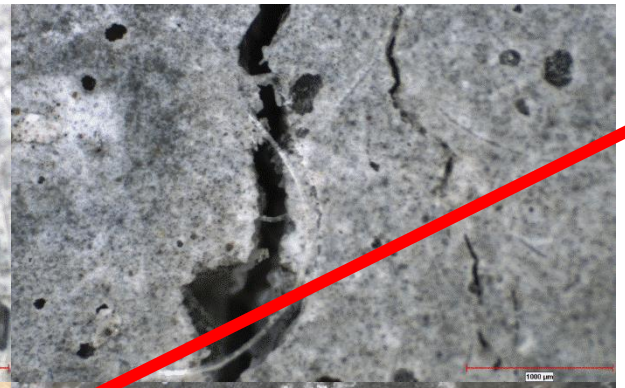
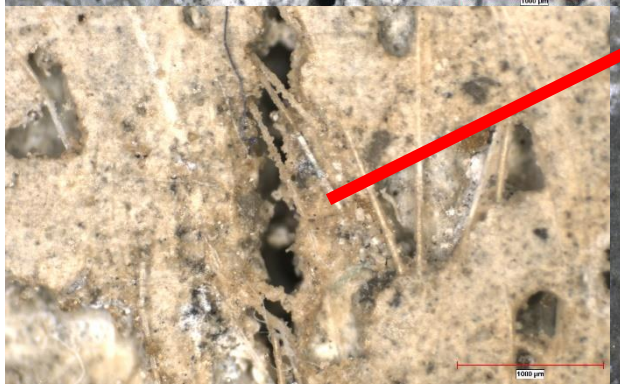


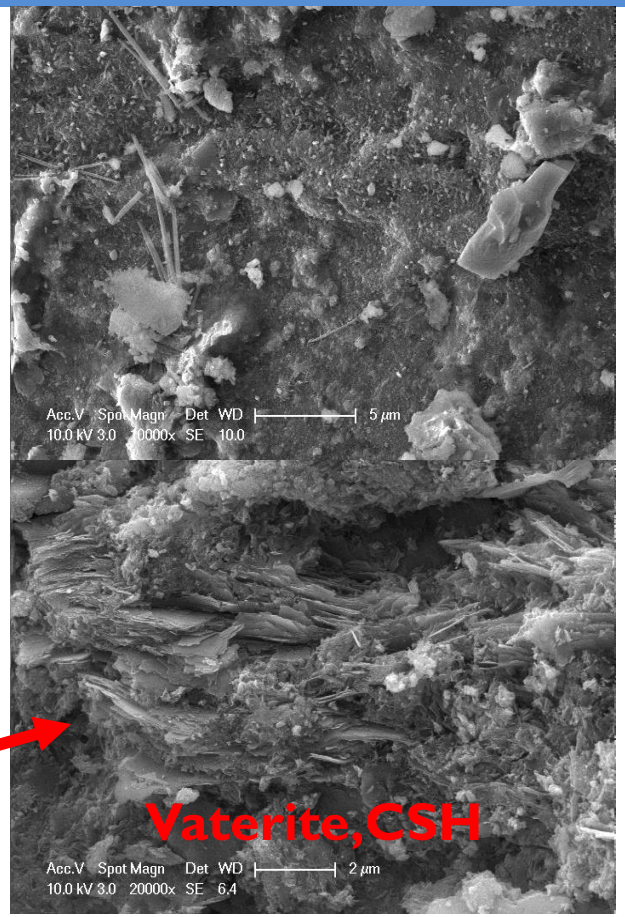
Crack Healing %

100% **35%**

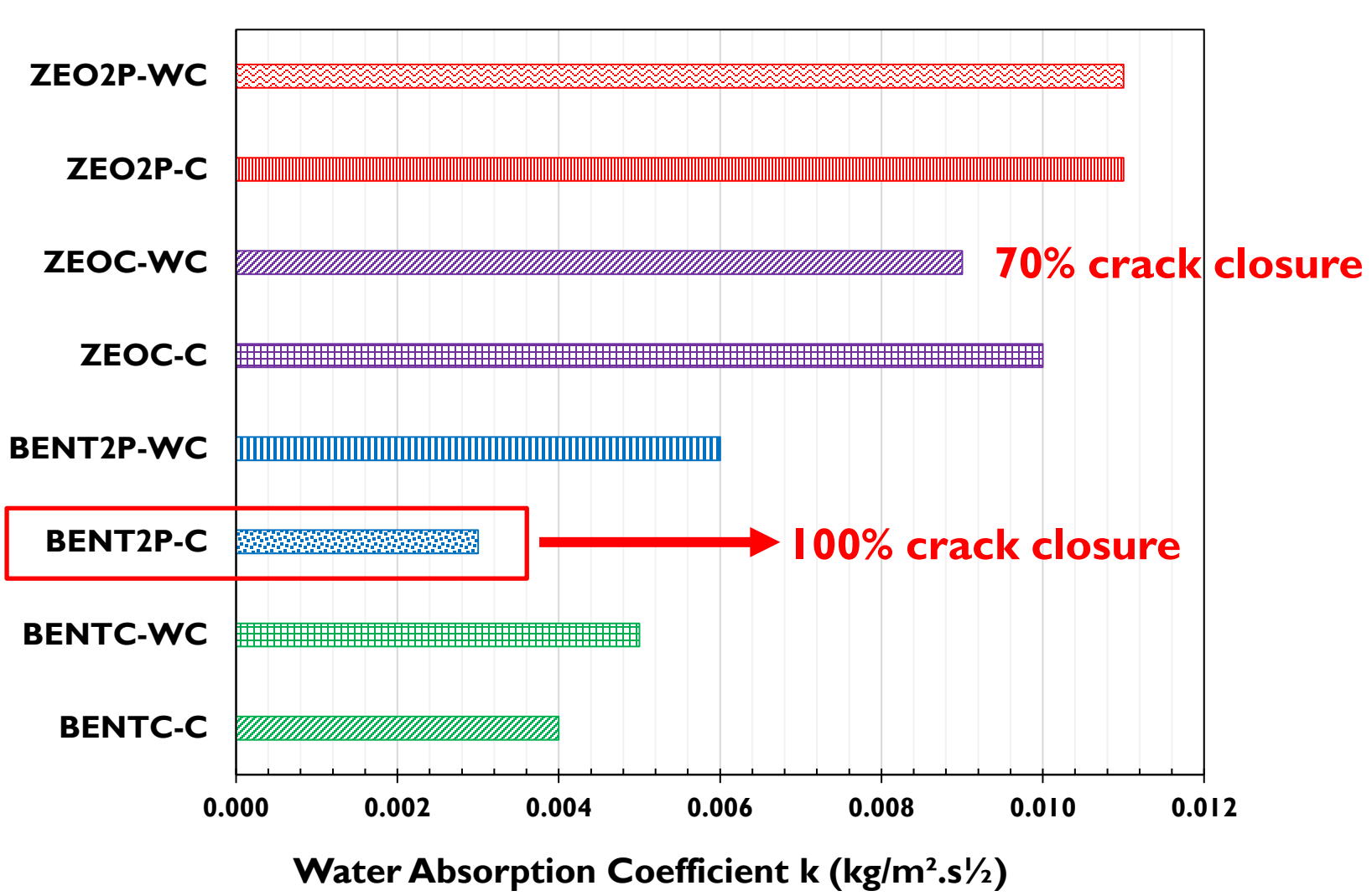
$$\% \; visual \; crack \; sealing = \frac{\sum_{n=1}^{10} w_i - \sum_{n=1}^{10} w_{7.,14.,21.,28.}}{\sum_{n=1}^{10} w_i}$$

VISUAL CRACK HEALING - ZEOLITE

	ZEOC-C	ZEOC-W
t=0		
t=28 day		
Crack Healing %	33%	70%



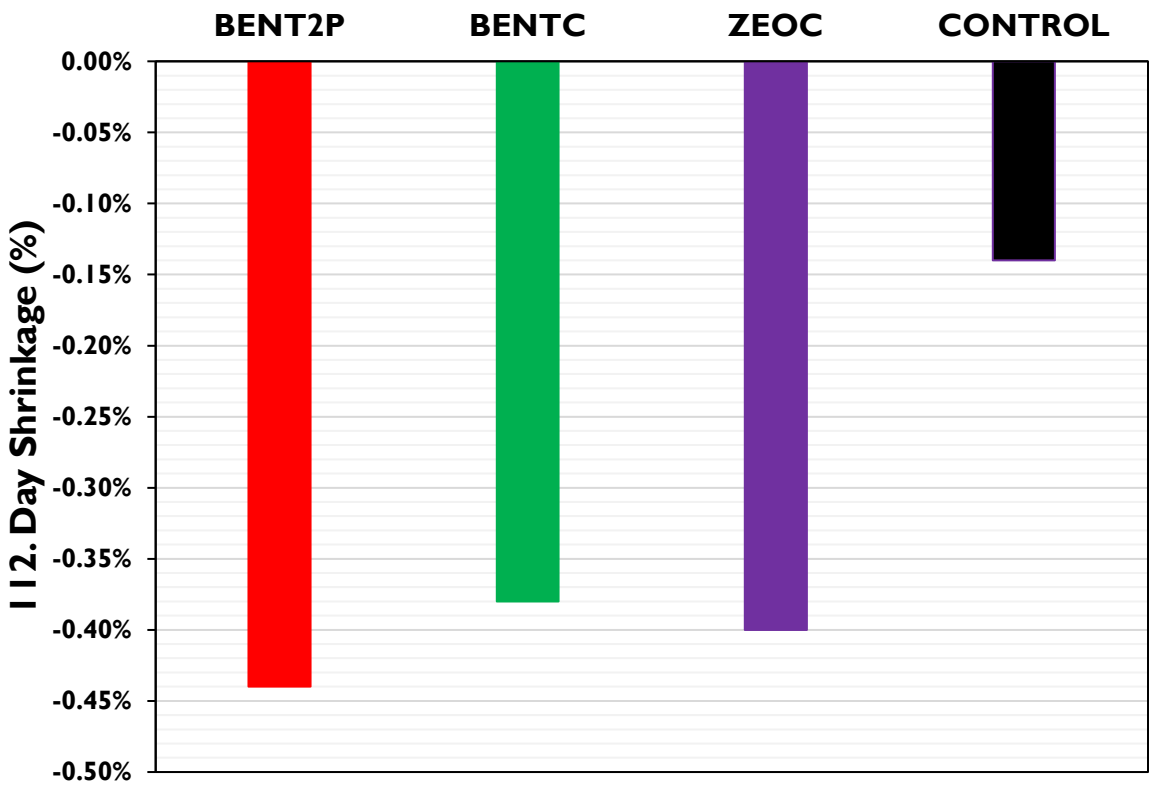
WATER ABSORPTION

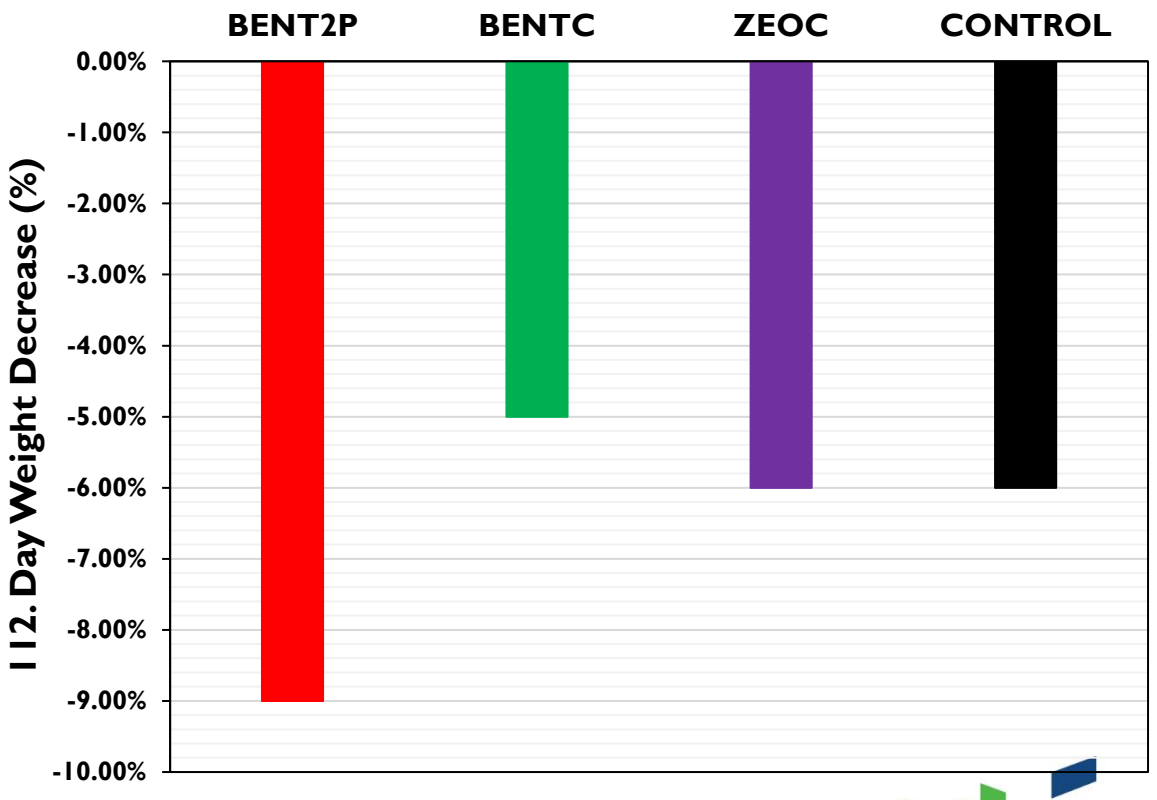


RILEM PEM 25

No Crack Sample
k=0.003±0.0005

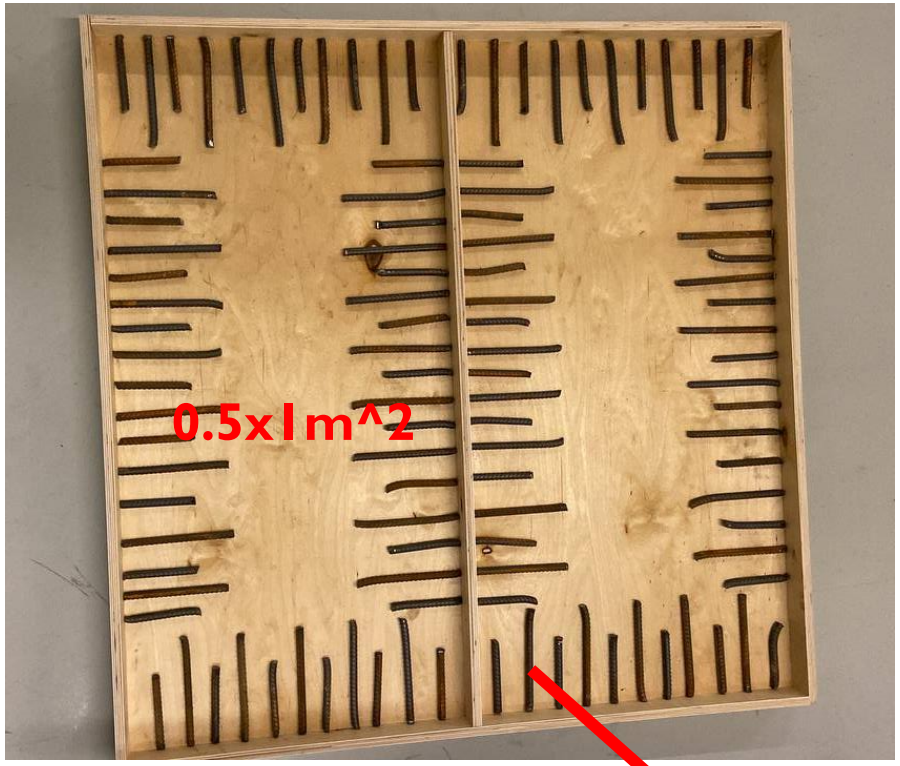
FREE SHRINKAGE

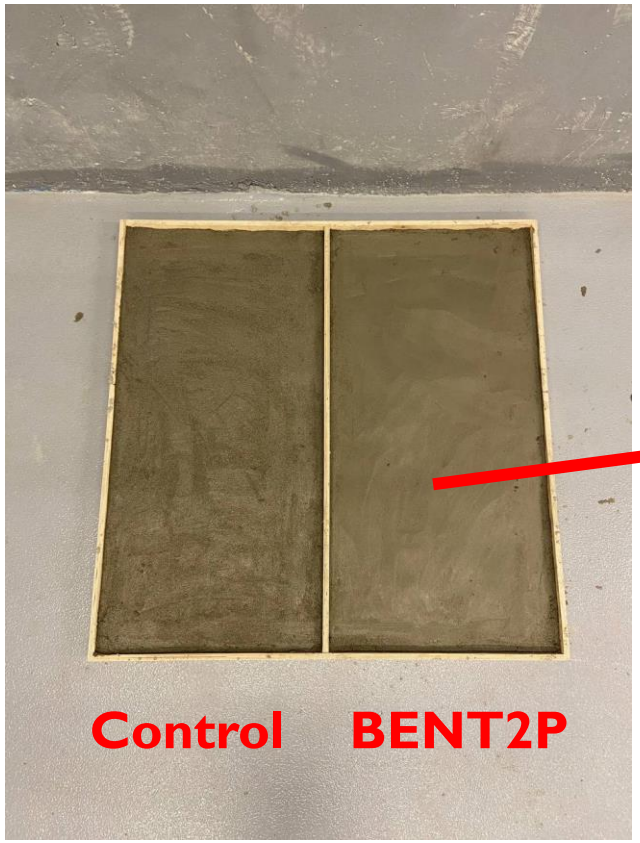


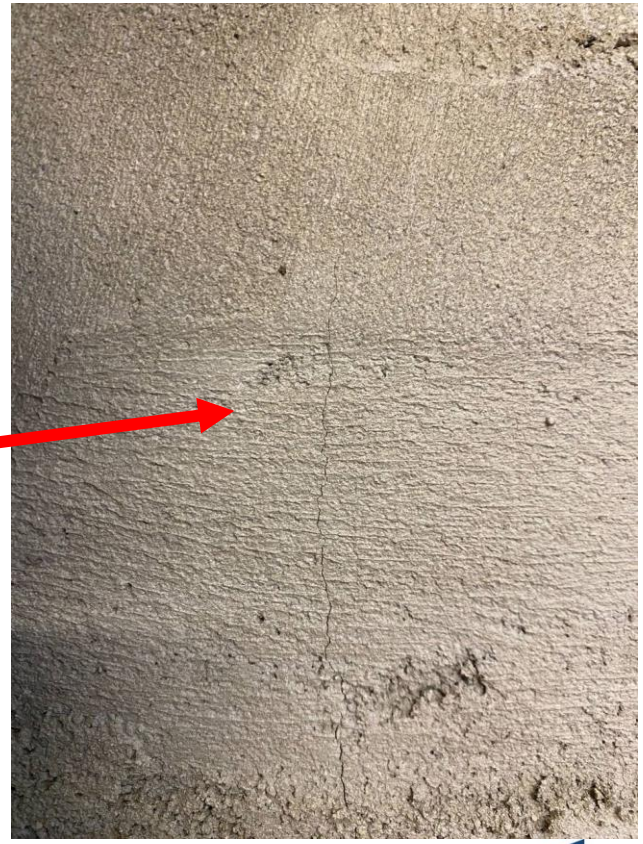


ASTM C596–09–17 & ASTM C157–17

RESTRAINED SHRINKAGE







restraining steel bars

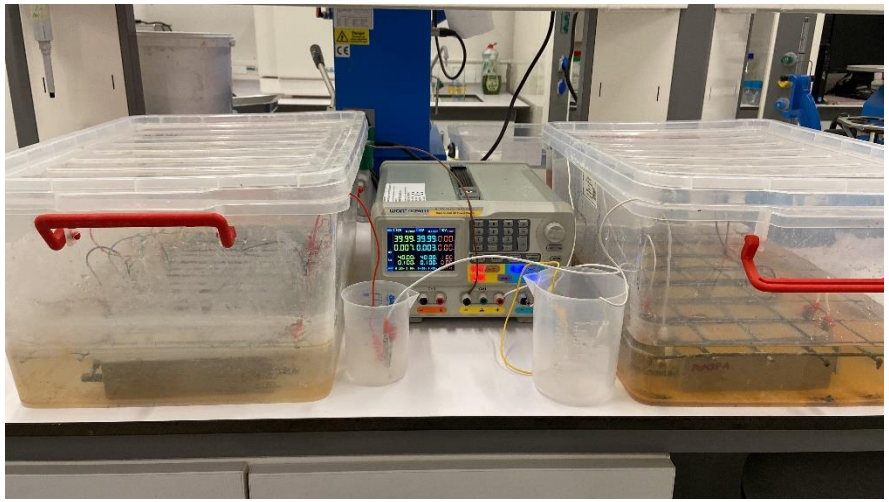
Yokoyama, K. Hiraishi, S. Kasai, Y. and Kishitani, K., 'Shrinkage and cracking of high strength concrete and flowing concrete at early ages' in Proc. 4th CANMET/ACI International Conference on Superplasticizers and other Chemical Admixtures in Concrete, V.M.Malhotra, editor, ACI SP- 148, American Concrete Institute, (1994) 243-258.

CORROSION

0.4 mm 16 mm depth cracks

14 days ambient conditions, 28 days nutrient medium curing solution (80% crack healing)

40V applied under 3.5% NaCl solution during 7 days



(Achal et al., 2012)

CORROSION

ASTM C876 Half-Potential Test

Pull-out Test

KEY POINTS

- **Bentonite** could be used to **immobilize *S. pasteurii* cells.**
- This methodology could be used for **healing cracks** as wide as **0.4 mm.**
- Water absorption was reduced due to crack sealing. A signifant **decrease in water absorption** can only be achieved if a visual **crack healing of at least 60%** was obtained.
- SEM and FTIR results revealed mostly **calcite** was the main polymorph through biomineralization cracks.

KEY POINTS

- **Clinoptiolite zeolite** was found to be **reactive** and efficient to heal cracks even without the incorporation of bacteria cells.
- At **high pH** reduced the reactivity of zeolites.
- Zeolite was **not suitable** bedding for the bacteria cells.

FUTURE WORK

- Adapt a new method for **corrosion** testing.
  - Chloride induced corrosion
  - Carbonation induced corrosion
- **Field application**
  - Industrial application of the system for insulation plaster (4 mm>)

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FTIR analysis was conducted in Faculty of Engineering and Natural Science laboratories of Sabancı University, Istanbul.