



Use of Admixtures for Long Term Durability with Type 1L Cement

Life with Type 1L: Cement in Practice
AIA Spokane and Associated General Contractors, Spokane WA
March 5, 2026



SMART CONCRETE®



Quick Note on Terminology

- GU or Type I or PC
- Regular Cement



- GUL or Type 1L or PLC
- Portland Limestone Cement



This time there may be no going back

Measuring Sustainability

- Environmental Product Declarations (EPD's)
- Estimates the lifecycle environmental impact of a material.
- Many impacts are estimated.
- Top focus = Global Warming Potential (GWP)
 - Expressed in **kg-CO₂-equivalent** for the material.
- The CO₂ (“energy”) required to extract, manufacturer and transport the material.

Environmental
Product
Declaration



**NRMCA MEMBER INDUSTRY-AVERAGE EPD FOR
READY MIXED CONCRETE**



Environmental Product Declaration

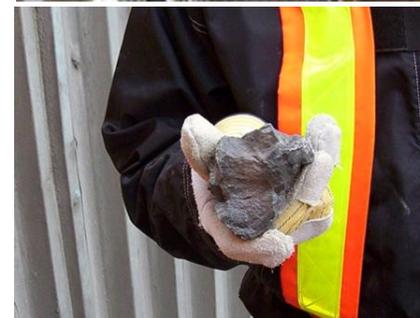
Global Warming Potential

- NRMCA – Industry Benchmarks for Concrete (2021)
 - 4000-5000 psi mix:
 - GWP **220-358** kg-CO2-eq per cubic yard
- Cement (per ton) **919 (GU-I)** **844 (GUL/1L)**
- Aggregates (per ton) ~10
- Admixtures Varies, but small

Cement is the **naughty** ingredient for GWP 🙅🏻👎

Fly Ash & Slag have low GWP compared to cement, but we still need cement

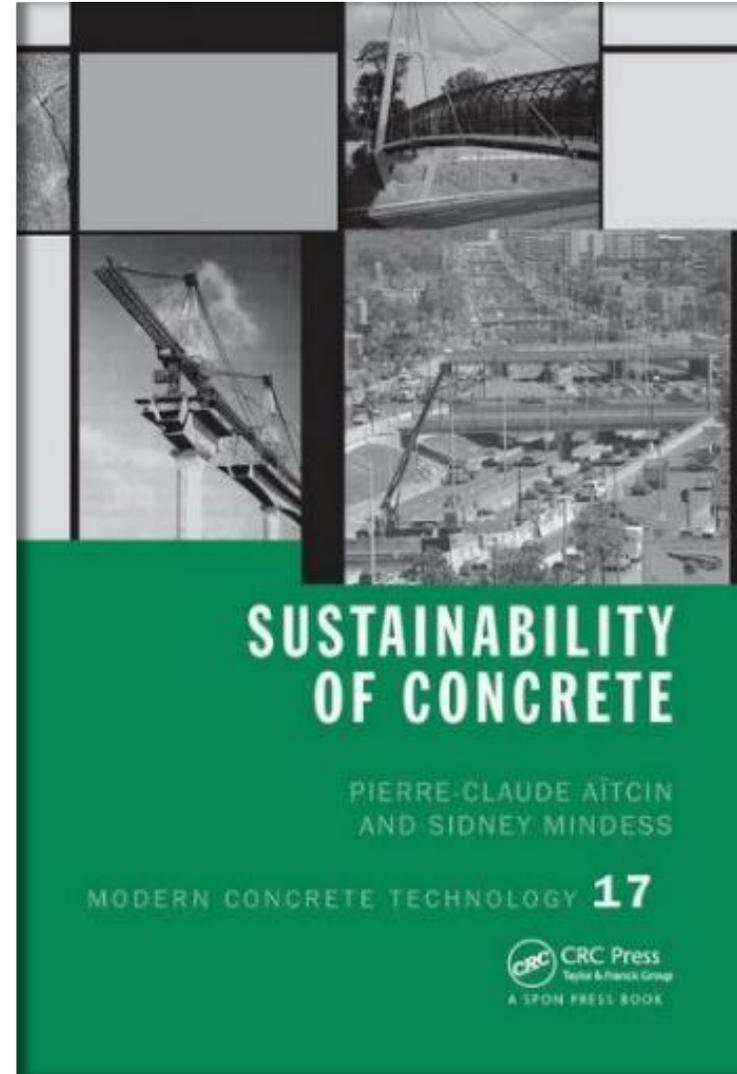
Big Emitters like cement plants are under pressure to reduce their emission, and PLC helps them do it.



But Durability is Still Important

“Probably the most effective way of making concrete more sustainable is to increase its effective service life.”

- *-Sustainability of Concrete
Aitcen and Mindess, 2011.*

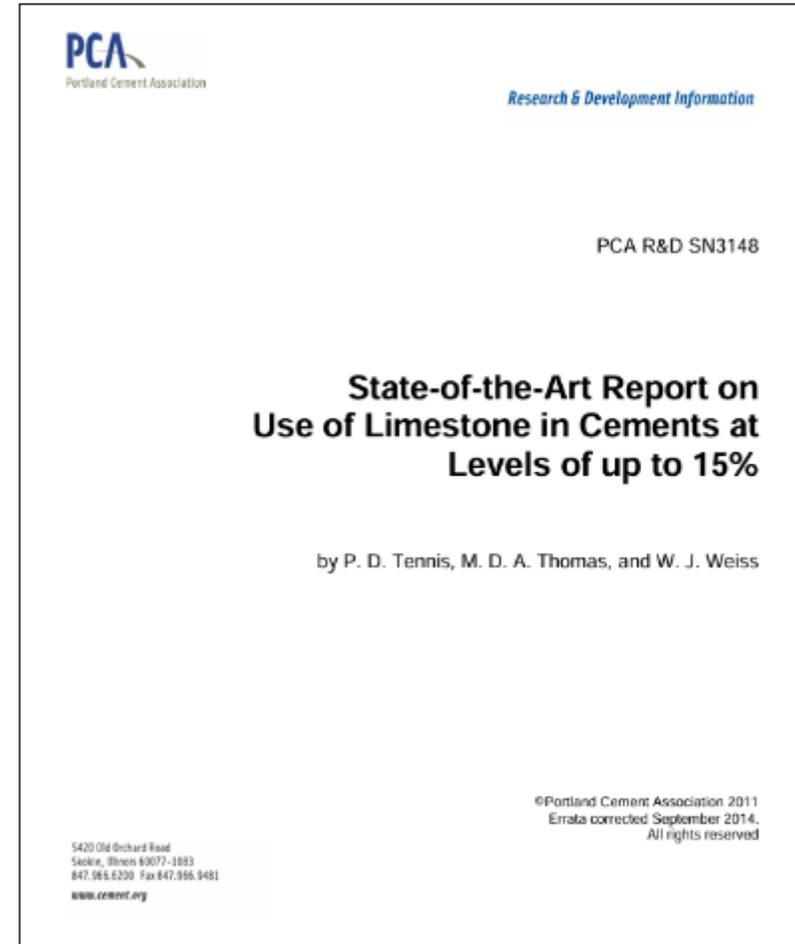




Abrasion and Wear Resistance

Abrasion Resistance with 1L Cement

- States PLC vs. PC abrasion resistance is comparable, but...
- The data indicates ~8% greater wear depth for PLC (15% limestone) compared to PC concrete.



Other Studies Show Greater Differences

- THE UNIVERSITY OF NEW BRUNSWICK (THESIS), April 2010

Mix	28 Day Strength (psi)	35 Day Abrasion Loss (g)
PC	4280	1.5
PLC-15%	4810	2.1

~30% less wear for PC

- 600 lb cement/cubic yard, 0.45 w/c
- ASTM C944, Rotating Cutter, 200 rpm, 20 kg load

Field Experience with PLC

Plastic Concrete

- Higher water demand
- Less bleed water
- More crusting
- Generally, more difficult finishing

Hardened Concrete

- Greater Dusting
- Reduced Wear Resistance

ACI-ASCC Survey on Portland-Limestone Cement Concrete

Summary of responses and comments

by James Kilger, Kevin A. MacDonald, Jerry A. Holland, Scott M. Tarr, Beverly A. Garnant, and Bruce A. Suprenant

The transition from Type I portland cement (also referred to as ordinary portland cement [OPC]) to Type II portland cement (also known as portland-limestone cement [PLC]) is well underway. The change has prompted many discussions among industry professionals in the United States. Unsurprisingly, the topic has been raised in many committee meetings at ACI Concrete Conventions.

At the Spring 2022 convention in San Francisco, CA, USA, Kevin MacDonald, Chair of ACI Committee 302, Construction of Concrete Floors, proposed a survey to gather information on contractors' experiences with PLC concrete. Beverly Garnant, Executive Director of the American Society of Concrete Contractors (ASCC) at the time, volunteered ASCC's assistance in the development and evaluation of the survey; and we, the co-authors of this article, served on the ensuing Joint ACI-ASCC Task Group that developed the survey questions. We also worked with Dean Frank, Executive Director of NEU: An ACI Center of Excellence for Carbon Neutral Concrete, and Michael Tholen, ACI Senior Managing Director of Technical Operations, to refine the questions.

This article presents 15 survey questions and a summary of answers provided by 173 respondents, as well as information from previous PLC surveys conducted by ASCC in March 2023,¹ the Tennessee Concrete Association (TCA) in June 2023,² and the National Ready Mixed Concrete Association (NRMCA) in October 2023.³ Readers are encouraged to evaluate the ACI-ASCC PLC survey data and draw their own conclusions.

Survey Basics

The Joint ACI-ASCC Task Group developed survey questions to gather information regarding the construction of concrete floors and slabs using Type I and Type II portland cement. The following paragraphs discuss survey distribution, sampling methods, and responses.

Distribution

ASCC's staff generated the survey in SurveyMonkey® and provided ACI staff with a URL link. The survey was distributed as an embedded link in the following media:

- Once per week in the Concrete SmartBrief—August 22 through September 30;
- In each ACI eNews—August 24 and September 7; and
- On ACI's LinkedIn and Facebook social media pages—August 16.

In addition, we (the authors) sent emails to our contacts at the Portland Cement Association (PCA), NRMCA, the California Nevada Cement Association (CNCA), and other groups to raise awareness of the survey and to encourage responses. The survey ended on September 30, 2023, with data collected from 173 respondents. While this may appear to be a small response, ACI staff has indicated that the largest previous survey, on the ACI Code 318 reorganization, included data from only 74 respondents.

Sampling

This survey featured nonprobability sampling based on links in emails to ACI members and contacts as well as postings on ACI's social media pages. Respondents had to take it upon themselves to submit responses, so the survey used a combination of convenience sampling and voluntary sampling. In contrast to the results of probability sampling based on random selection from a population, the results of this sampling approach are not suitable for statistical inference, and the results cannot be considered representative of all PLC users in the concrete industry.

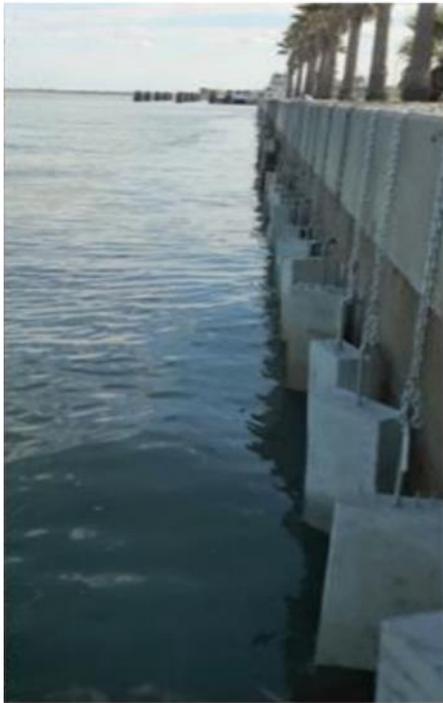
Responses

The survey comprised multiple-choice questions, with each accompanied by a text box for comments. Table 1 summarizes

PLC Corrosion Performance with Abrasion

Laboratory and Outdoor Exposure Site Evaluations of Portland Limestone Cements

University of Texas at Austin, Technical Report 0-6858-1, October 2019



Corrosion specimens hanging from seawall

“...the corrosion potential increases as the limestone content increases.”

The results were “surprising” and contradictory to chloride diffusion coefficients and previous research.

*“PLC concrete systems are more **susceptible to abrasion** that should be expected in marine environments. Abrasion **can lead to a significant decrease in concrete cover and corrosion initiation may occur faster than laboratory tests may indicate.**”*

THE PROBLEM

CONCRETE:
CEMENT, WATER, FINE AND COARSE AGGREGATE

***“cement paste does not
have good resistance to
attrition”***

– the Civil Engineering Handbook

Cement Paste
(approx. 30% of concrete volume)

Aggregate
(approx. 70% of concrete volume)



Effects of Poor Abrasion Resistance



Abrasive Wear
Heavy Industry



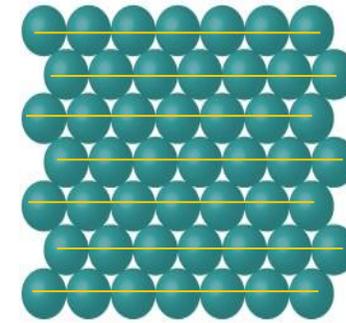
Big Box Retail Slab

Admixture for Integral Abrasion Resistance

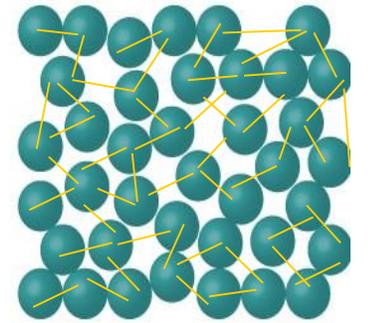
Unique amorphous mineral-metal micro-structure.

Irregular, non-repeating microstructure for durability. Integrates and bonds with cement paste.

Non-rusting and not staining – suitable in wet environments or with air entrained concrete.



Repeating



Amorphous



ASTM C627: ROBINSON FLOOR TESTER



Abrasion Resistance

INTEGRAL HARDENING ADMIXTURE
INCREASE WEAR-RESISTANCE OF CONCRETE



CONTROL CONCRETE



CONCRETE WITH INTEGRAL HARDENER

Erosion/High Pressure Water Resistance

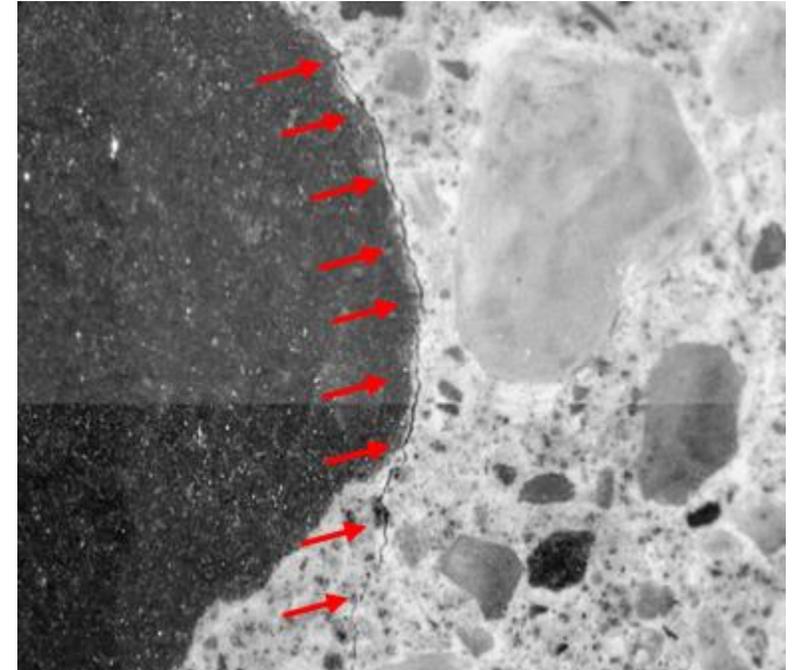




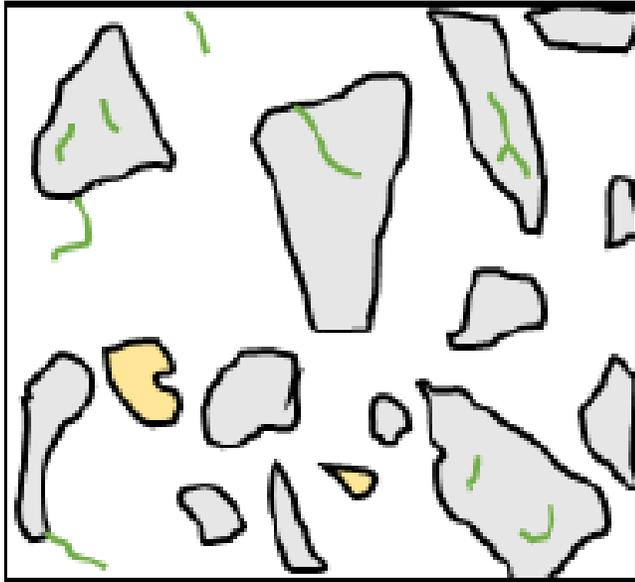
Microcracking and Corrosion Resistance

The Effects on Microcracks on Durability

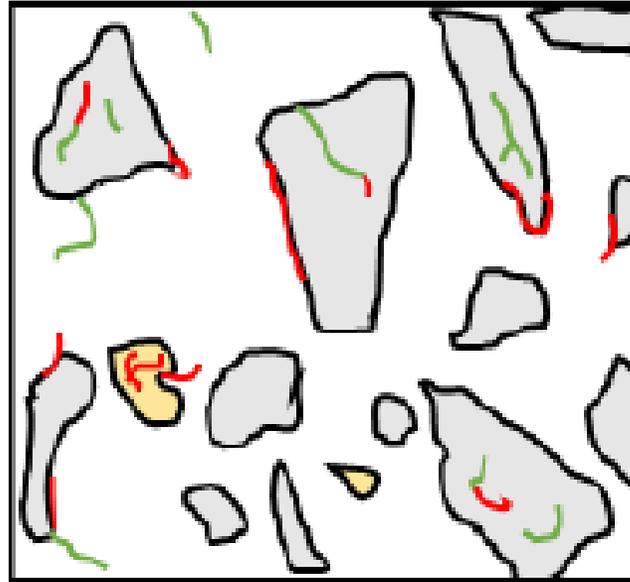
- Weathering and service-related microcracks present a hidden threat to long-term durability that is easy to overlook.
- Microcracks increase permeability and reduce the time to corrosion but have a small effect on compressive strength.
- The concrete looks fine and the strength is fine.
- Finer cements like Type 1L can develop more microcracks, especially in the aggregate interface zone.



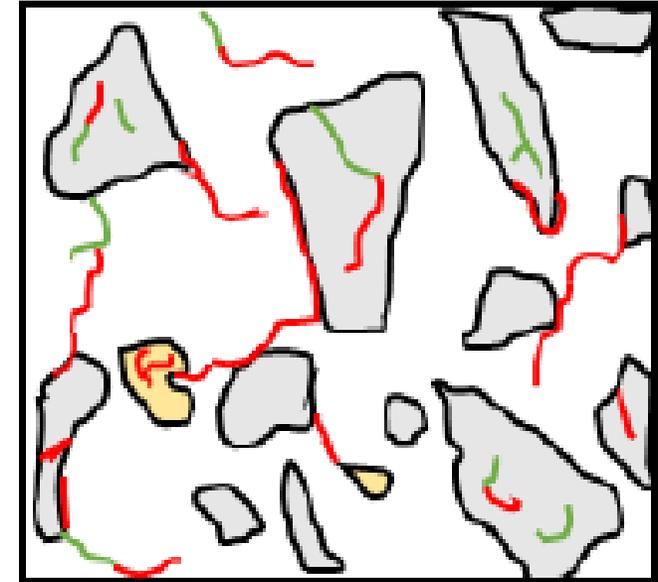
Microcracking and Durability



Initial



Early Propagation



Late Propagation



Loading, restraint and weathering during service

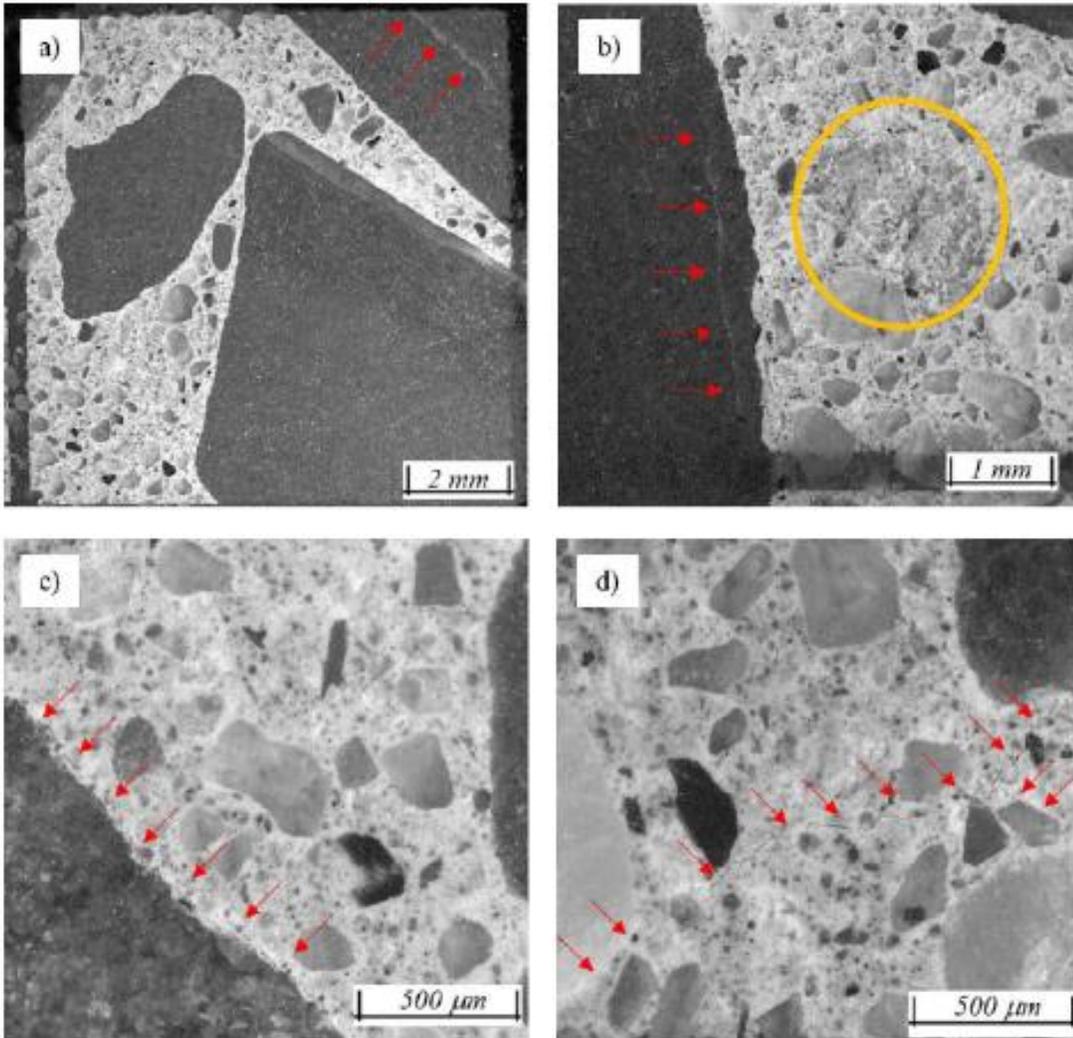
Microcracking and Crystalline Self Healing Admixtures

Studied micro-cracking and sealing/healing in concrete.



uOttawa

Research Methodology



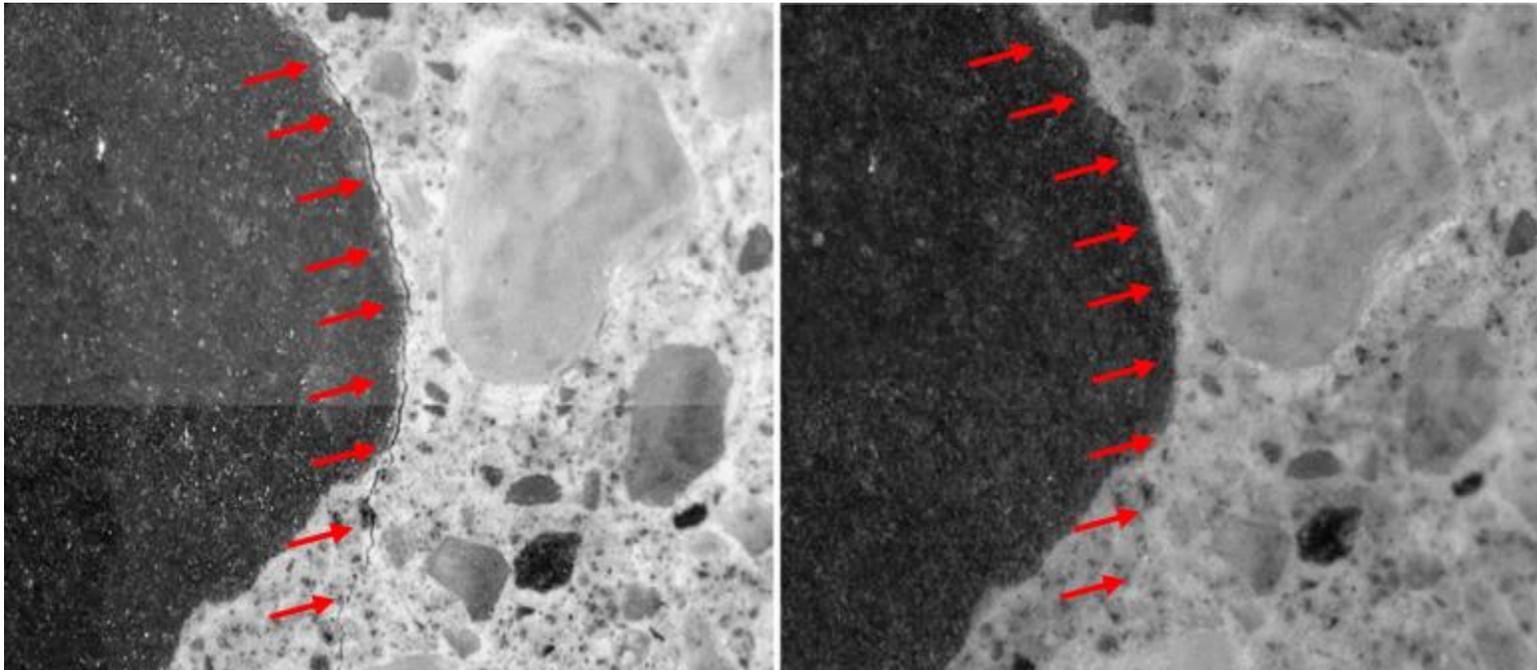
Samples pre-loaded (PL) up to 90% of strength after 28 or 180 days of curing.



Microscopic analysis of micro-crack features.
Mechanical Testing.

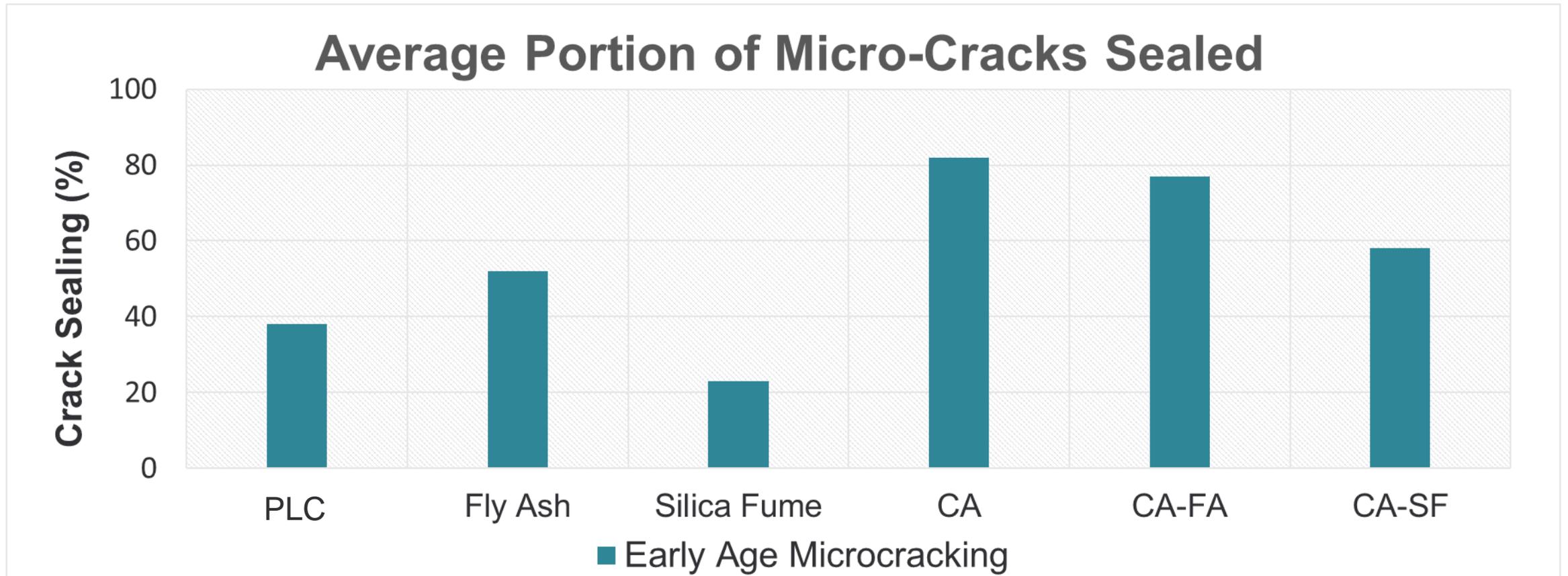


Re-evaluated after 90-days sealing/healing

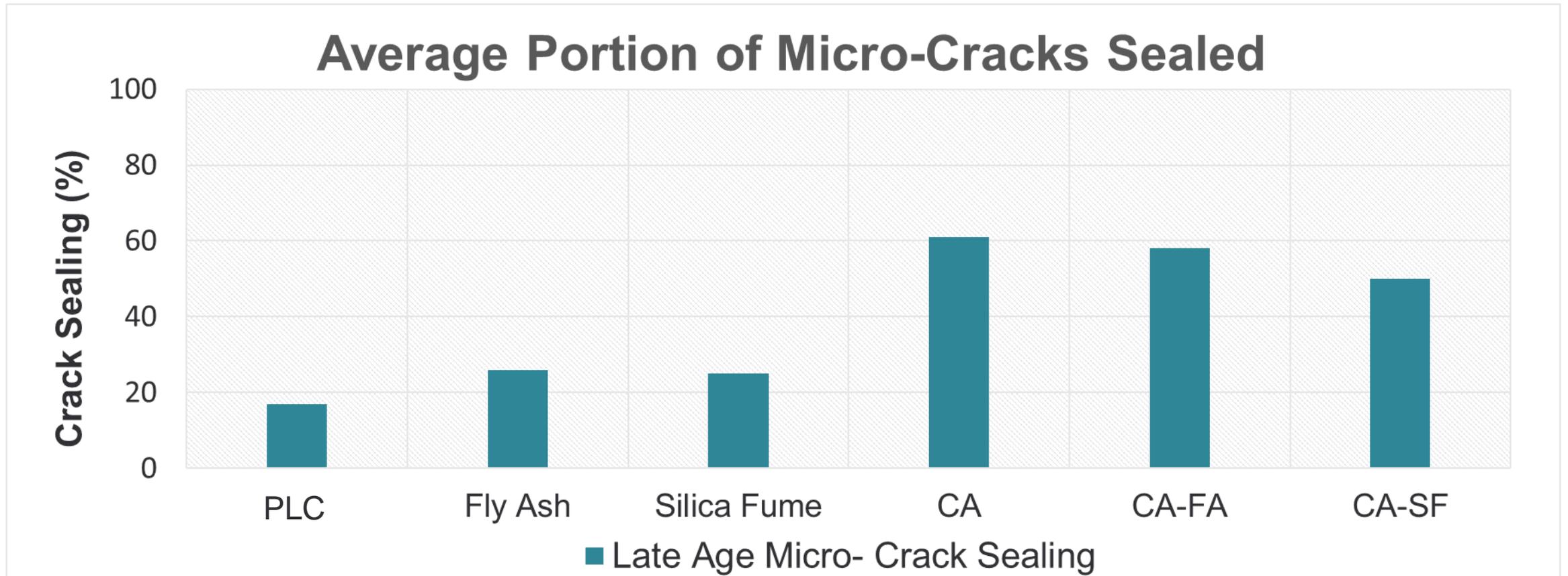


Microscopic observation of the sealing-healing
Left: Just after pre-loading. Right: After 90 days curing.

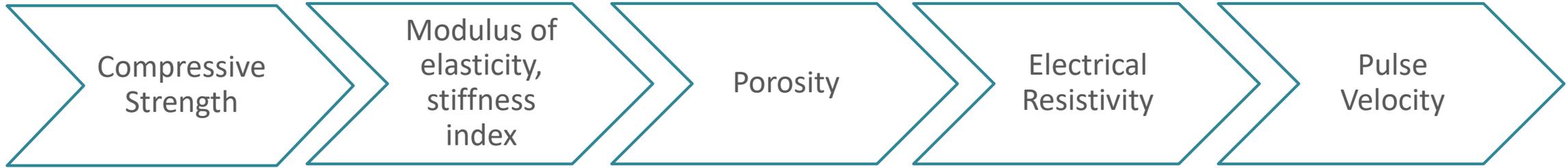
28 Day Sealing Results



180 Day Sealing Results



Mechanical Testing – Recovery Ratio (Healing)



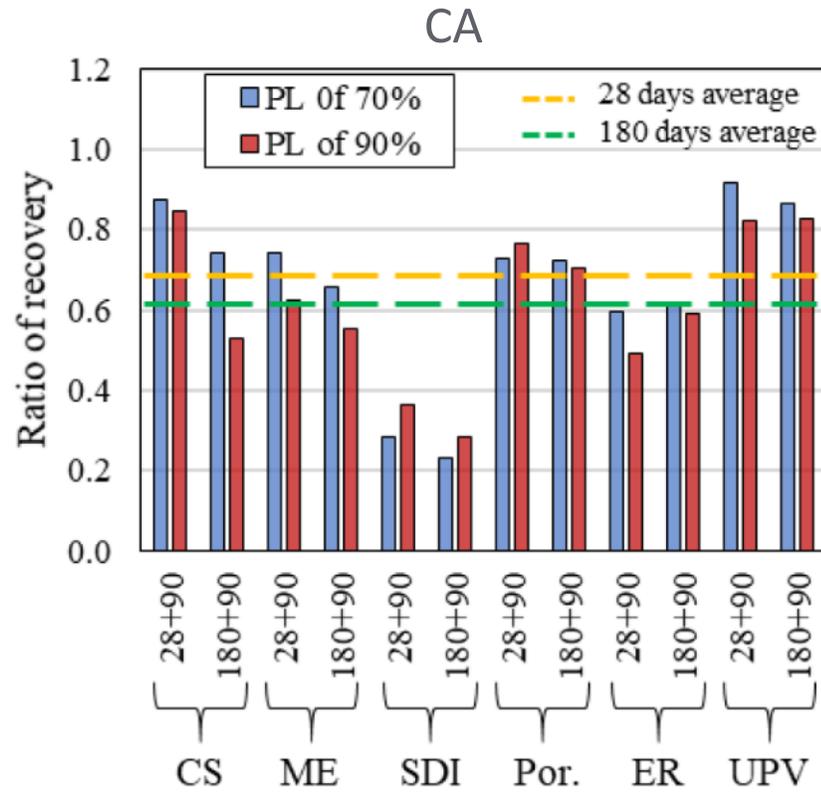
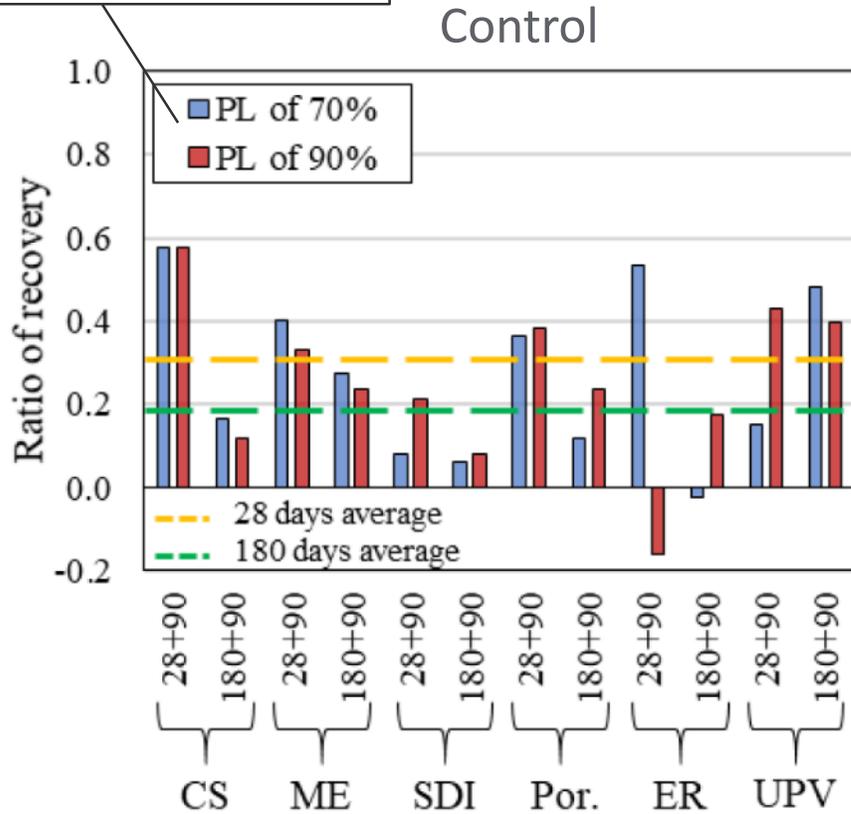
$$\text{Ratio of Recovery (RR)} = \frac{\# \text{ Damage}_{(\text{initial})} - \# \text{ Damage}_{(\text{after healing})}}{\# \text{ Damage}_{(\text{initial})}}$$

RR = 0 = No Recovery.

RR = 1 = Full Recovery.

Recovery Ratios with 1L Cement and Healing Additive

Pre-loaded to 70% or 90% of strength to induce microcracking



Improved Recovery (Healing)

Research Findings

Concrete may develop a permeable network of micro-cracks.

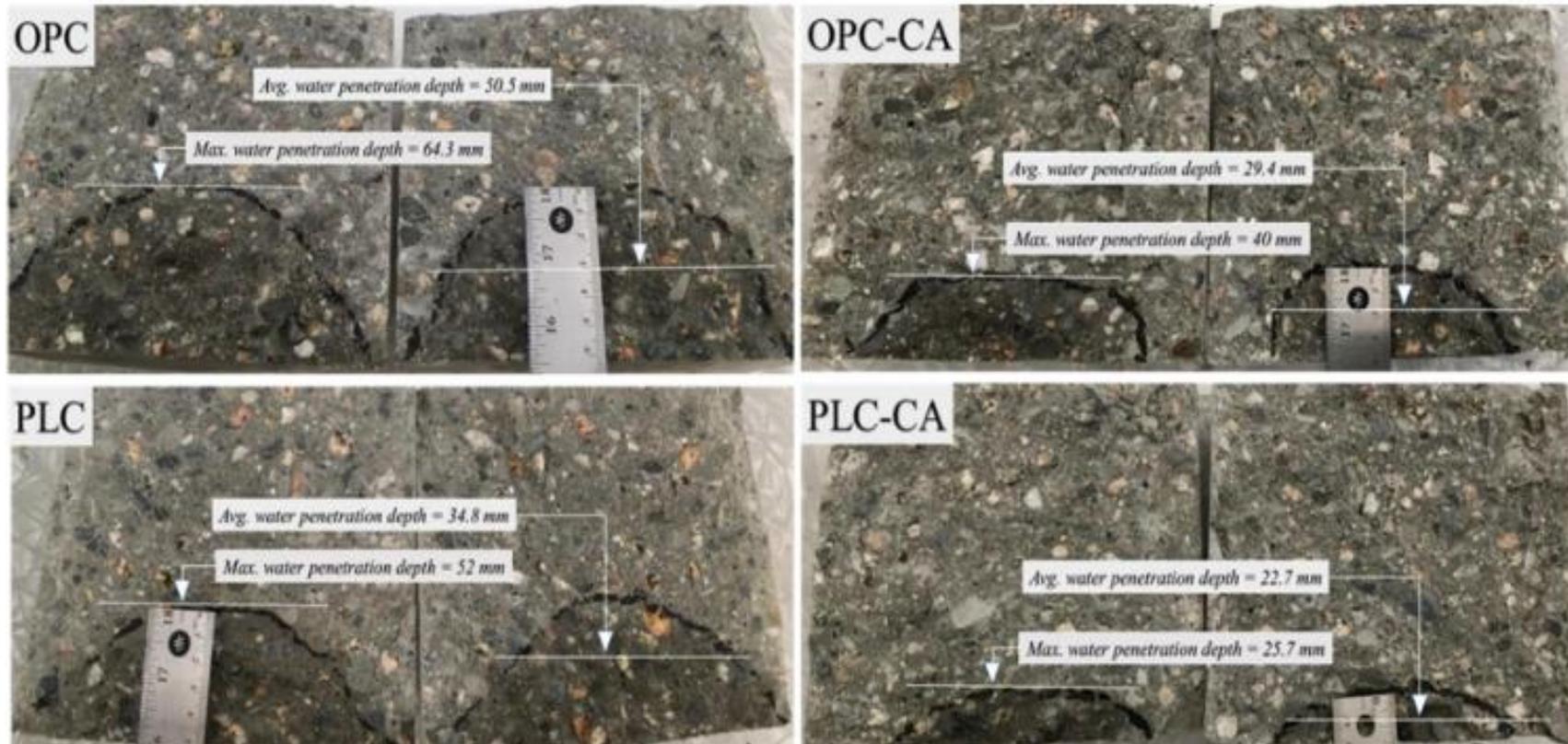
Concrete has a limited ability to seal and heal micro-cracks.

Sealing and mechanical recovery (healing) are correlated.

Certain crystalline admixtures enhance sealing and healing properties.

Permeability with Type 1 and 1L Cement

Assessment of self-healing and durability parameters of concretes incorporating crystalline admixtures and Portland Limestone Cement. UVIC, 2019



Lowest Permeability with Crystalline Admixture (CA)

Enhancing 1L Durability Through Admixtures



Admixtures help address specific performance concerns with PLC in certain applications.



Requiring High Abrasion Resistance

Integral Hardening Admixture



Requiring low permeability and corrosion resistance:

Crystalline Permeability Reducing and Sealing/Healing Admixtures



Performance with PLC Concrete has been positive and comparable PC Concrete.

References

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 - Portland Cement Association, 2011, by P. D. Tennis, M. D. A. Thomas, and W. J. Weiss