A PRESENTATION

ON

Multi-Level Assessment of the Influence of Moisture and Temperature in ASR-Induced Expansion and Deterioration

BY:

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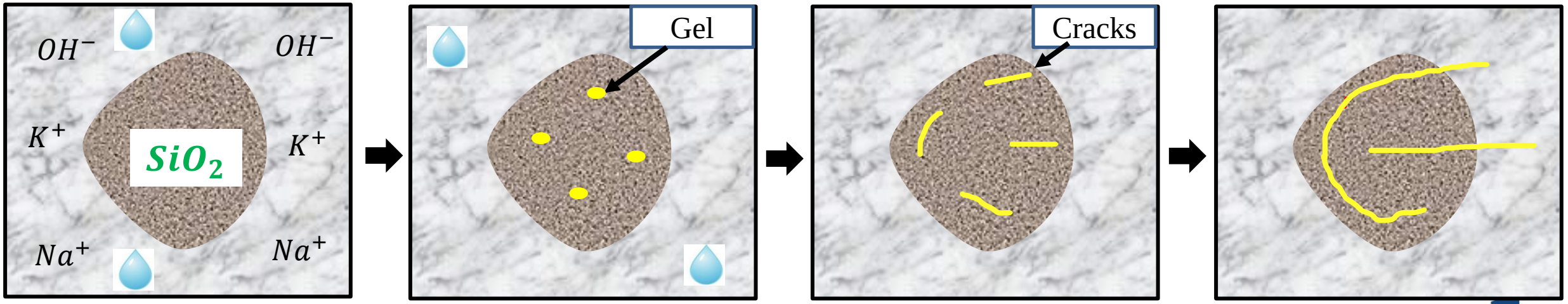
INTRODUCTION – Alkali Aggregate Reactions

Alkali Aggregate Reactions (AAR)

- **Alkali Silica Reaction (ASR)**
- Alkali Carbonate Reaction (ACR)



Alkalis + Reactive silica + water

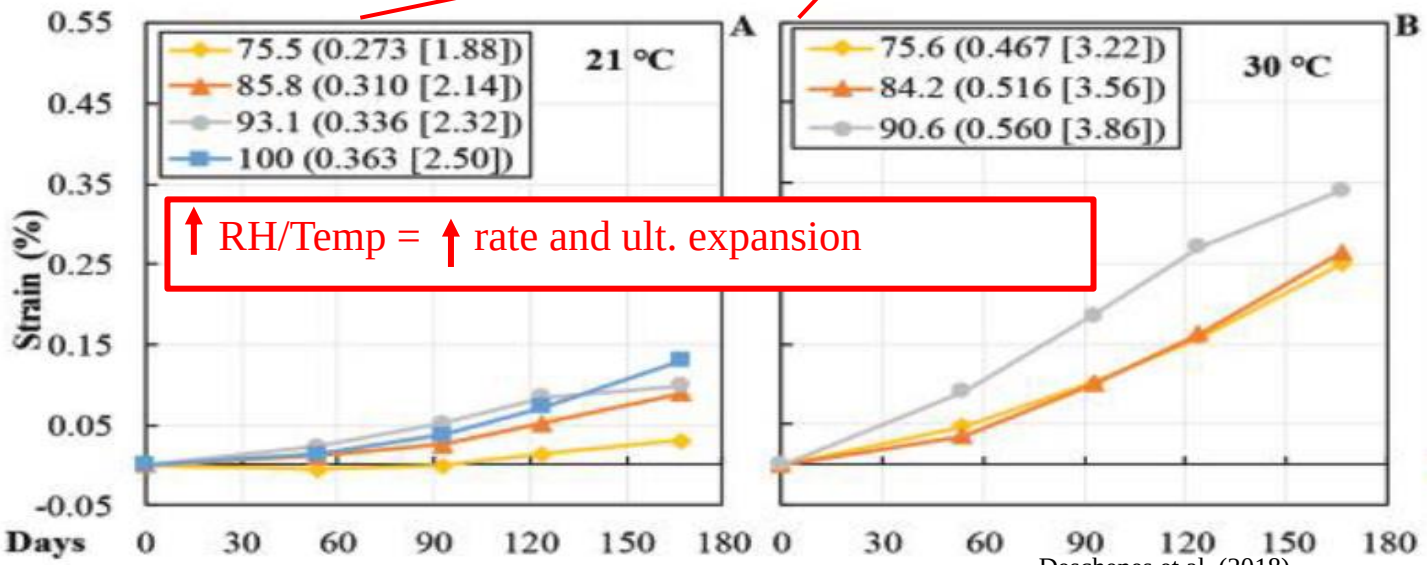
Expansive Gel

Cracking

INTRODUCTION – Role of Moisture and Temperature

- Moisture and temperature improves the development of ASR; Moisture threshold of 80% critical
- Studies has been limited to the use of external moisture
- Most of the studies on role of moisture and temperature only consider on expansion measurements

External Relative Humidity (RH)



Deschenes et al. (2018)

Influence of expansion on internal distress features

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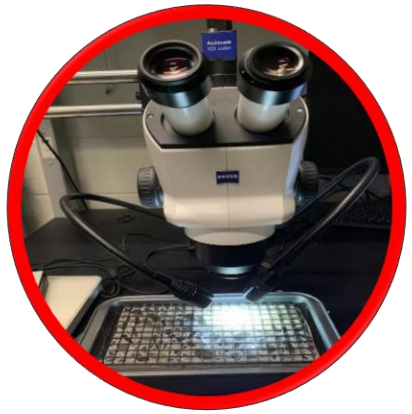
Correlation of mechanical and microscopic properties

Influence of expansion on mechanical losses

Multi-level Assessment Of ASR Induced Deterioration

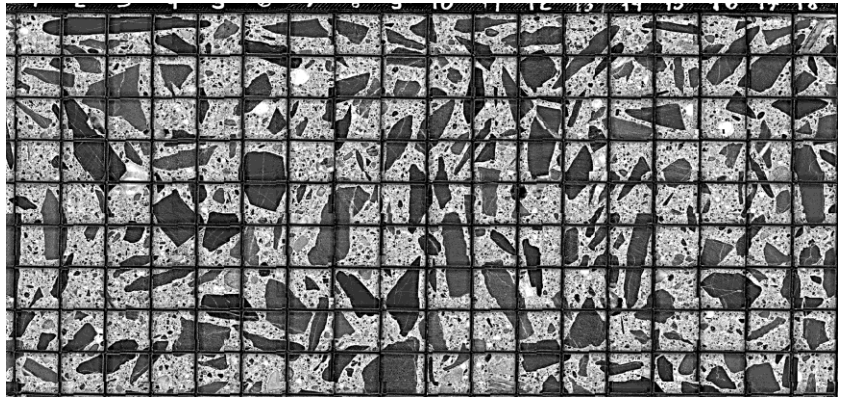
- Damage Rating Index (DRI)
- Direct Shear Test
- Stiffness Damage Test (SDT)



M L A

Damage Rating Index (DRI)

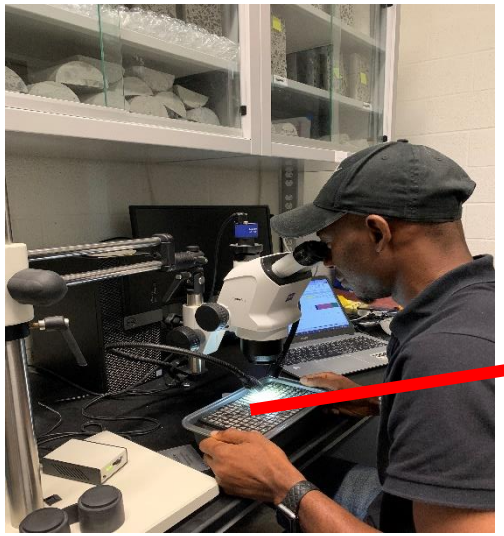
- Semi-quantitative microscopic tool on polished concrete sections
- Performed with a stereomicroscope (15-16x)

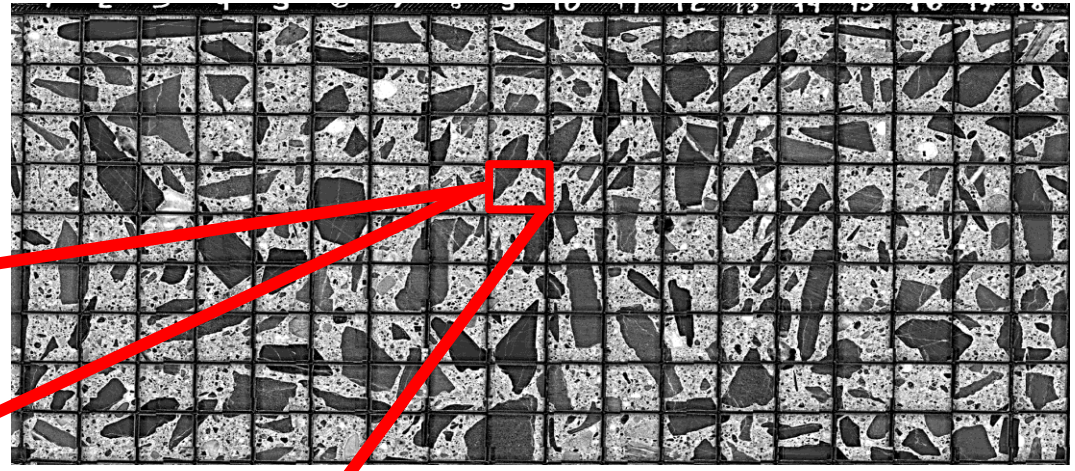


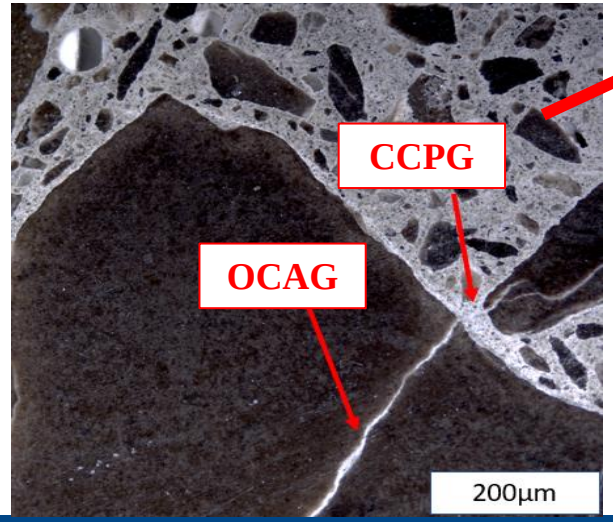
Features	Weighting factors
CCA: Closed Cracks in aggregates	0.25
OCA: Open cracks in aggregates	2
OCAG: Cracks with reaction products in aggregates	2
CAD: Debonded aggregates	3
DAP: Disaggregated/corroded aggregate particle	2
CCP: Cracks in cement paste	3
CCPG: Cracks with reaction products in cement paste	3

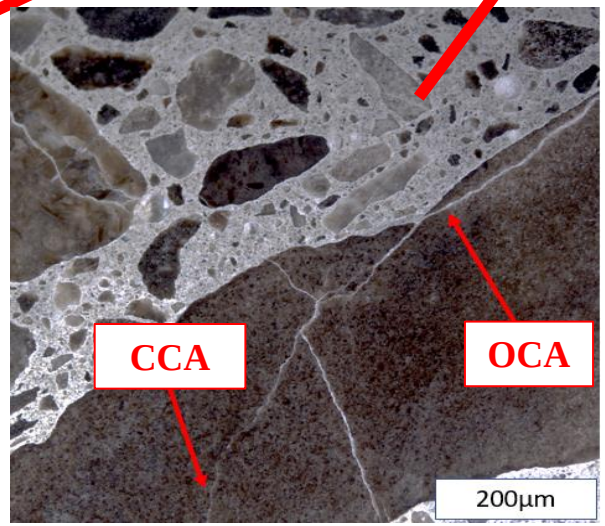
$$DRI = \frac{\sum((0.25CCA) + 2(OCA + OCAG + DAP) + 3(CCP + CCPG + CAD))}{\#\ of\ analysed\ 1\ cm\ by\ 1\ cm\ squares} \times 100\ cm^2$$

Damage Rating Index (DRI)





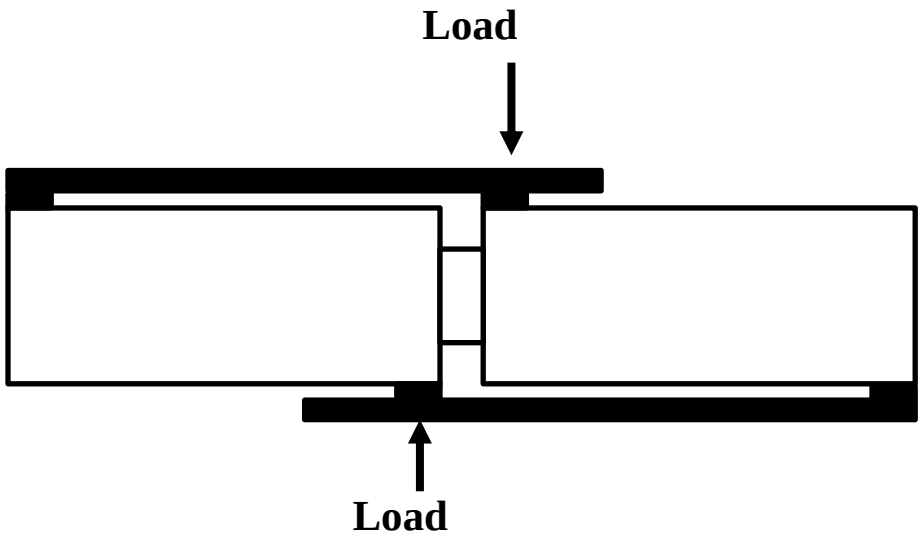


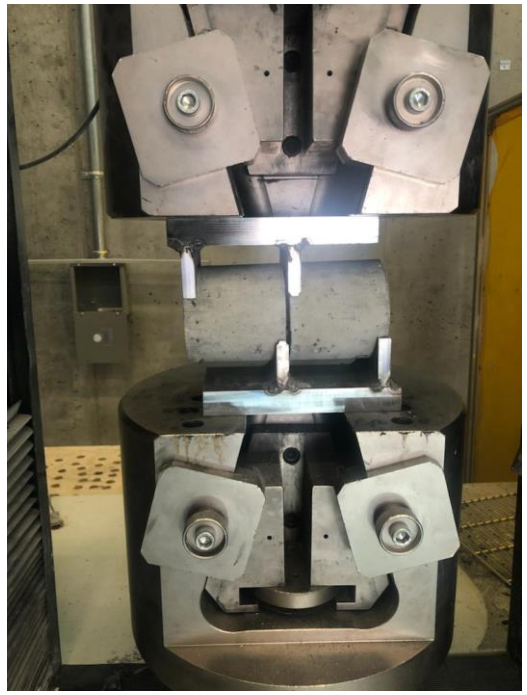


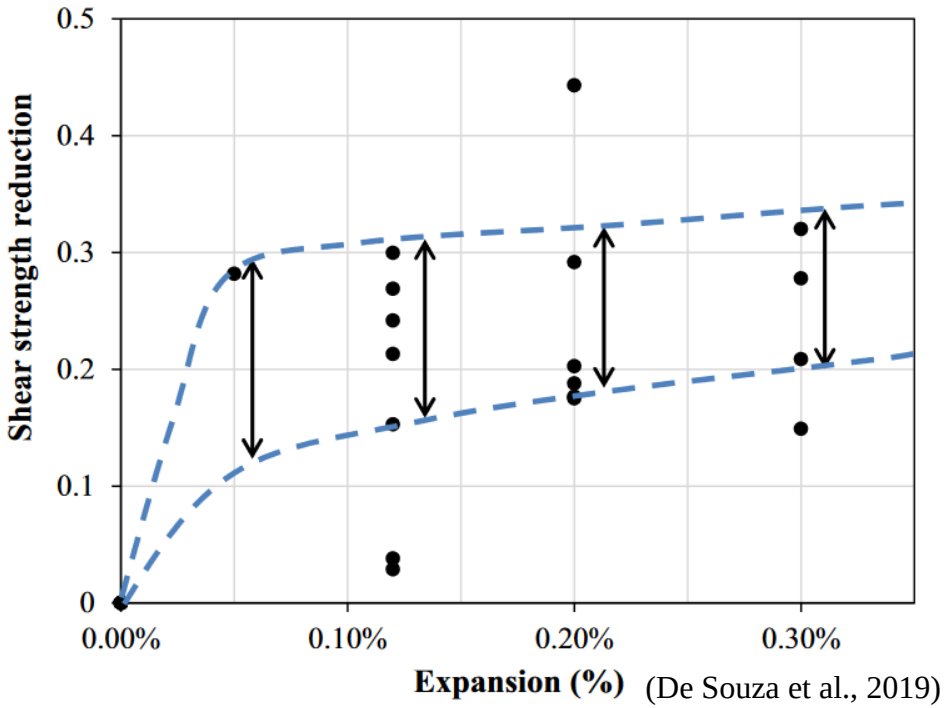
↑ DRI NUMBER = ↑ ASR INDUCED DAMAGE

Direct Shear Test

- Aggregate interlock improves shear resistance
- ASR affects aggregate interlock







(De Souza et al., 2019)

Cylinder size: 100 x 200mm

Notch Width: 5mm, Loading rate: 100 N/s (Ziapour et al., 2022)

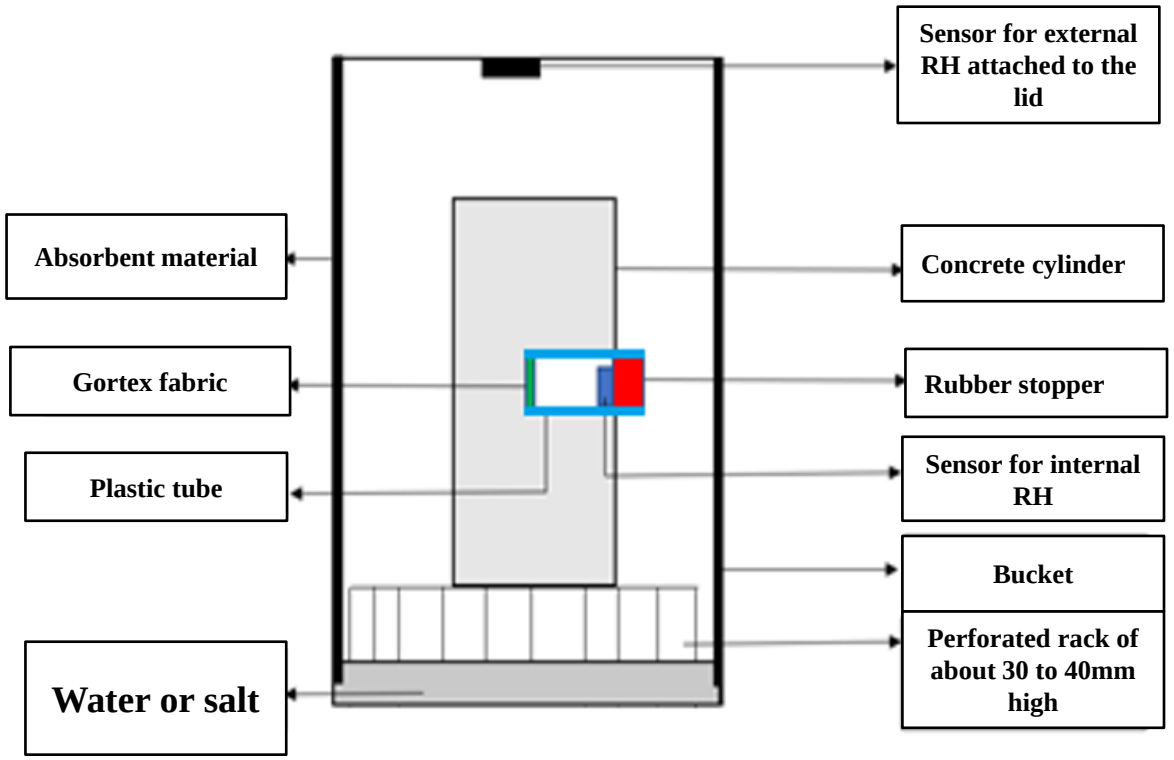
Notch depth: 22 ± 1mm (Barr and Hanso, 1986)

OBJECTIVES

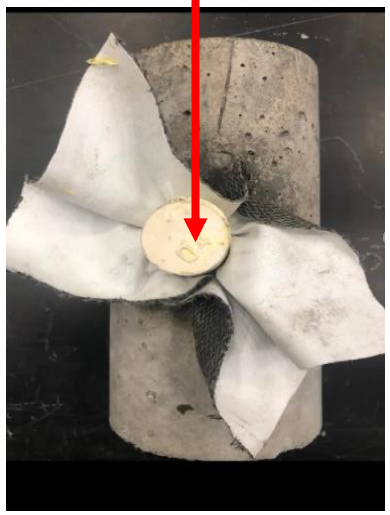
1. Internal versus external moisture and ASR development
2. Influence of moisture and temperature on the kinetics of ASR
3. Microscopic damage features at numerous exposure conditions
4. Mechanical properties loss

MATERIALS AND METHODS – Framework for moisture measurement

1



External RH



Internal RH

MATERIALS AND METHODS

2 3 4

Experimental Program

Spratt coarse

Highly reactive

1.25% Na2eqO

Reference Aggregate

Alkali Level

Temperature

21ºC | 38ºC | 60ºC

Relative Humidity

62% | 75% | 82% | 90% | 100%

Exposure conditions

Tests

DRI

Internal distress

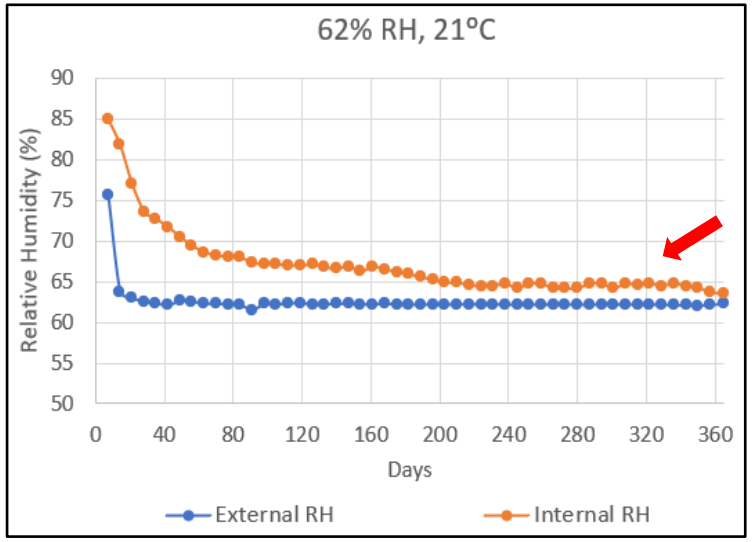
Shear Strength

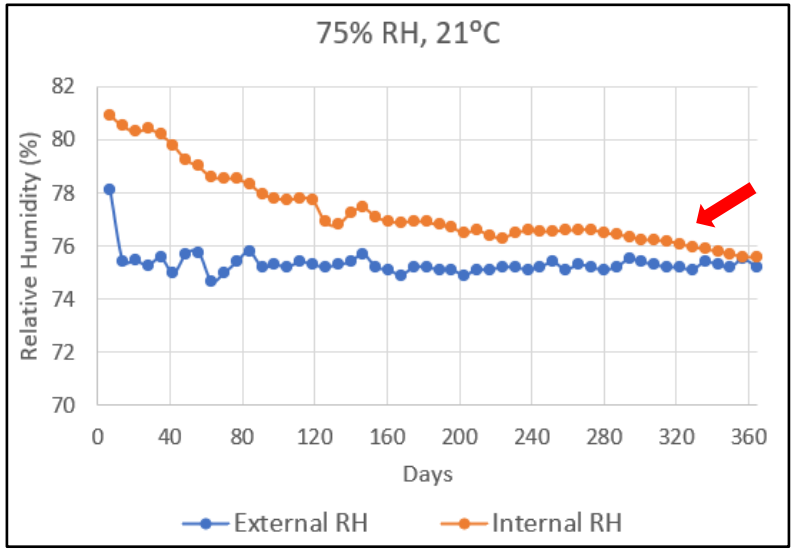
Mechanical property loss

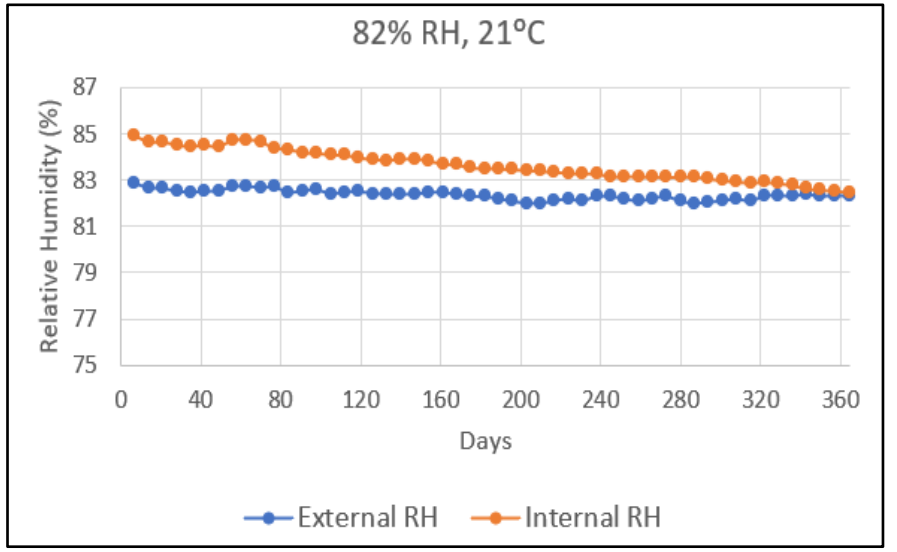
6/12M (21ºC & 38ºC)

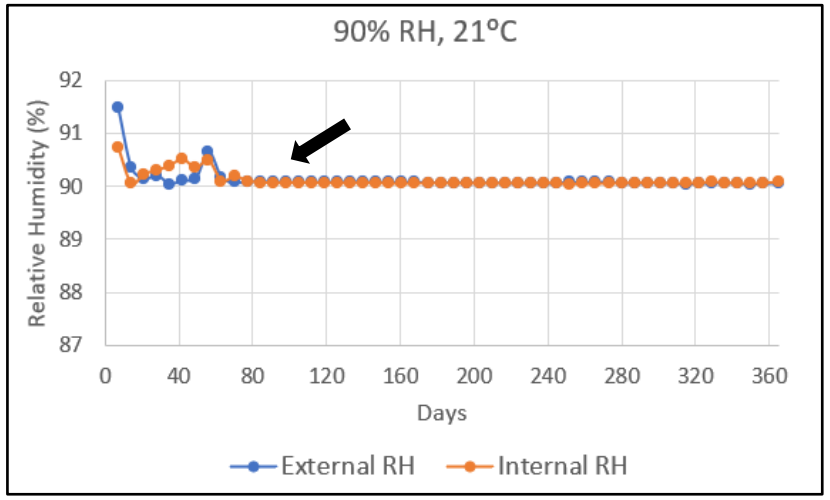
3/6M (60ºC)

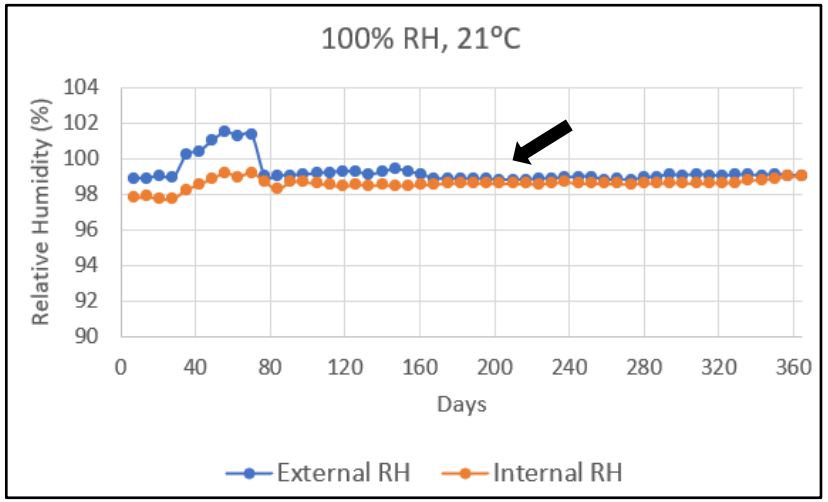
RESULTS AND DISCUSSION - Internal versus External RH







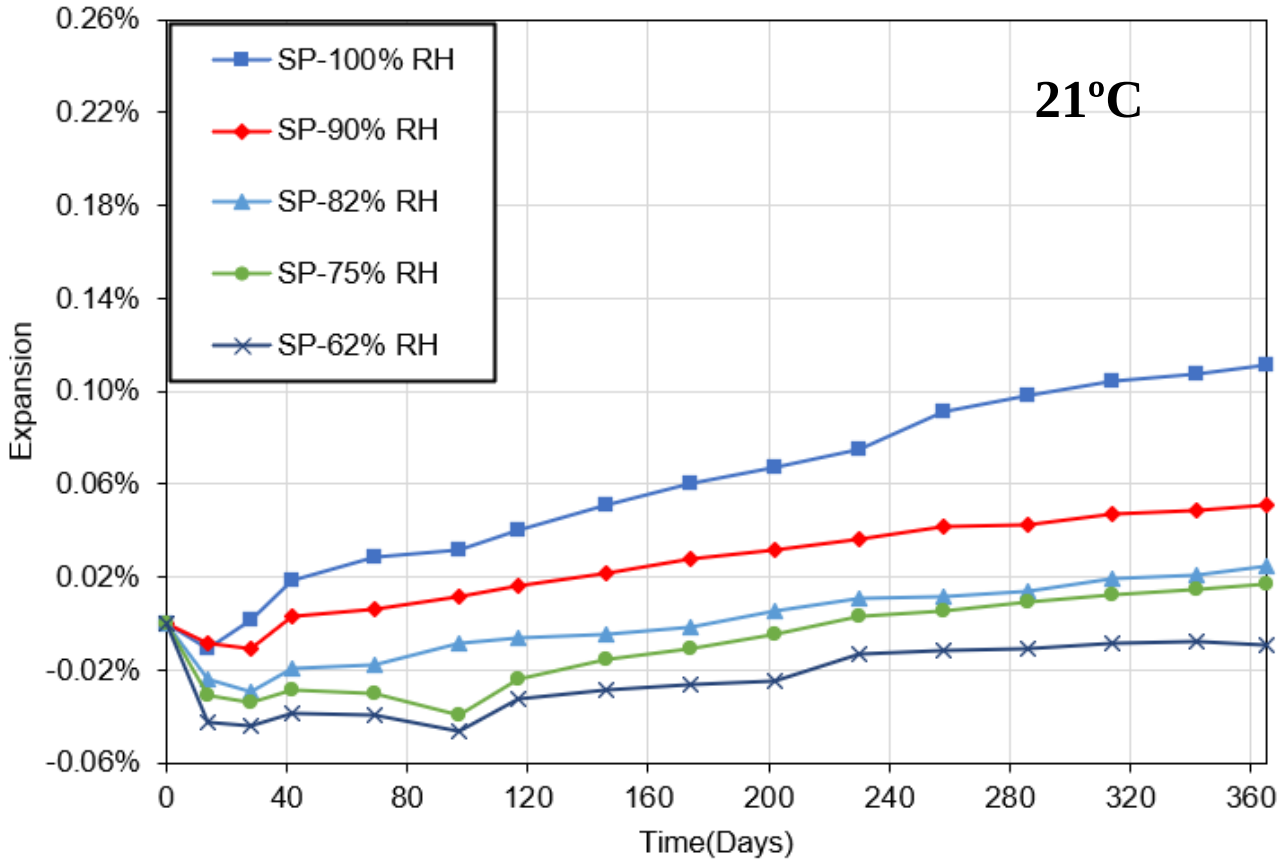




➡ **Equilibrates faster**

➡ **Longer equilibration period**

Kinetics of ASR at numerous moisture and temperature



100% RH

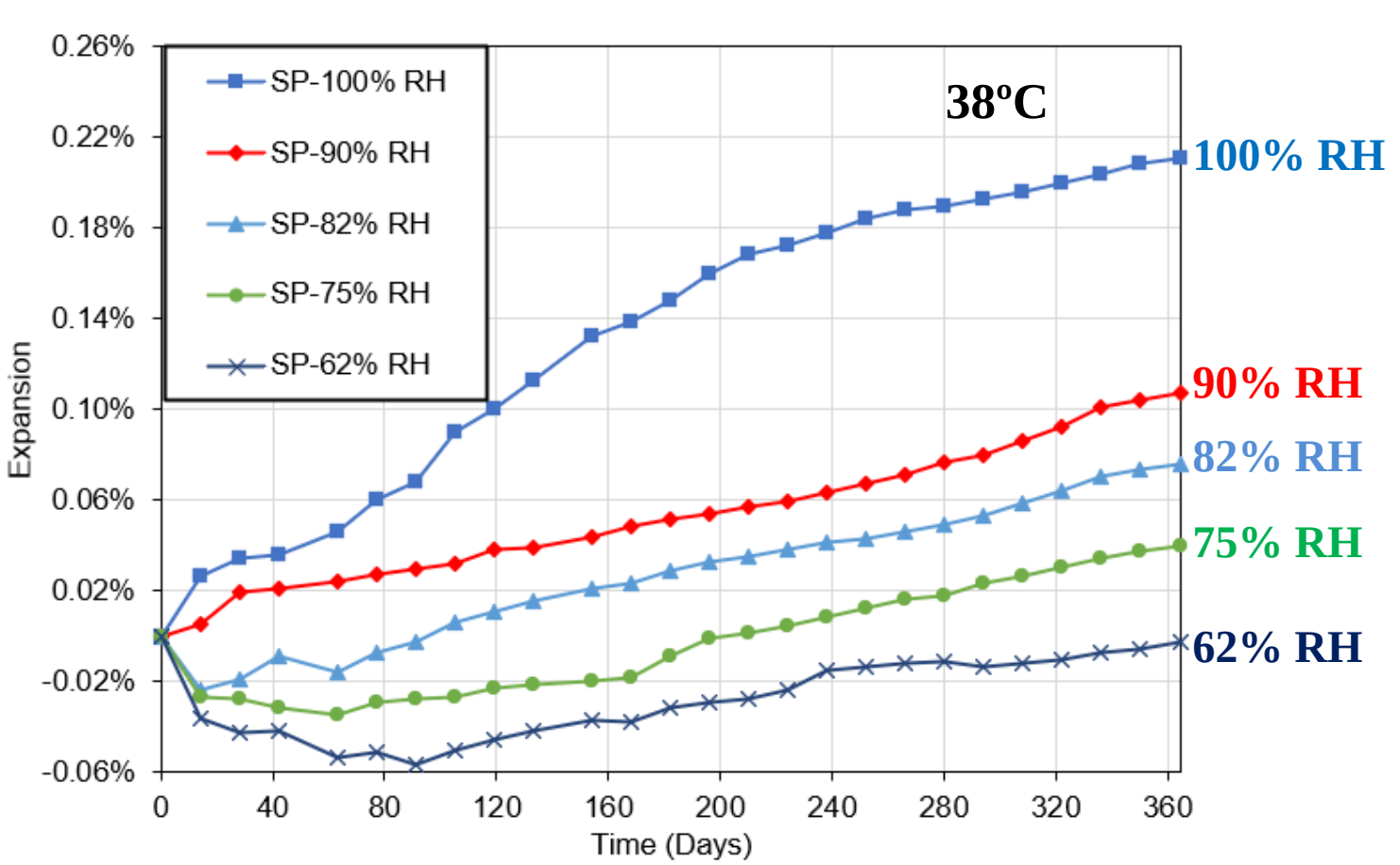
90% RH

82% RH & 75% RH

62% RH

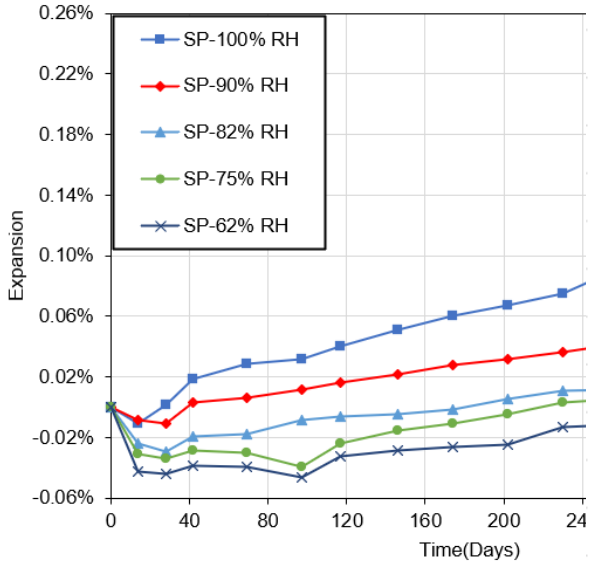
SP: Spratt

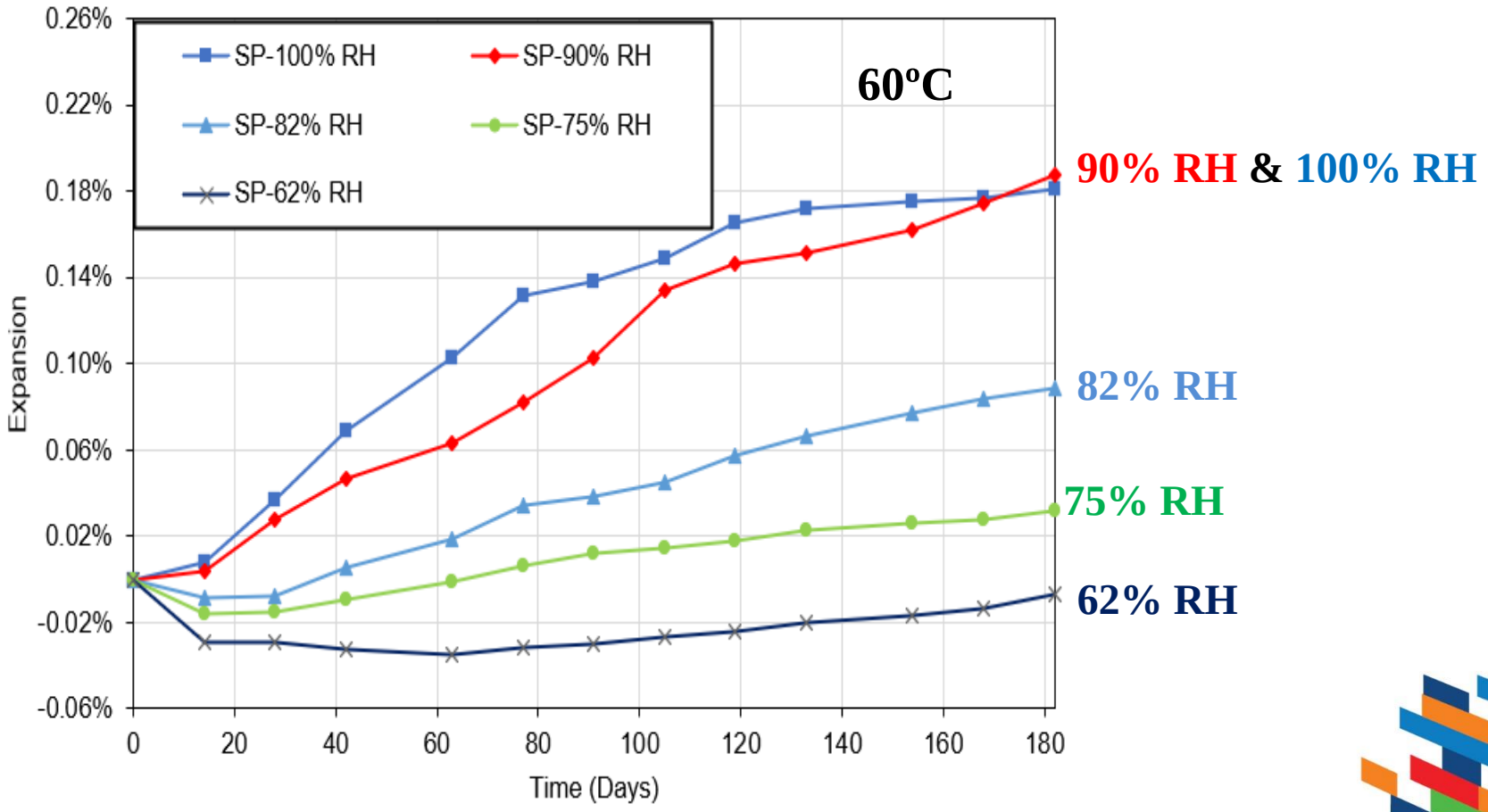
Kinetics of ASR at numerous moisture and temperature



SP: Spratt

Kinetics of ASR at numerous moisture and temperature





90% RH & 100% RH

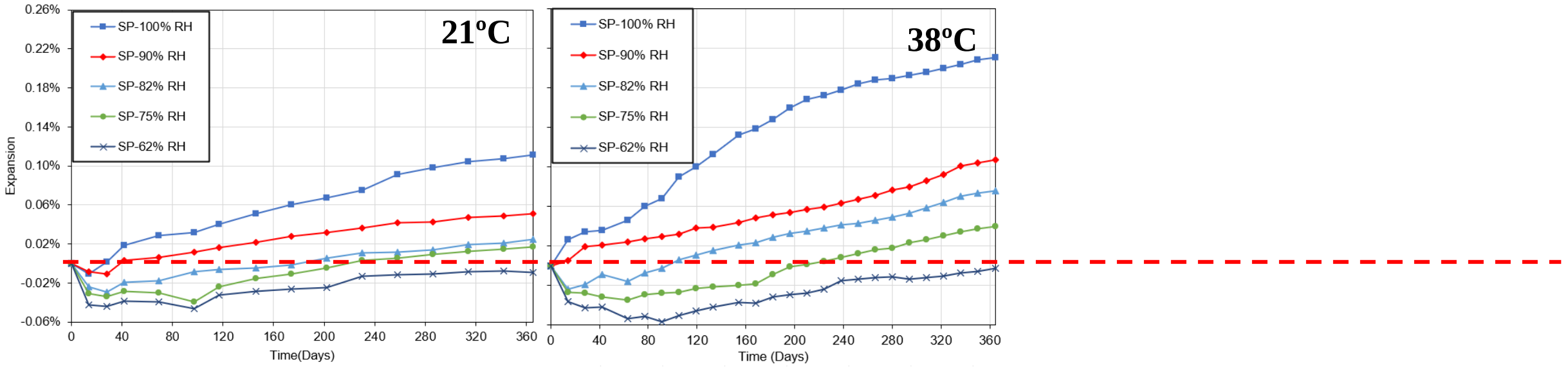
82% RH

75% RH

62% RH

SP: Spratt

Kinetics of ASR at numerous moisture and temperature

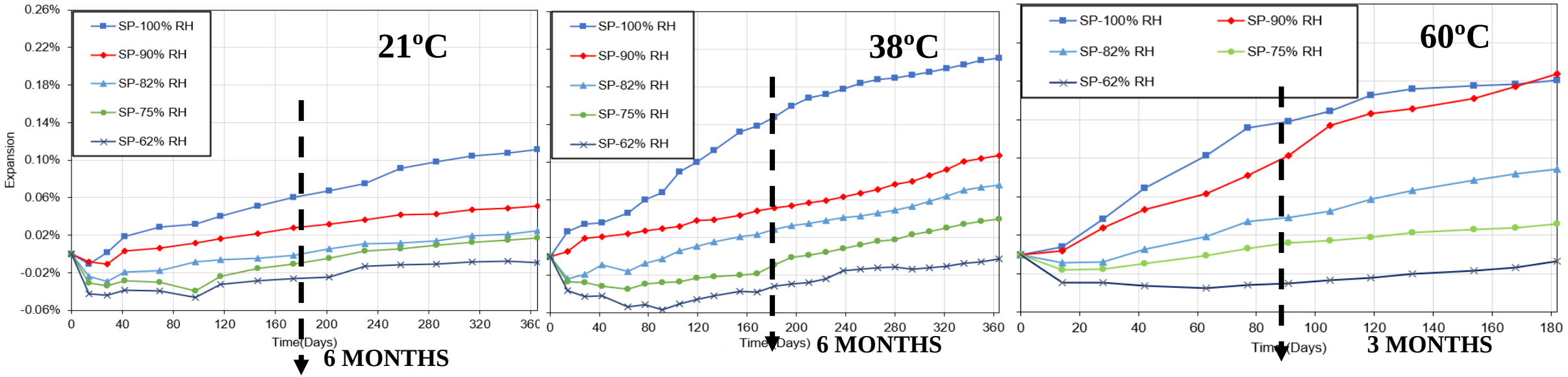


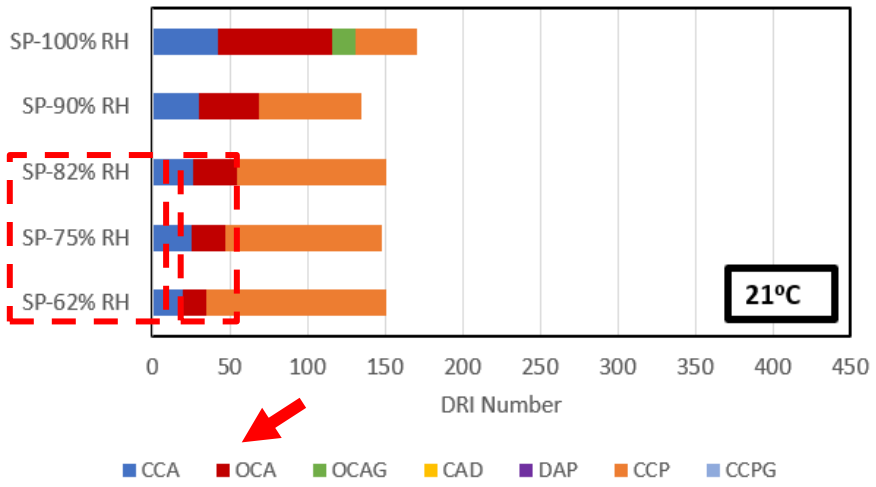
RH ↑ Temperature ↑ = Expansion ↑

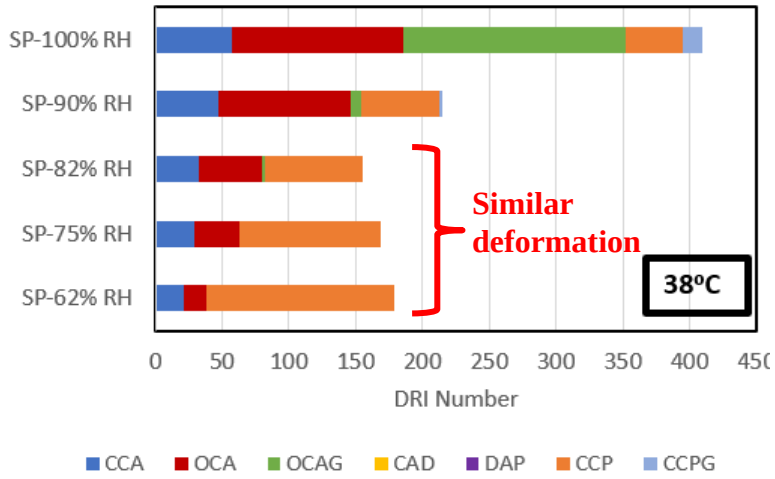
Drying shrinkage ↑ = RH ↓

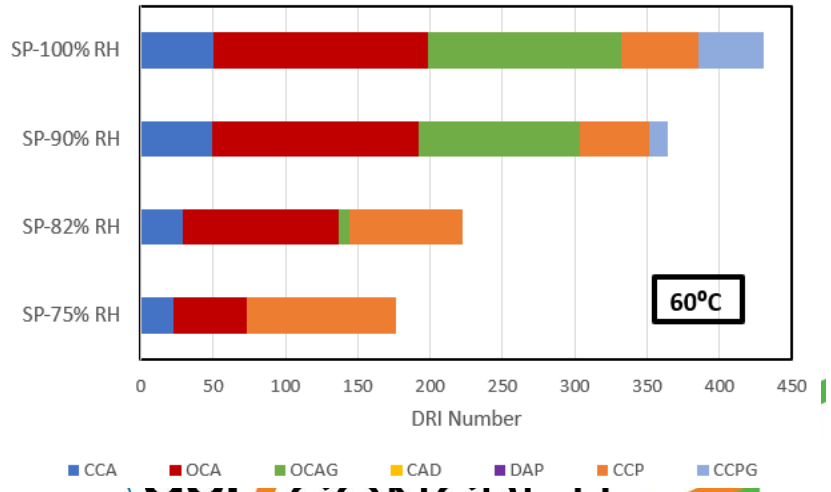
SP: Spratt

Damage Rating Index Results (Spratt Reactive aggregates; SP)

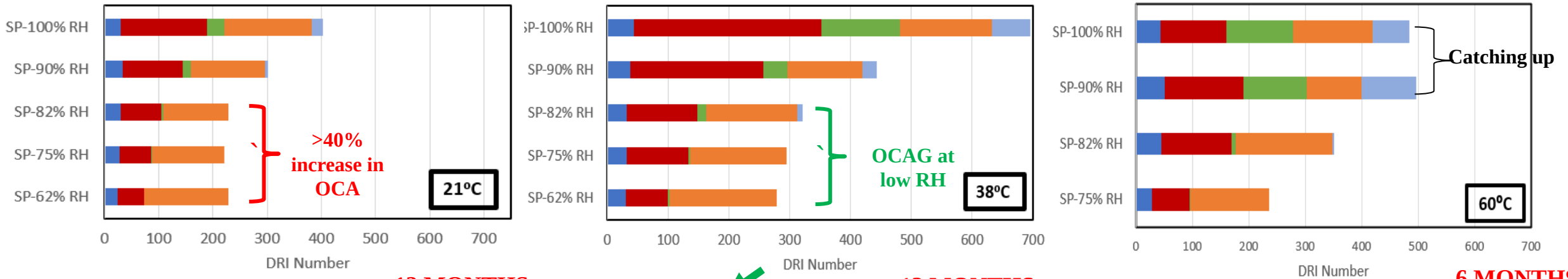


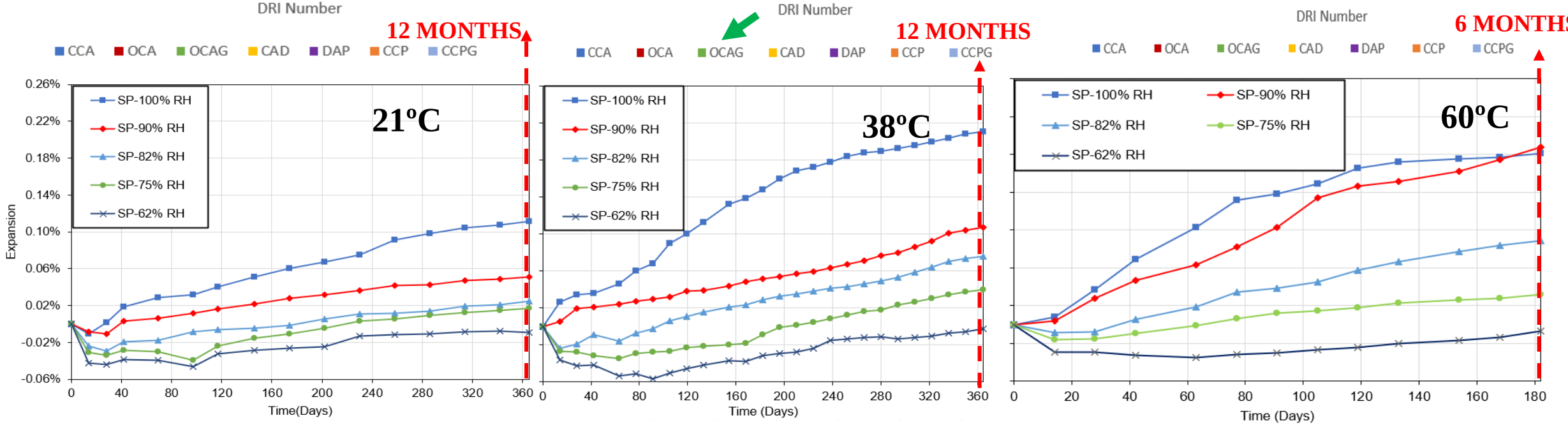




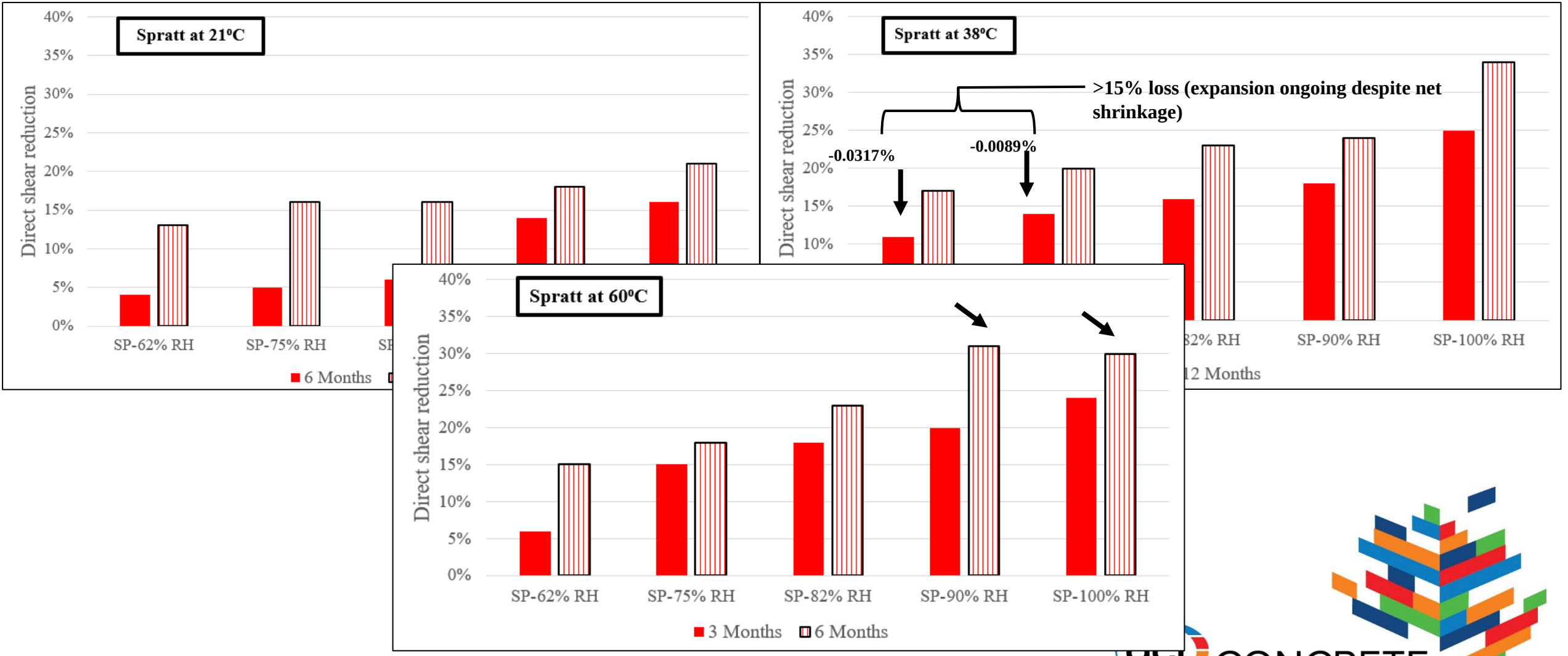


Damage Rating Index Results (Spratt Reactive aggregates; SP)

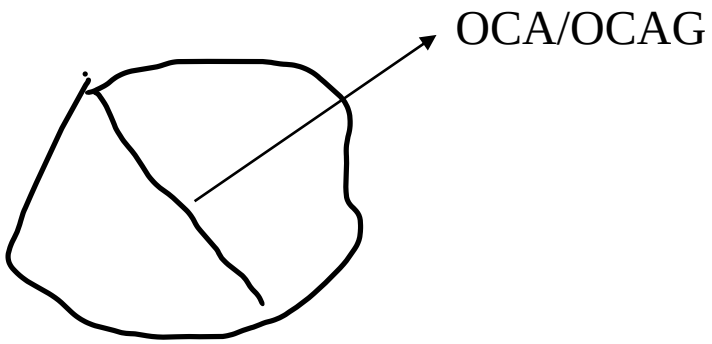




Direct Shear Test Results (Spratt Reactive aggregates; SP)

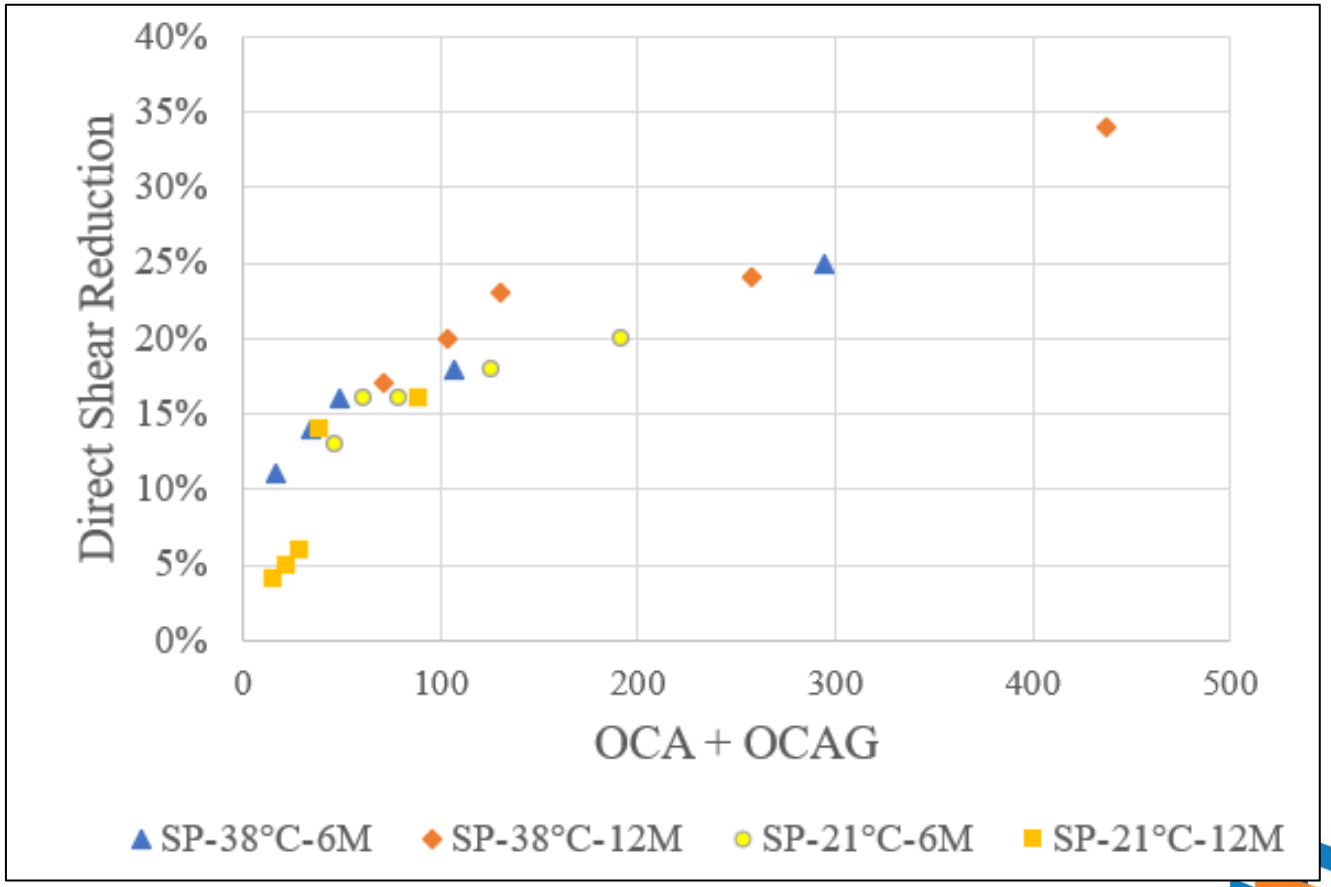


Direct Shear reduction versus DRI features (Spratt Reactive aggregates; SP)



ASR affected coarse aggregate

RH/Temp **Expansion** **OCA + OCAG** **Shear resistance**



OCA: open cracks in aggregates, OCAG: Cracks with reactive products in aggregates

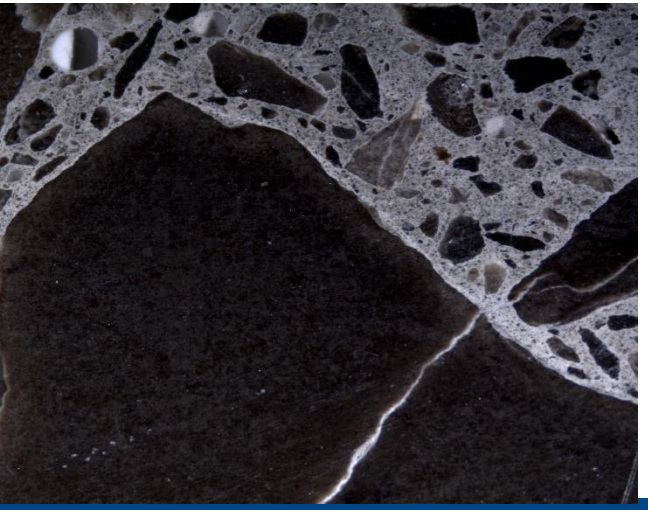
Internal RH is higher than the external RH at low moisture levels for most part of the experiment

ASR expansion is coupled with **drying shrinkage** at low moisture levels

The moisture threshold is dependent on **temperature** of aggregates

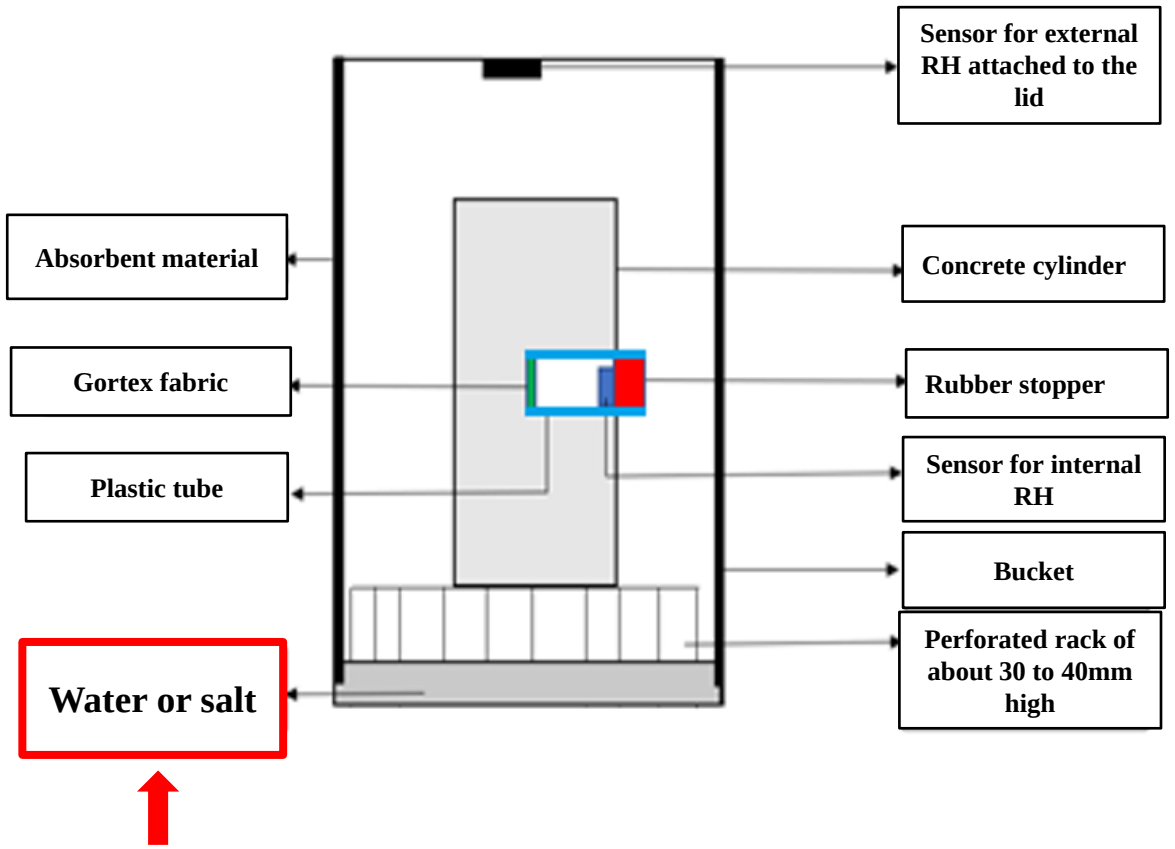
Correlation exists between **petrographic features and shear loss** at numerous exposure conditions using Spratt reactive aggregates

MERCI !!!



QUESTIONS?

MATERIALS AND METHODS – Control of Relative Humidity (RH)



Temp/RH	21°C	38°C	60°C
100%	distilled water	distilled water	distilled water
90%	barium chloride	potassium nitrate	potassium sulfate
82%	ammonium sulfate	potassium chloride	potassium nitrate
75%	sodium chloride	sodium chloride	sodium chloride
62%	sodium bromide	sodium nitrite	sodium nitrite

ASTM E104