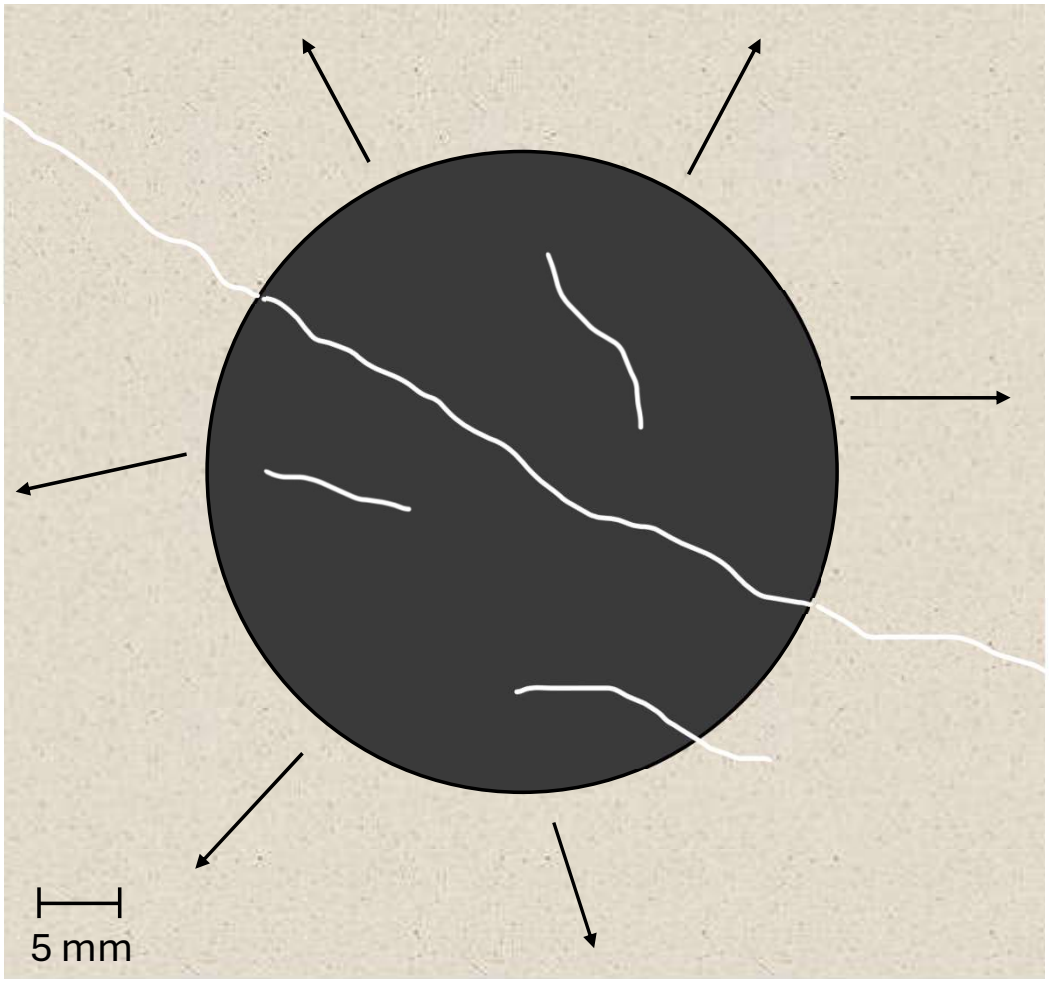
Correlation between damage parameters and mechanical properties of concrete affected by ASR

Authors : E. Baret, M. Kaleghi, B. Fournier, B. Bissonnette, **L. Courard**

ICCRRR 2024, 04-06 November, Cape Town, South Africa

Alkali-silica reaction (ASR)



Champlain bridge (Fournier et al., 2024)

Champlain bridge (Fournier et al., 2024)

Protocol developed for roadway structures affected by ASR

Diagnosis

SDT

DRI

Preliminary study

↓

Laboratory study

- Diagnosis
- Prognosis

↓

Repair

Fournier et al., 2010

Prognosis

Residual expansion test

Humid air, 38+/-°C, HR >95 %

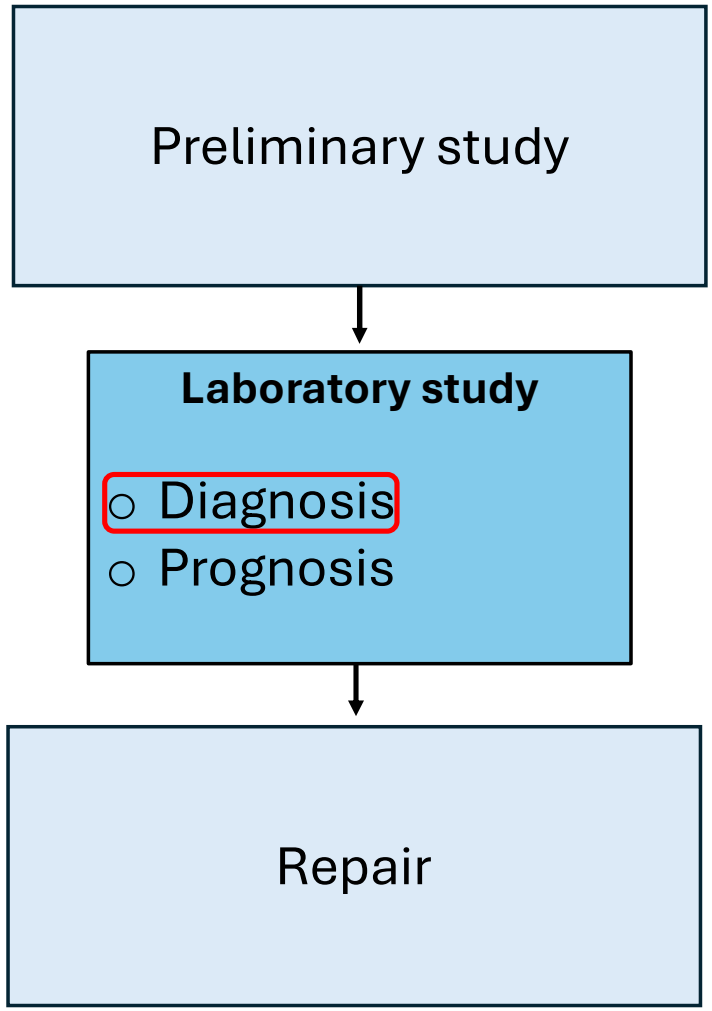
Alkaline solution, 38+/-°C, NaOH 1N

Protocol developed for roadway structures affected by ASR

Diagnosis

SDT

DRI



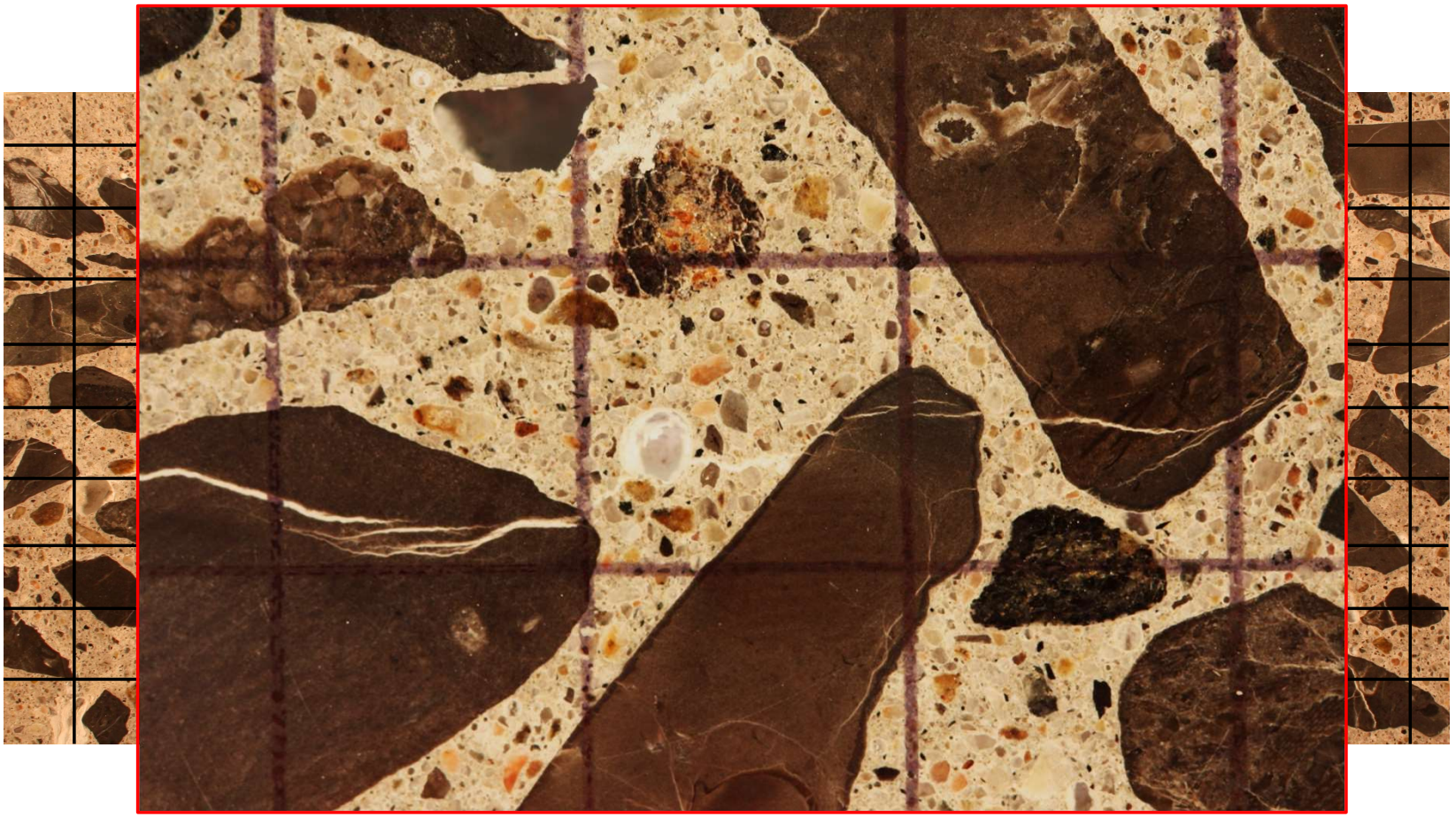
Fournier et al., 2010

Protocol developed for roadway structures affected by ASR

Diagnose

SDT

DRI



Protocol developed for roadway structures affected by ASR

Diagnosis

SDT

DRI

Protocol developed for roadway structures affected by ASR

Diagnosis

SDT

8,5	12,5	17	30	26,25	0,5	10,25	11	24,25	28	18,5	12,75	11,75	15,5	18,75	3,25	14,75	10,5
19	14,75	32	30,25	27,75	23,5	17,25	17,5	17,5	12	13	4,5	20	22,25	18,5	12,75	3,5	7,5
20	24,5	34,25	14	19,75	11	14,5	25,5	12,5	15,25	25	22	23,5	13	16	25,25	33	11,5
21	42	19,25	6	10,25	3,75	0,75	14,5	0,25	7	21,5	8	32,75	21	21	12	13,75	21,5
9,75	18,5	12,25	0,25	4,25	2,75	17,25	21,75	17,5	4	9	6	23,5	4,25	13,25	18,25	13,5	11,5
13	18,75	23,75	3	23,75	9,25	13	5	18,75	14,5	12	4	6,5	8,25	15,5	18,75	8,5	10,25
13	0	13	15,5	11,5	4	0	9	8,75	12,75	6	3	7	8	10	12,5	5,5	2,5
16	4,75	17,25	9,5	5,5	4	0	0,75	11,5	13	17	27	10,25	10	17,75	7,5	8,75	5,5

DRI

$$\text{DRI} = \frac{(\sum cracks) * factors}{Surface\ [cm^2]} * 100\ [cm^2]$$

Protocol developed for roadway structures affected by ASR

Diagnosis

SDT

DRI

Preliminary study

↓

Laboratory study

- Diagnosis
- Prognosis

↓

Repair

Fournier et al., 2010

Prognosis

Residual expansion test

Humid air, 38+/-°C, RH >95 %

Alkaline solution, 38+/-°C, NaOH 1N

Protocol developed for roadway structures affected by ASR

Diagnosis

SDT

DRI

Young's modulus

Expansion [%]

fc

Prognosis

Residual expansion test

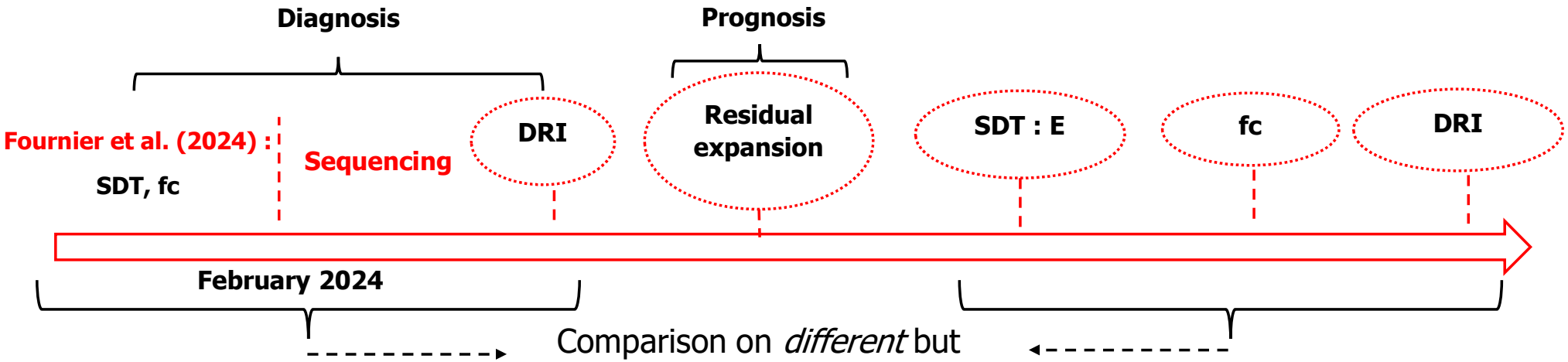
Humid air, 38+/-°C, HR >95 %

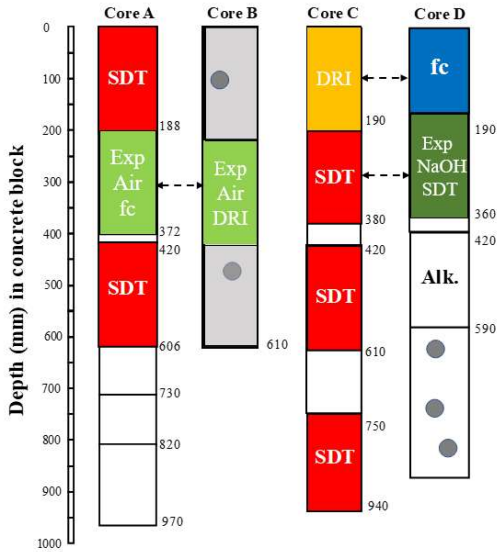
Alkaline solution, 38+/-°C, NaOH 1N

Materials and methods

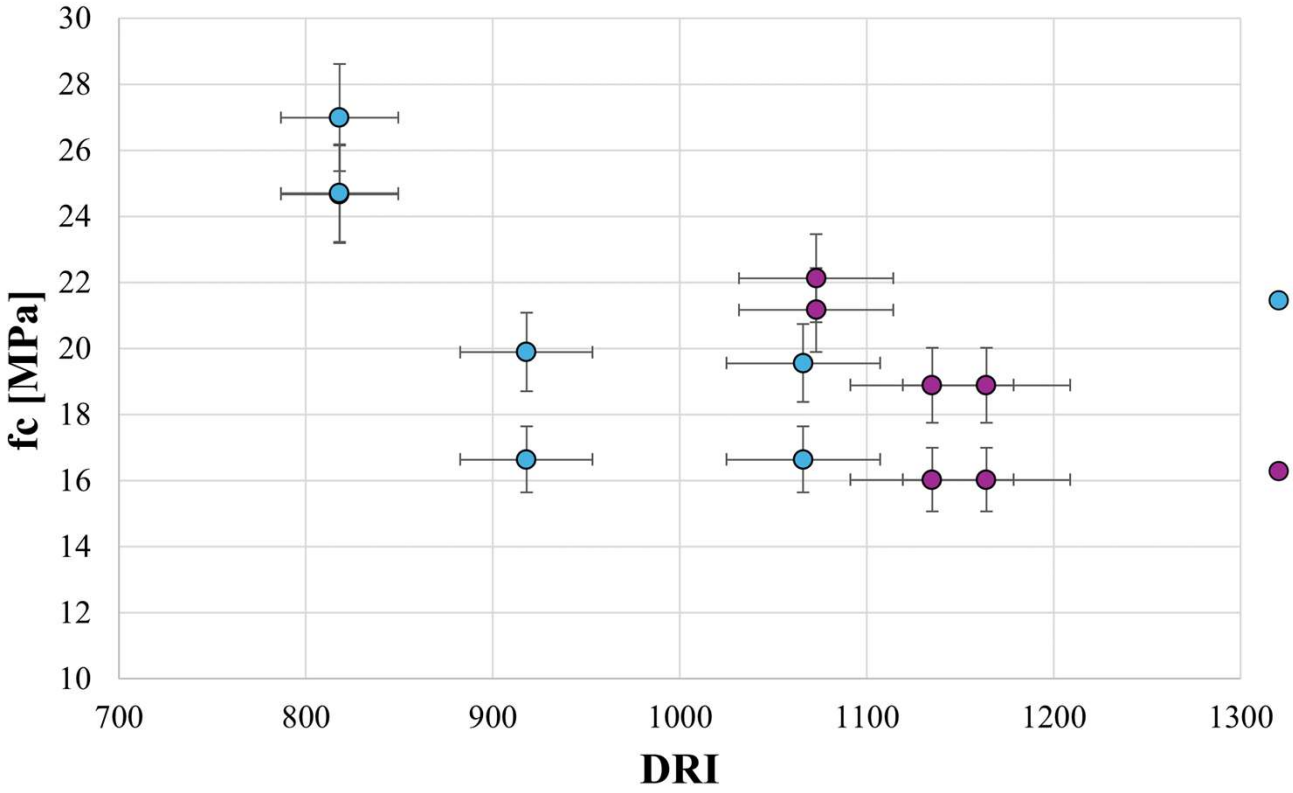
Pont Champlain

Materials and methods





Results : Compressive strength vs DRI

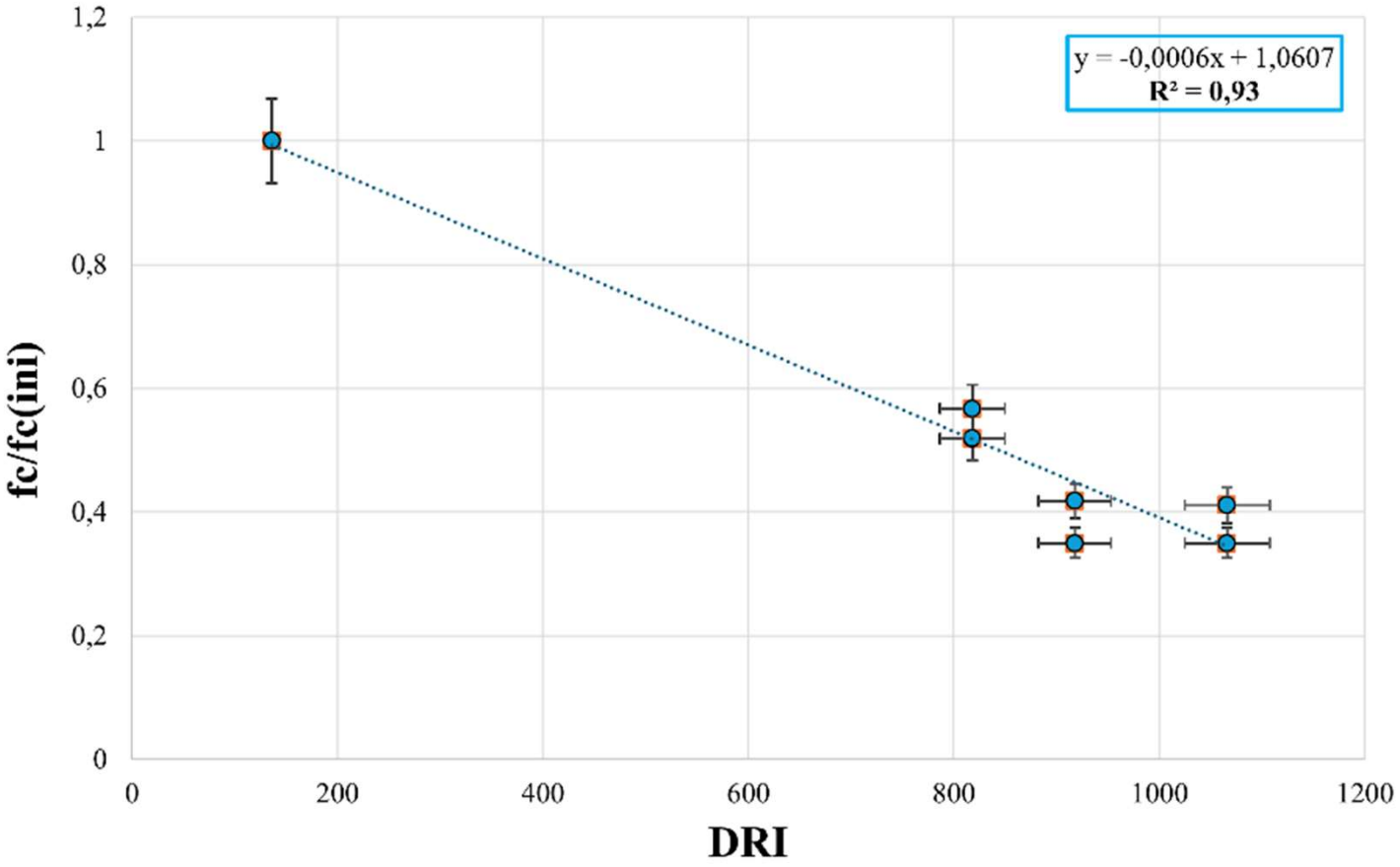


- Compressive strength decreases -> DRI increases
- **DRI** ≈ cracks in the aggregates + cracks in the cement paste
- Difference observed between pre- and post-expansion samples :

  1) **Concrete hydration :** unlikely

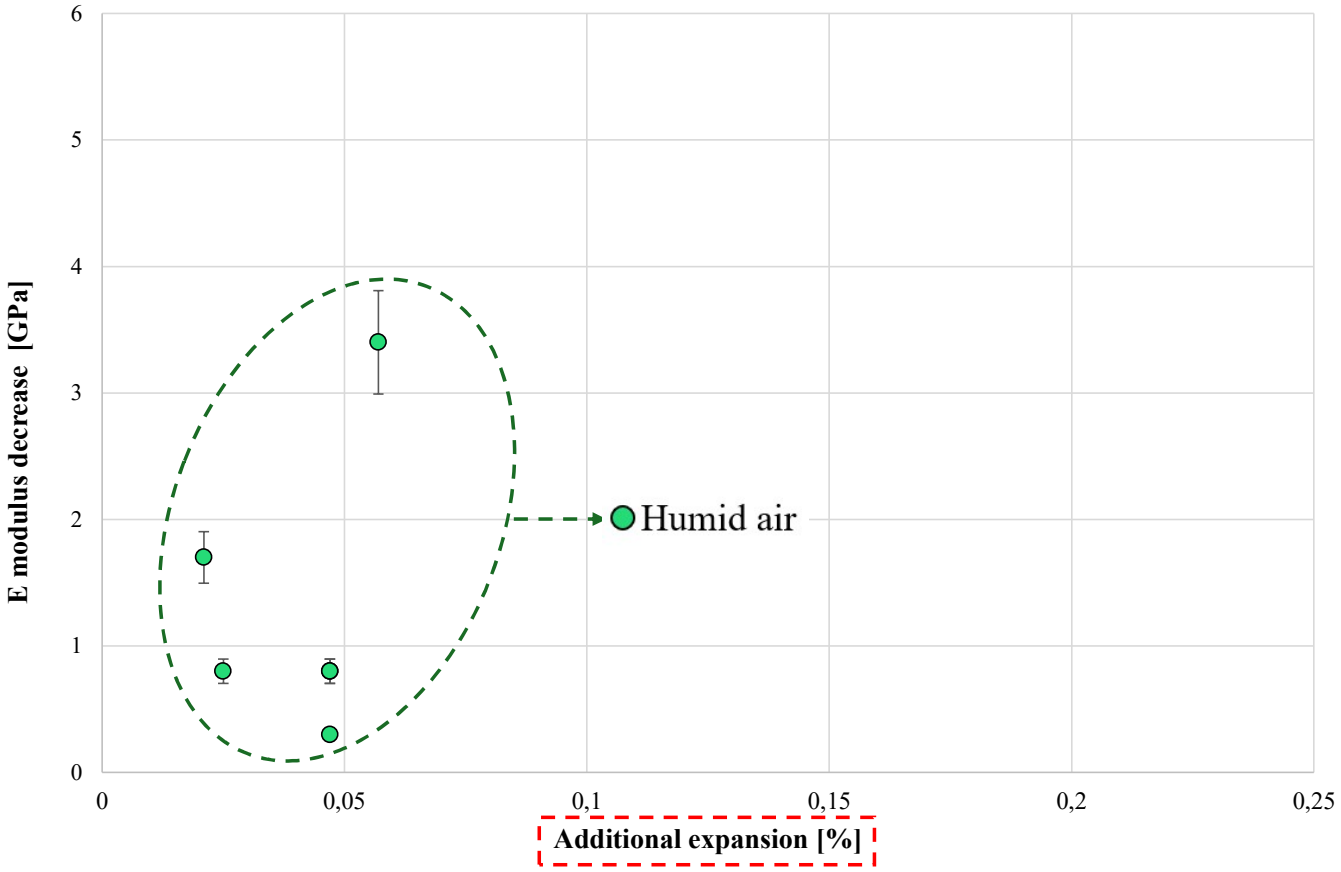
  2) **Leaching of alkalis :** makes the results unreliable

Results : Compressive strength vs DRI

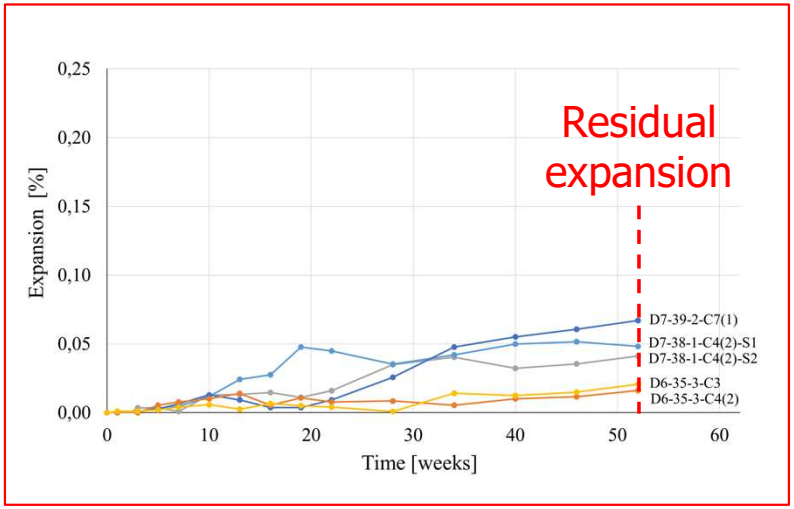


- **Limited data** points and narrow range -> **additional point** from undamaged internal bridge element of concrete
- Undamaged concrete :
  DRI ≈ 100-150 & fc ≈ 47,6 MPa
- Uncertainty about the concrete composition compared to the pile
- **Linear relationship** between compressive strength decrease and DRI number
- Initial strength **consistency** suggested by the alignment

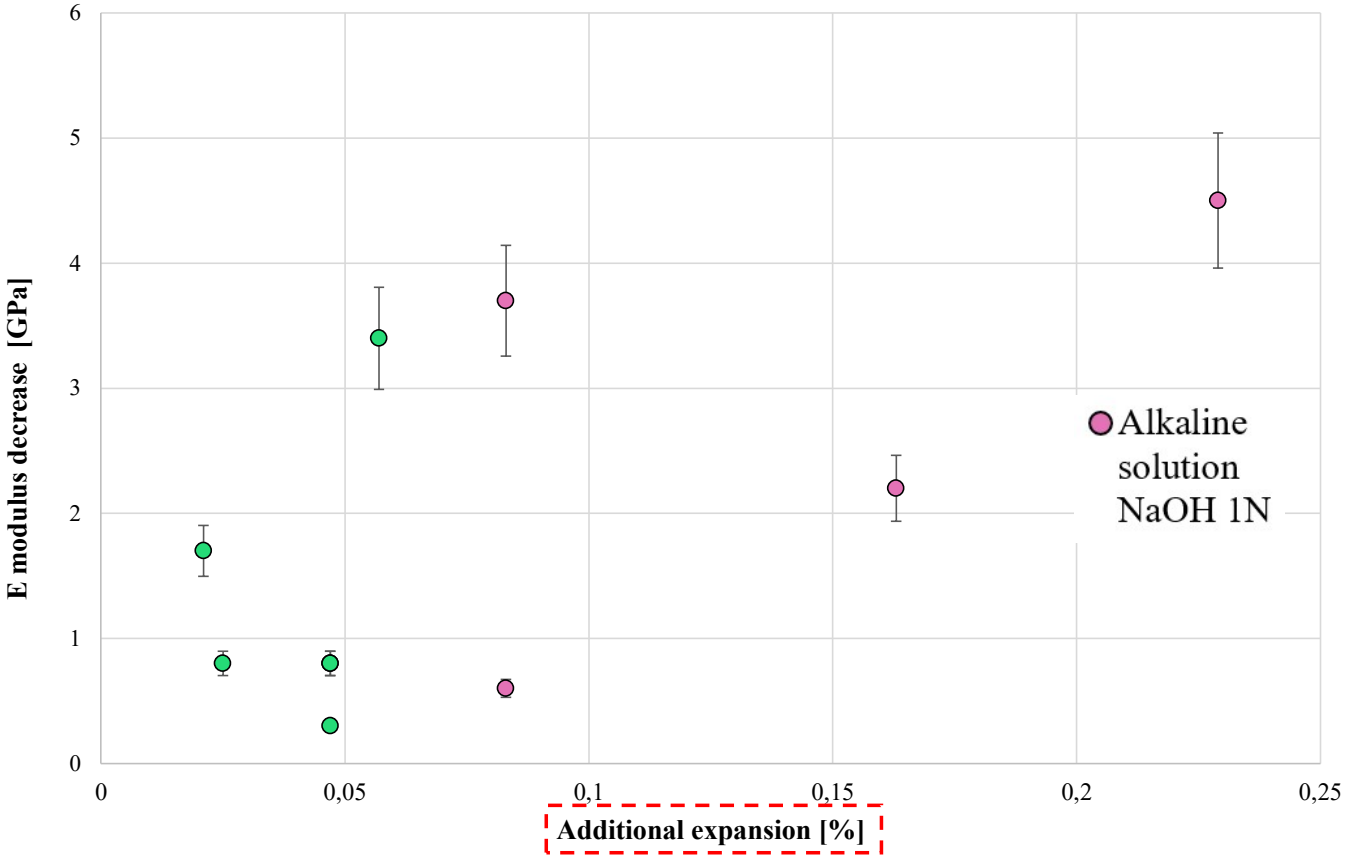
Results : E modulus vs residual expansion



- Humid air : Low residual expansion -> leaching of alkalis

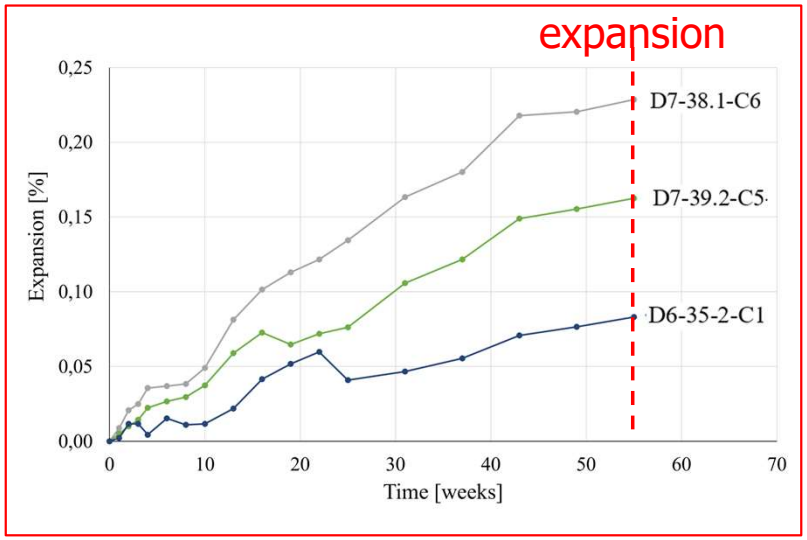


Results : E modulus vs residual expansion

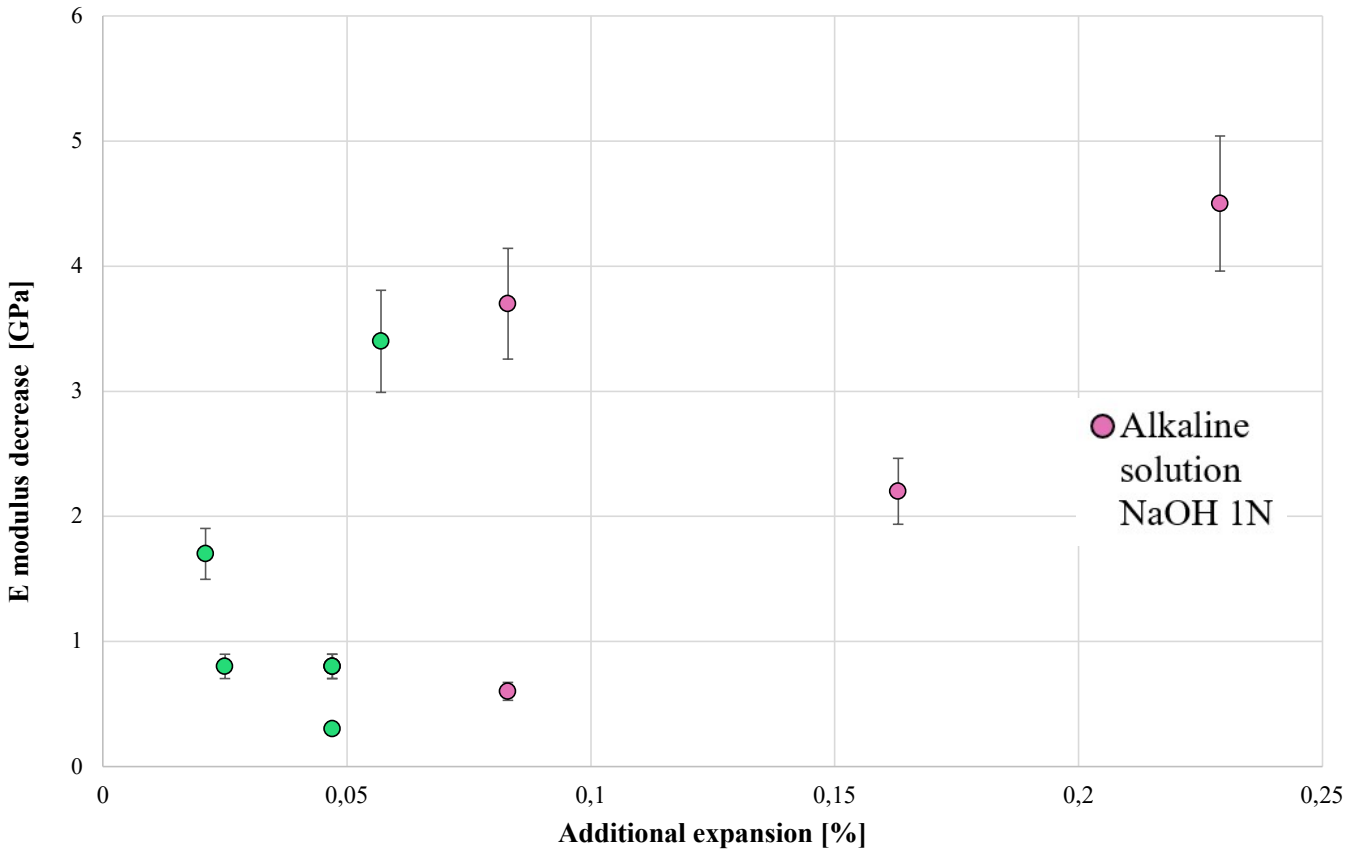


- Humid air : Low residual expansion -> leaching of alkalis
- Alkaline solution : Higher residual expansion

Residual expansion



Results : E modulus vs residual expansion



- Humid air : Low residual expansion -> leaching of alkalis
- Alkaline solution : Higher residual expansion
  - Expansion increases, Young's modulus decreases
  - No plateau around 0.2% -> cracks continue to develop with higher expansion

Conclusions

- A linear decreasing trend is observed between DRI and fc
- When expansion increases -> Young's modulus decreases

} Decrease of mechanical properties with increasing number of cracks in the aggregates

- Compressive strength tests are recommended
- DRI tests are essential

Protocol recommendations

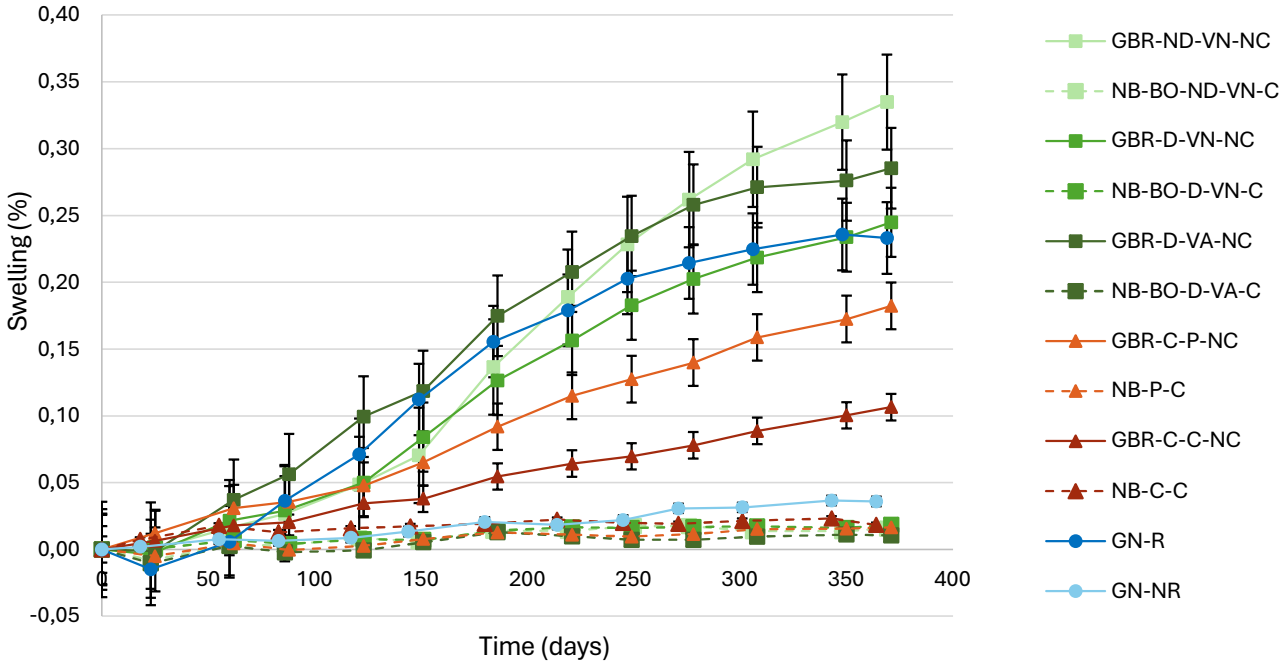
- **Performing compressive strength tests** during diagnosis
- Compressive strength is not the primary indicator of ASR-related damage: **Maintain the use of the DRI** test for a thorough understanding of the cracking state
- *Supplementary studies are coming ……*

Treatment of Recycled Concrete Aggregates affected by ASR (S. Grigoletto)

- Carbonation of Recycled Concrete Aggregates affected by ASR: efficiency of the process (39°C – 60%R.H. – 20%CO_2) → reduction of water absorption (up to 35 %), increase of $CaCO_3$ content (up to 7%), increase of mass (up to 4.8%)

- RCA from structure (= Champlain Bridge) affected by ASR for new concrete: continuing swelling process depending on the location of coring

- Carbonation: reducing pH and alkali availability in cement paste → reduction of swelling

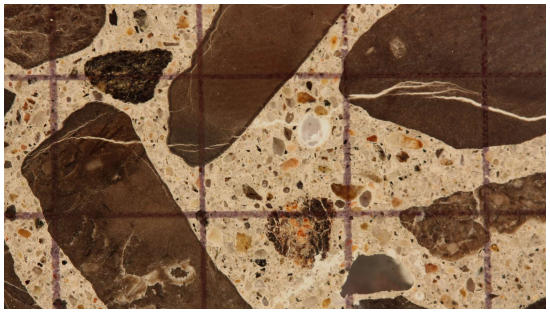


Mitigation of Alkali-Silica Reaction Through Carbonation of Recycled Concrete. S. Grigoletto, J. Hubert, J. Duchesne, B. Bissonnette, F. Michel, L. Courard. Proceedings of the 17th International Conference on Alkali Aggregate Reaction in Concrete ICCAR 2024, 18-24 mai 2024, Ottawa (Canada), pp626-634 (https://hdl.handle.net/2268/320679)(http://dx.doi.org/10.1007/978-3-031-59349-9_72)

Collaboration project funded by MITACS and ERASMUS

(Université Laval, Quebec, Canada

Université de Liège, Wallonia, Belgium)



Thank you for your attention !