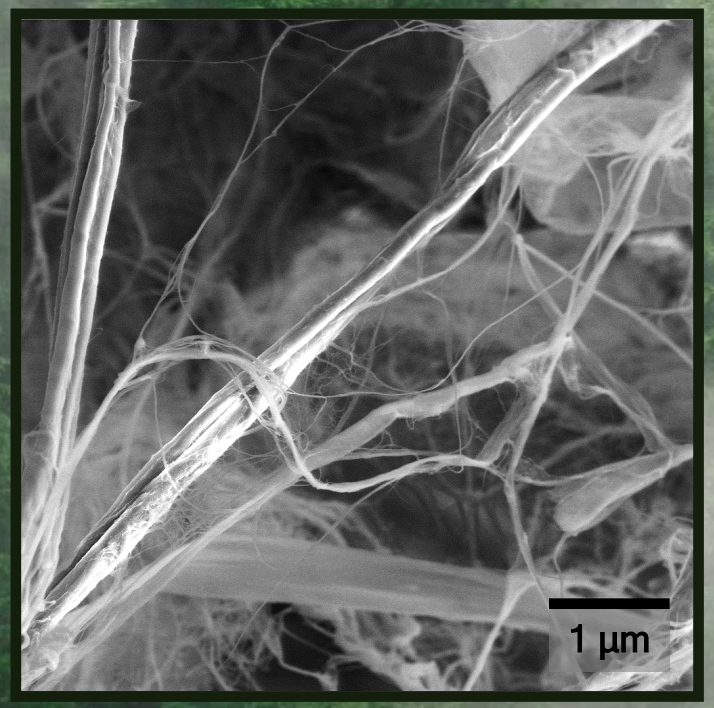
Use of NanoFibrillated Cellulose in Concrete

Reducing corrosion and cracking while improving adhesion and mechanical performance

PERFORMANCE BioFilaments

making great materials better



- Performance BioFilaments is commercializing mechanically-refined NFC
- 7,000 tpy facility began production in Jan 2023
- Co-located at Resolute's Kenogami mill

MERCER

Vancouver based integrated forest products company with operations in Canada, USA, Germany, and Australia.

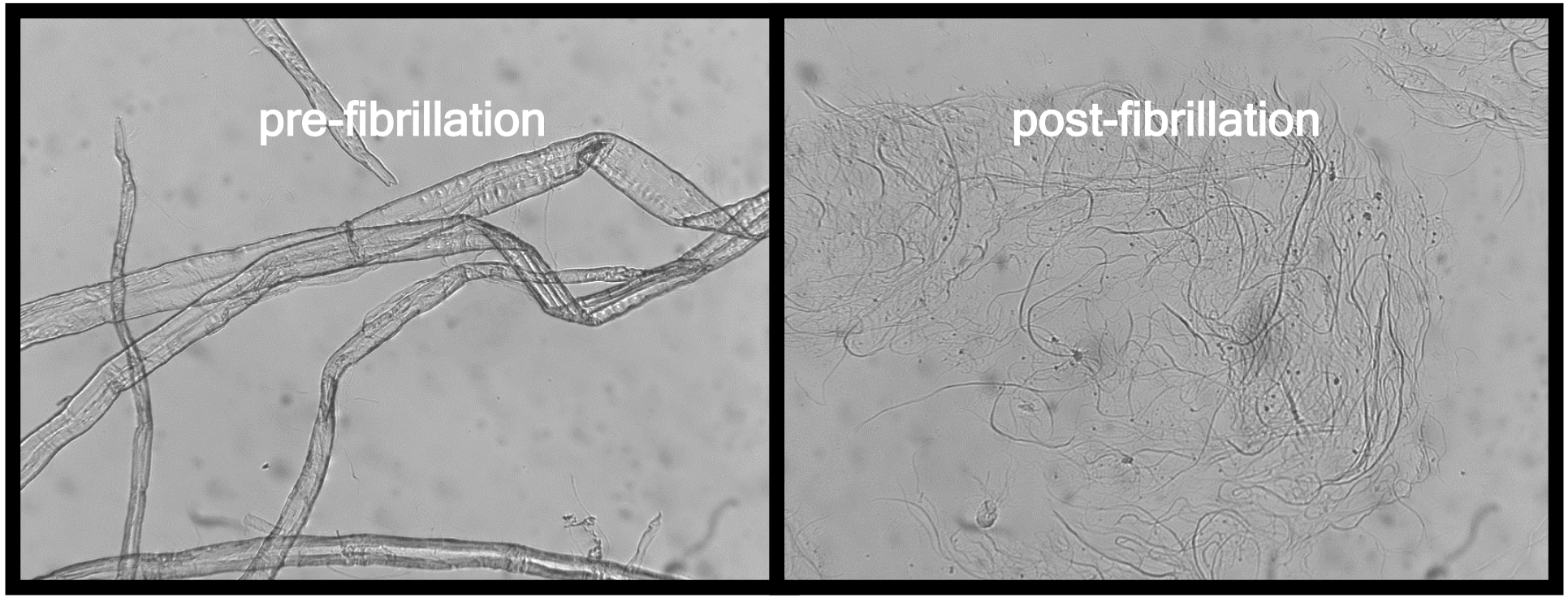
shareholders

Montreal based integrated forest products company with operations in Canada and the United States.

resolute Forest Products

Mechanical fibrillation technology

Fibrillation process was developed by FPInnovations



images are at the same resolution and scale

Individual delignified wood fibers

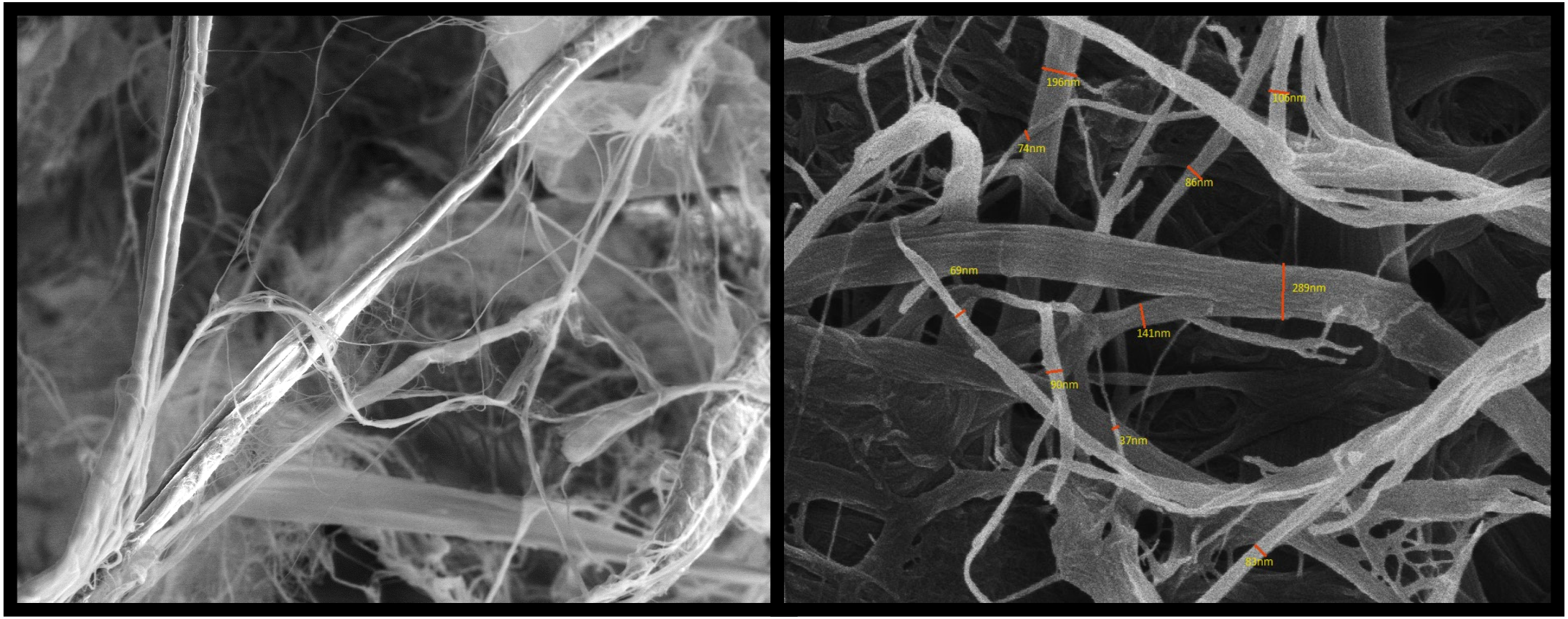
pre-fibrillation: ~20um typical width

Nanofibrillated cellulose fibrils

post-fibrillation: <1um typical width

chemical-free mechanical refining - powered by renewable energy

Micro/Nano width distribution



left image - micro fraction | right image - nano fraction

micro-fibrils

<1 um typical width

nano-fibrils

<500 nm typical width

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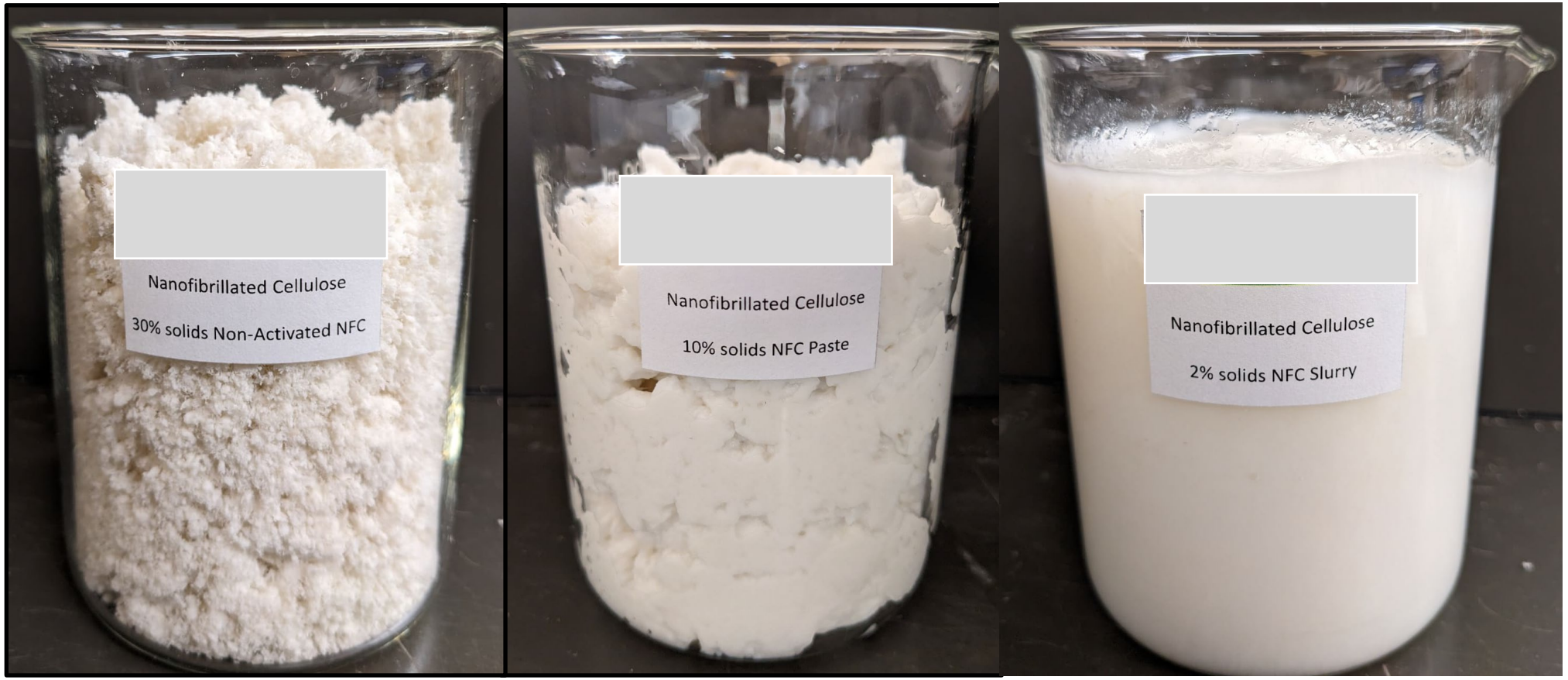
very high aspect ratio (up to 1200 L/W) and high surface area (~150 m^2/g)

NFC forms



30% solids
Non-Activated

10% solids
Paste

2-5% solids
Pumpable Slurry

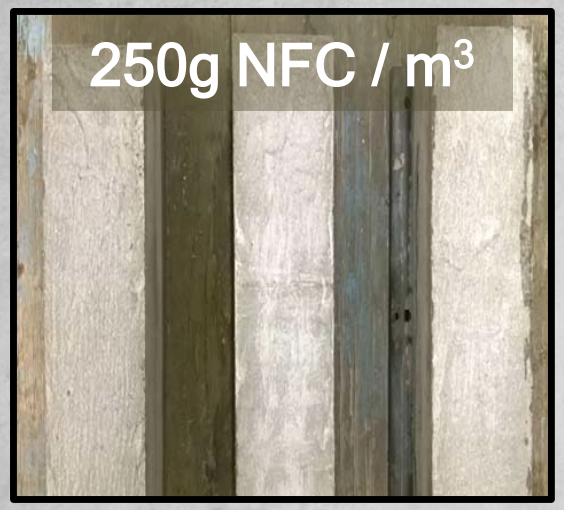
Why concrete?

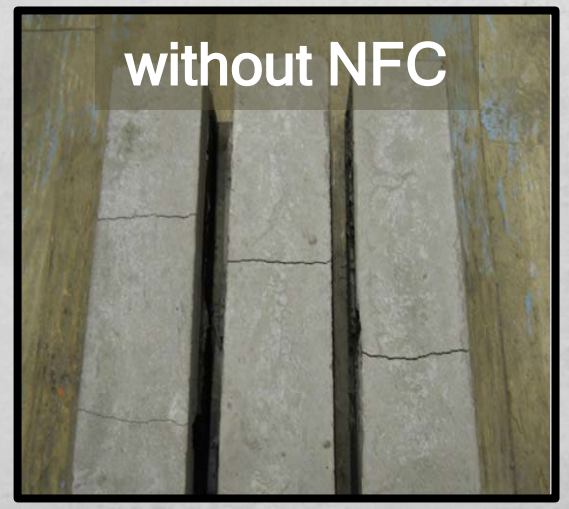
- Up to 8% of global CO_2 emissions come from concrete production
  - Close to 2 Billion tons of CO_2 per year
- Large market; 30 Billion tons of concrete are produced annually (!)
  - At 0.1 wt% NFC = 30 Million tons per year
- Water-based chemistry
  - Plays well with bio-based additives
- NFCs (and CNCs) are highly effective at very low loading levels
  - Improved performance leads to reduced carbon footprint (more on that later)

construction & infrastructure

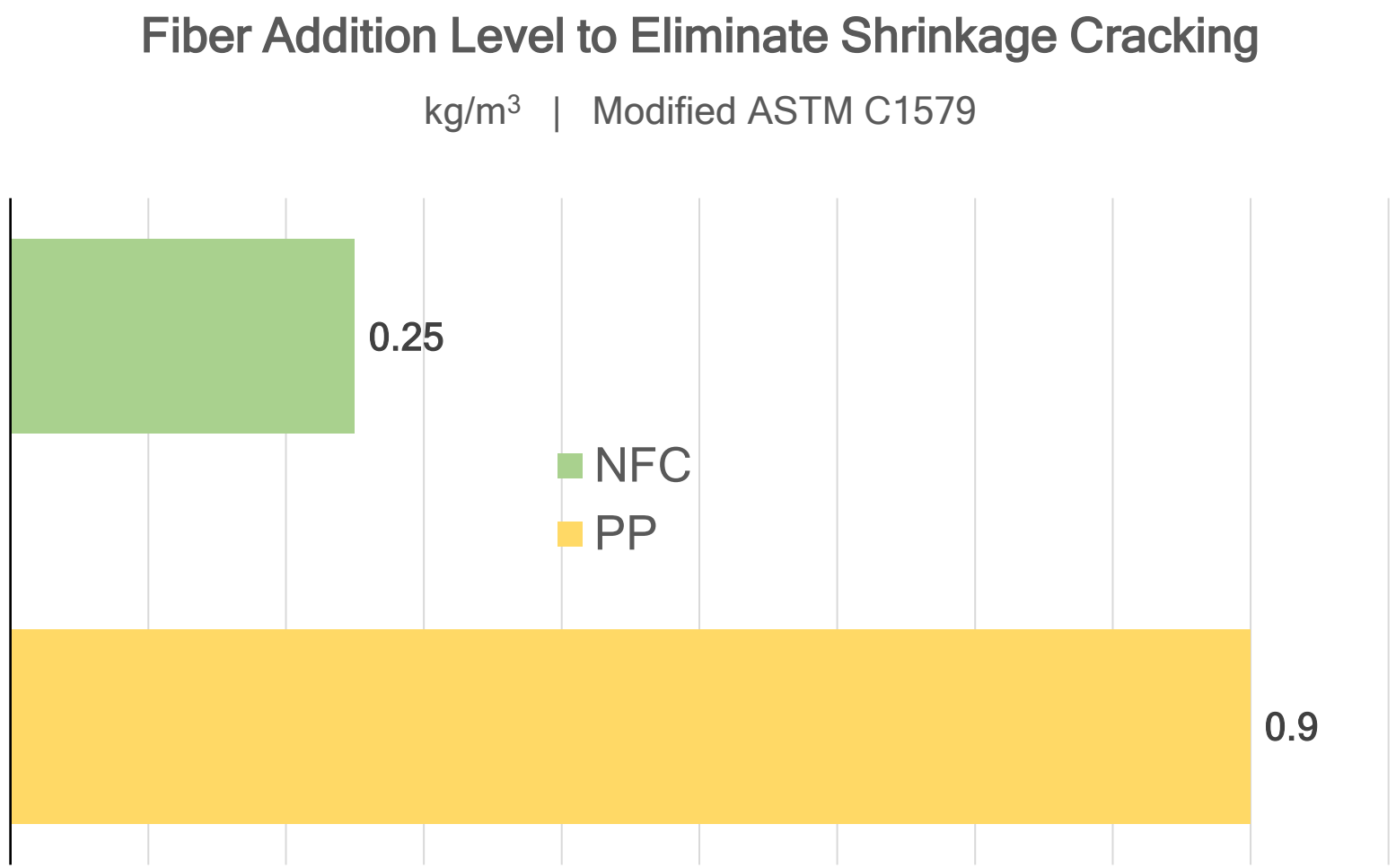
NFC improves internal curing, reduces corrosion, mitigates cracking, increases strength, and enhances durability.

reduced shrinkage cracking

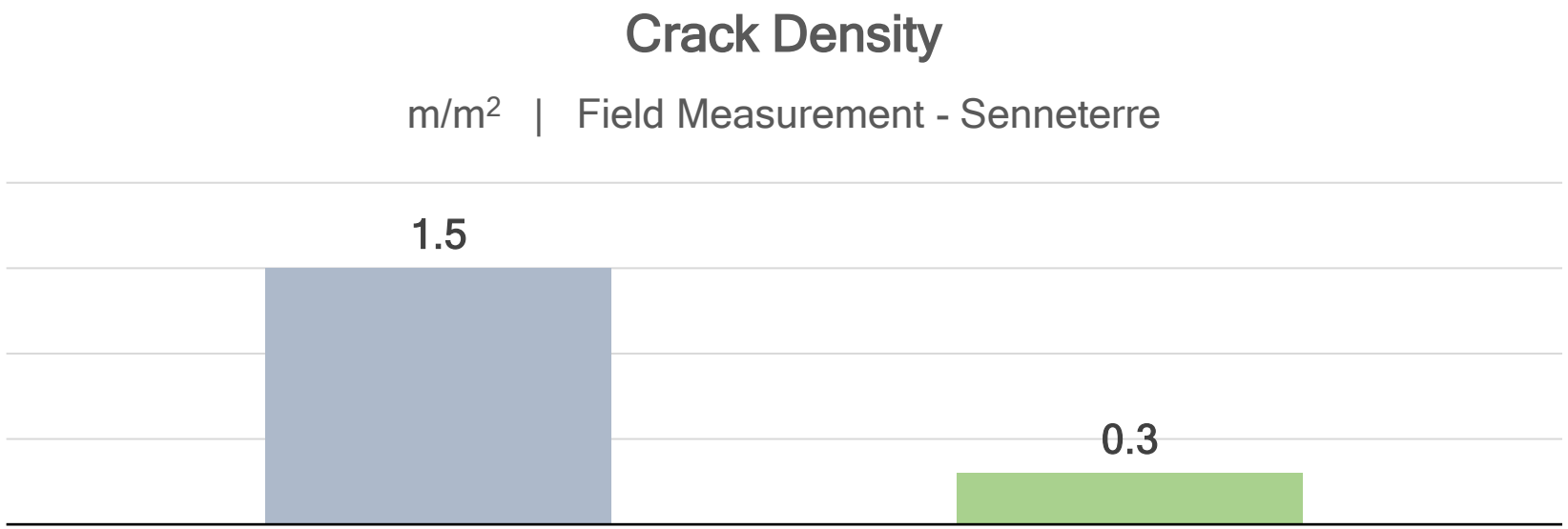


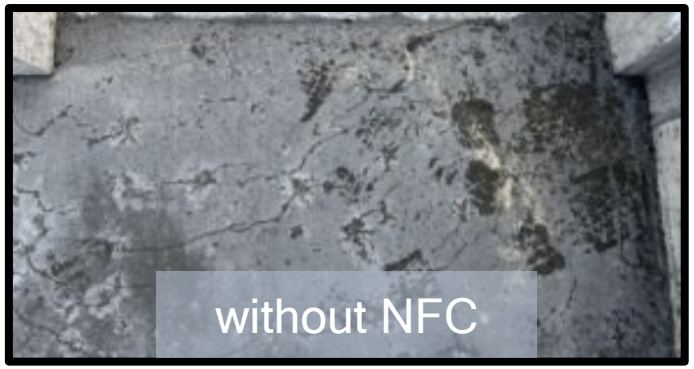


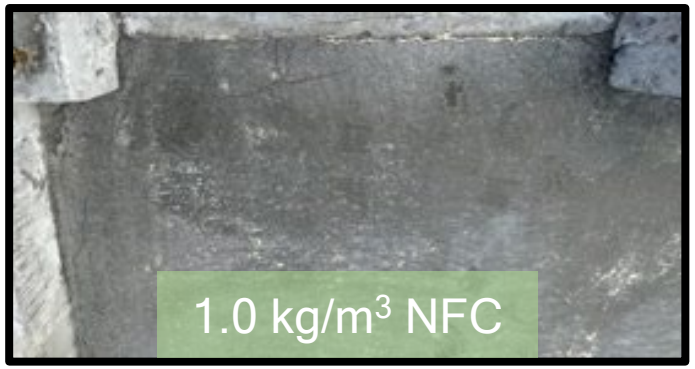
4X more effective than Polypropylene Fiber



80% less cracking





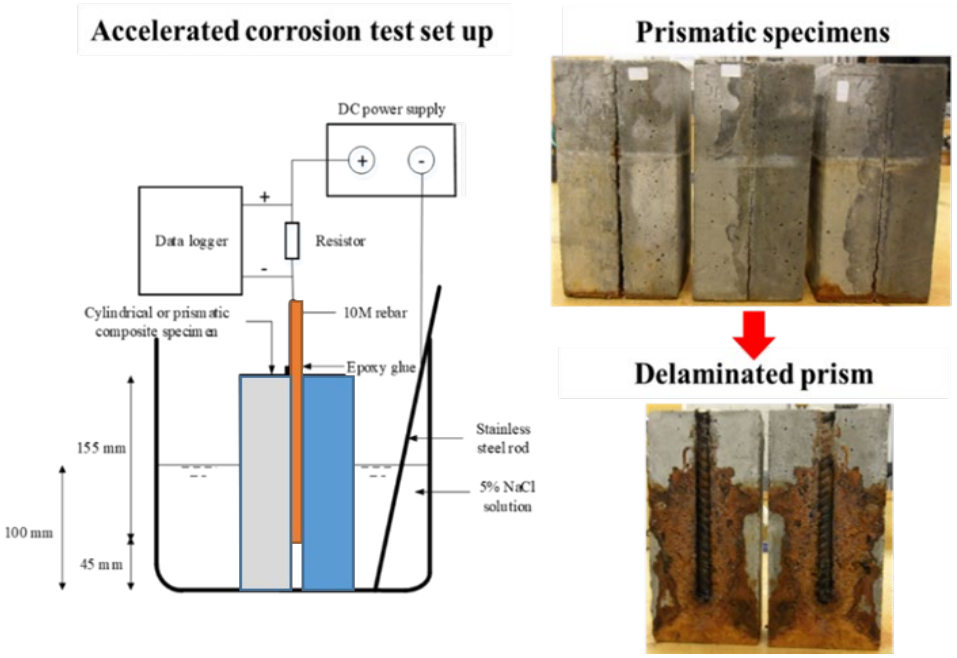


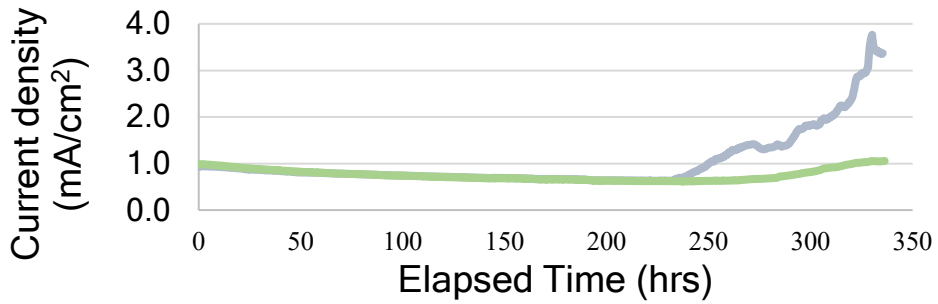
Why?

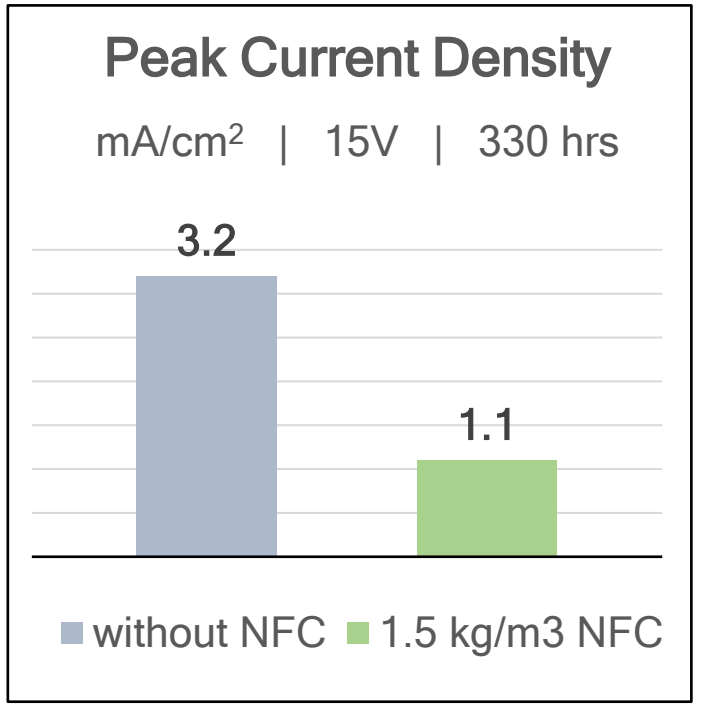
- Internal curing
  - Water holding and delayed release
  - Water transport throughout the matrix during curing
  - Both lead to even, consistent curing throughout the concrete, preventing localized dimensional changes
- Improved dimensional stability
  - Reduced overall shrinkage
- Prevention of crack initiation
  - Nano-crack bridging throughout (?)

reduced rebar corrosion

66% lower peak current density



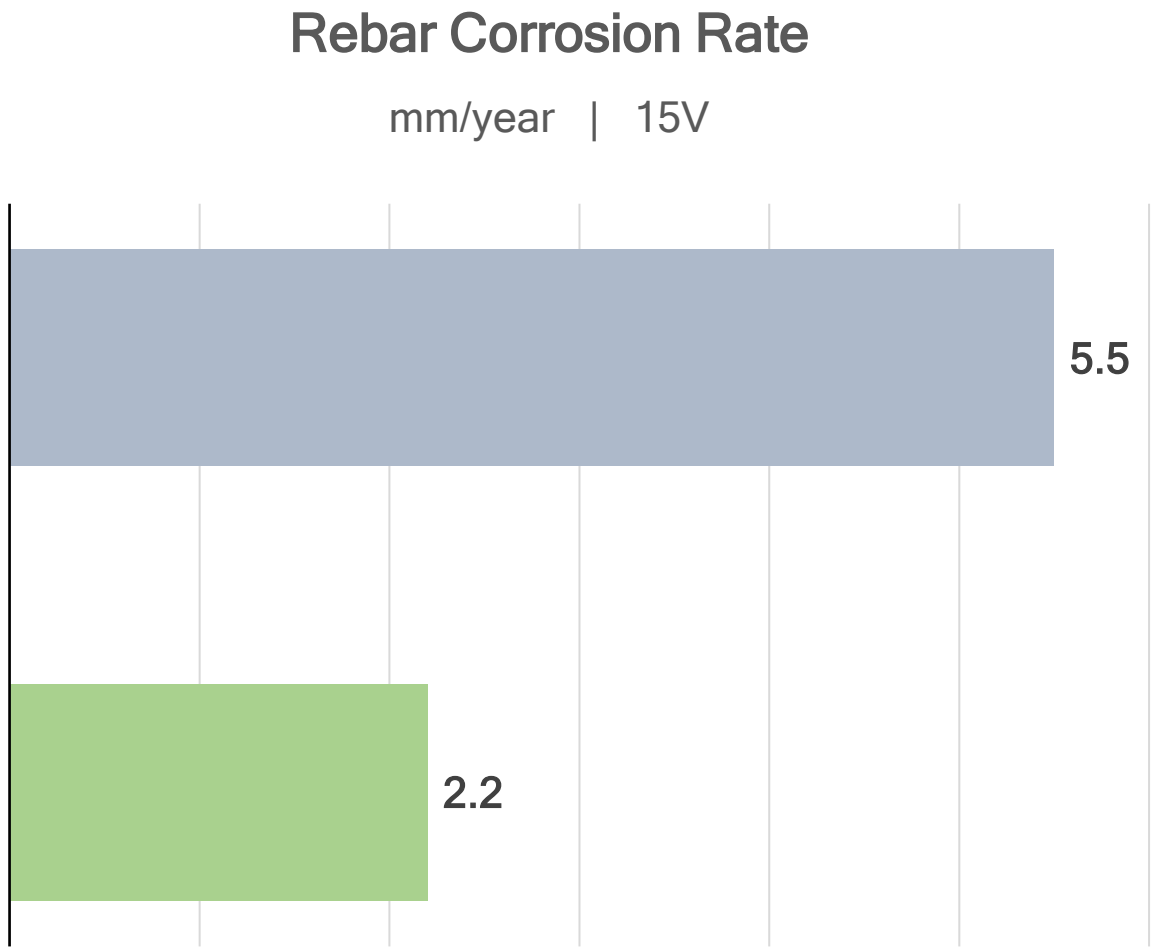




Plain Substrate - Plain Repair

Plain Substrate - Plain + 0.1% NFC Repair

64% lower corrosion rate

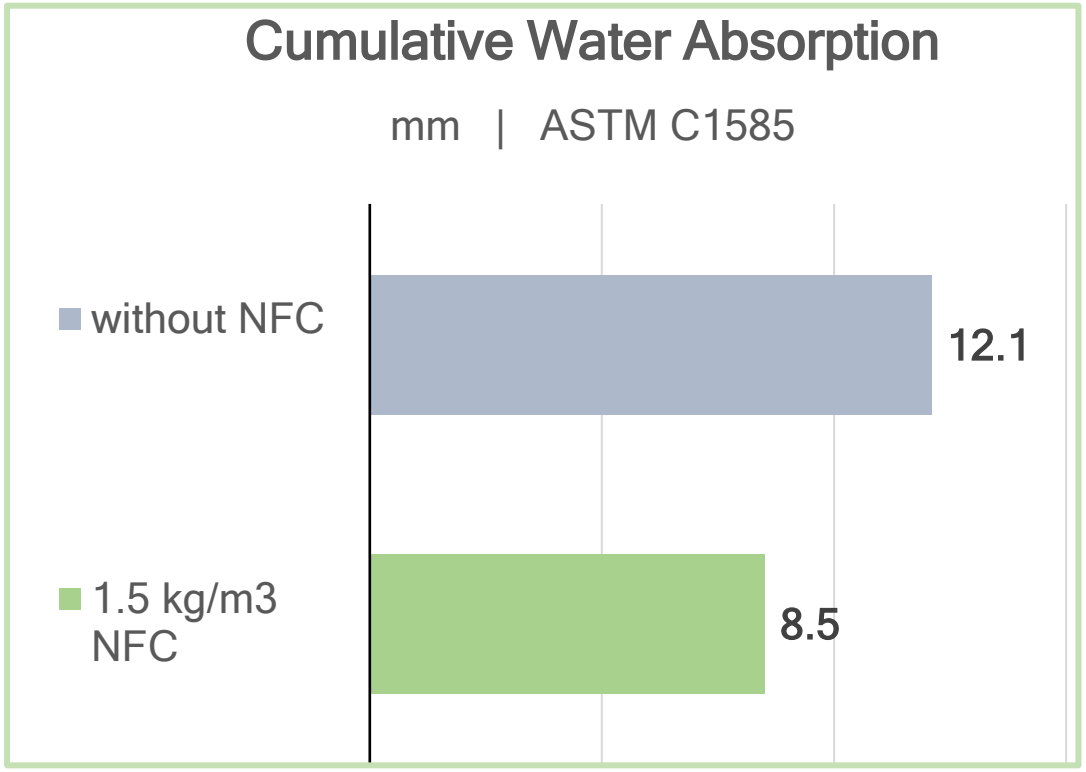


without NFC

1.5 kg/m³ NFC

Why?

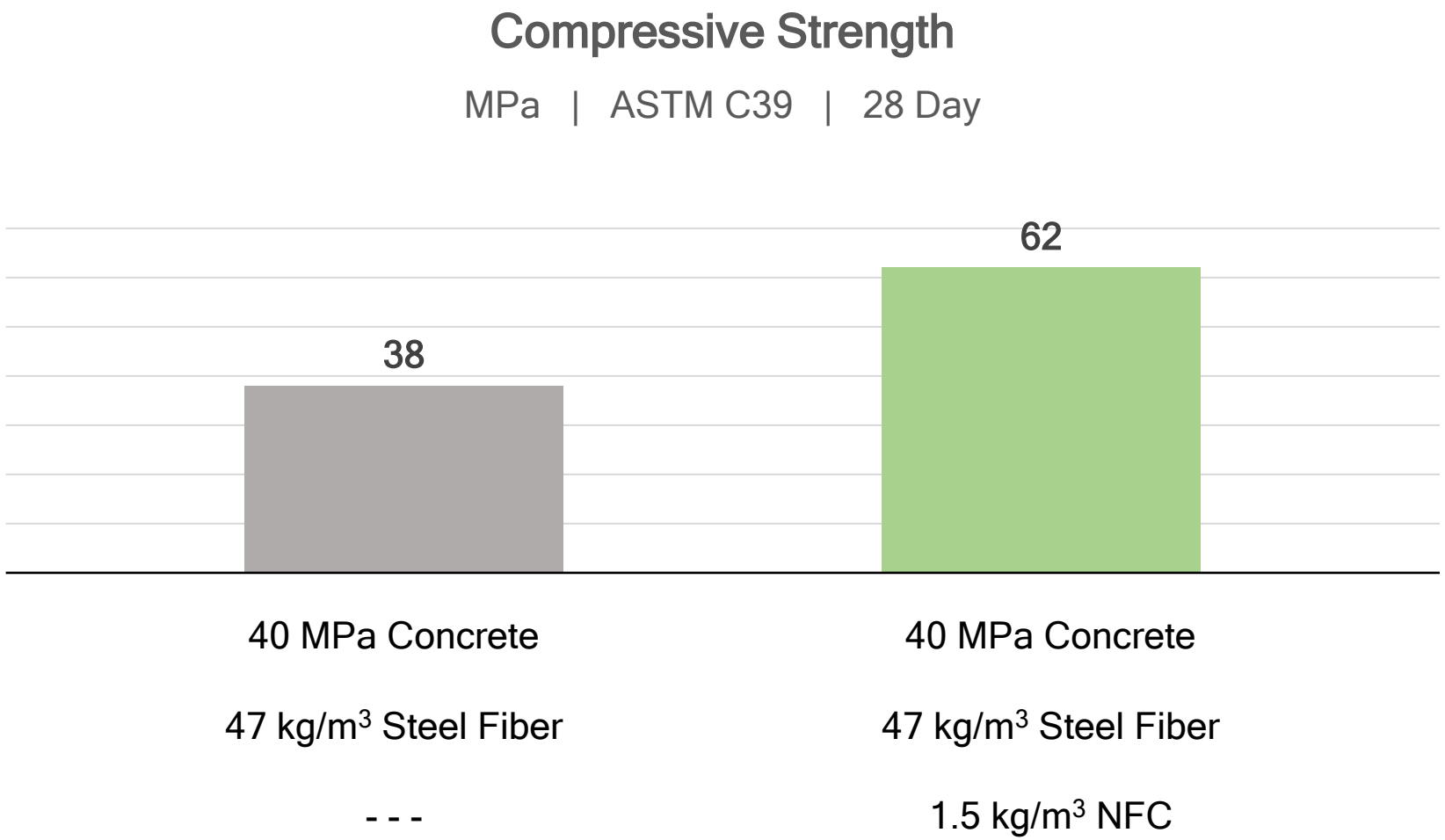
- Porosity / Permeability !
- NFC reduces the permeability of concrete
- Nano-level restructuring of the pores
- Less water absorption and reduced ion transport leads to reduced corrosion



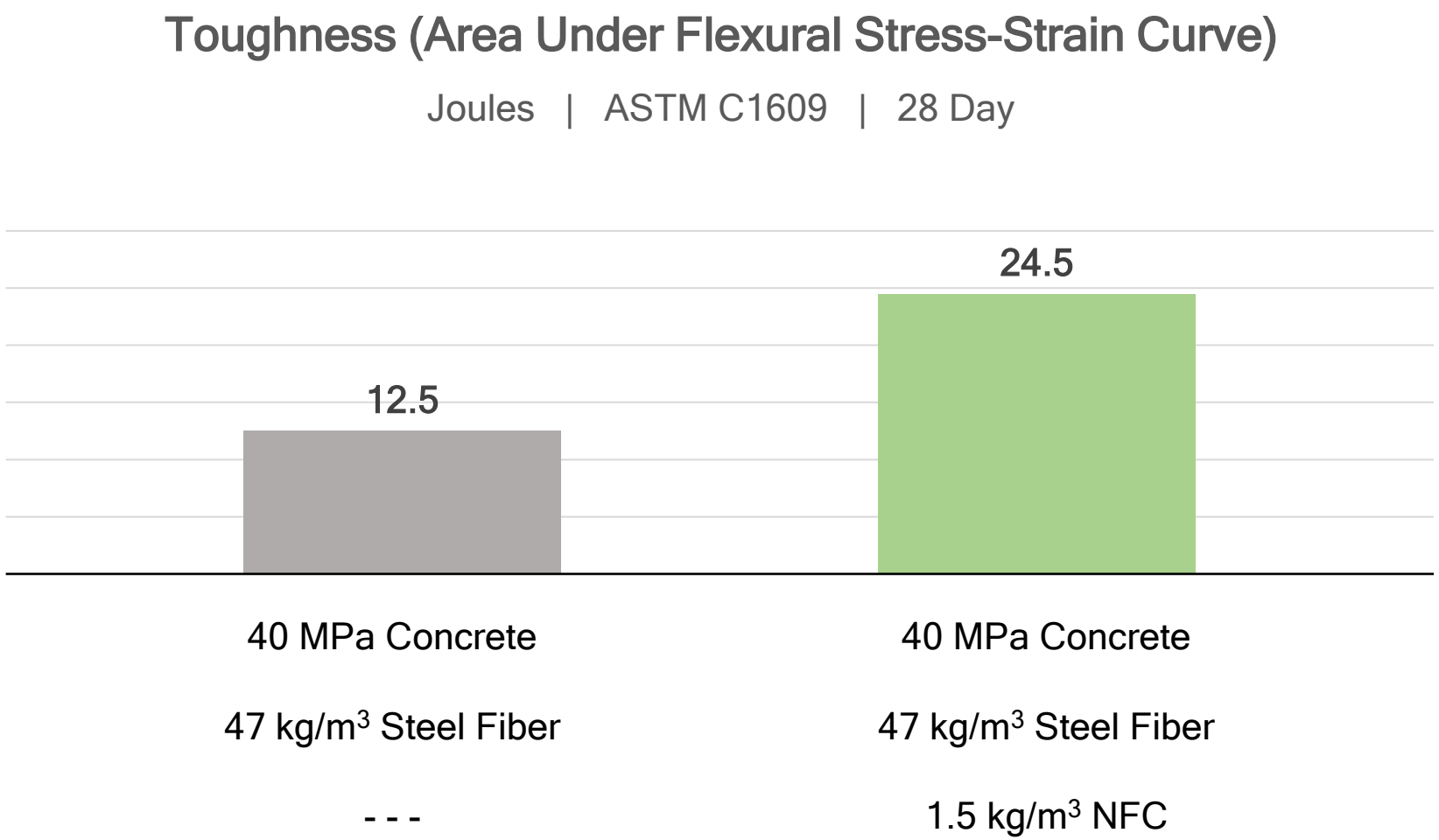
Evidence of reduced surface permeability and reduced capillary action with NFC addition.

increased strength

63% greater compressive strength



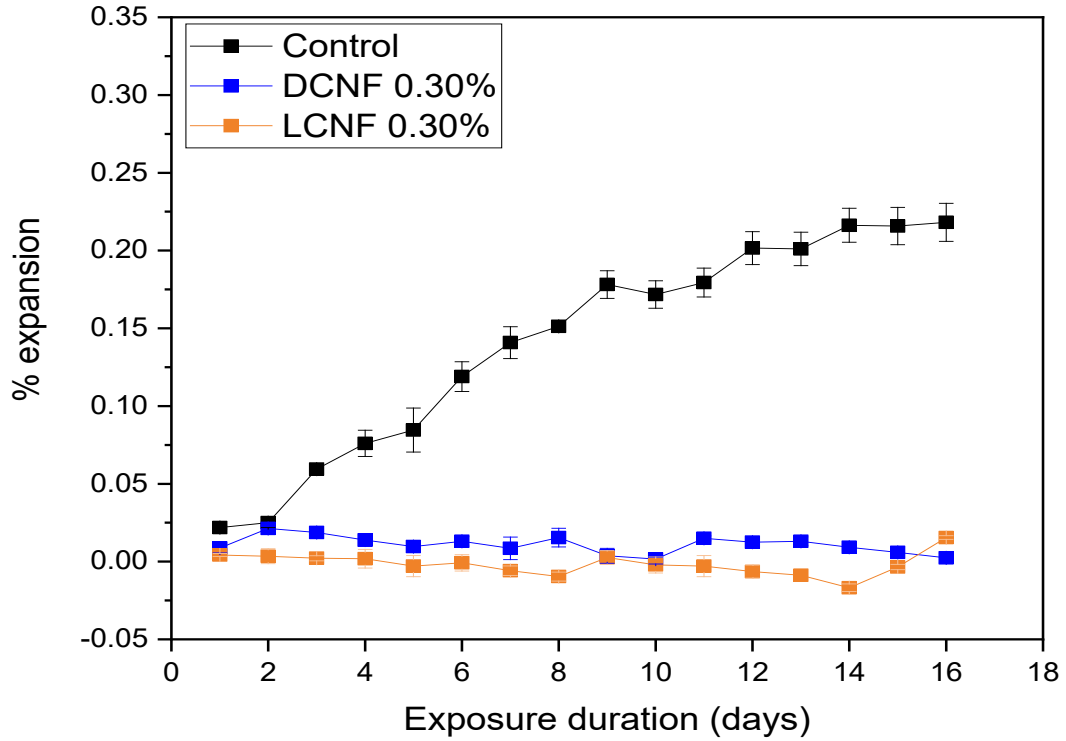
96% greater flexural toughness



reduced chemical attack

95% reduction in ASR-induced swelling

- Poor-quality aggregate can lead to extensive swelling/cracking of concrete
  - Due to alkali-silica reaction (ASR)
  - Also known as concrete cancer
- NFC eliminates ASR-induced swelling
- Why?
  - Chemical sequestration of alkali?
  - Reduced permeability?
  - Physical restraint?



increased overlay adhesion

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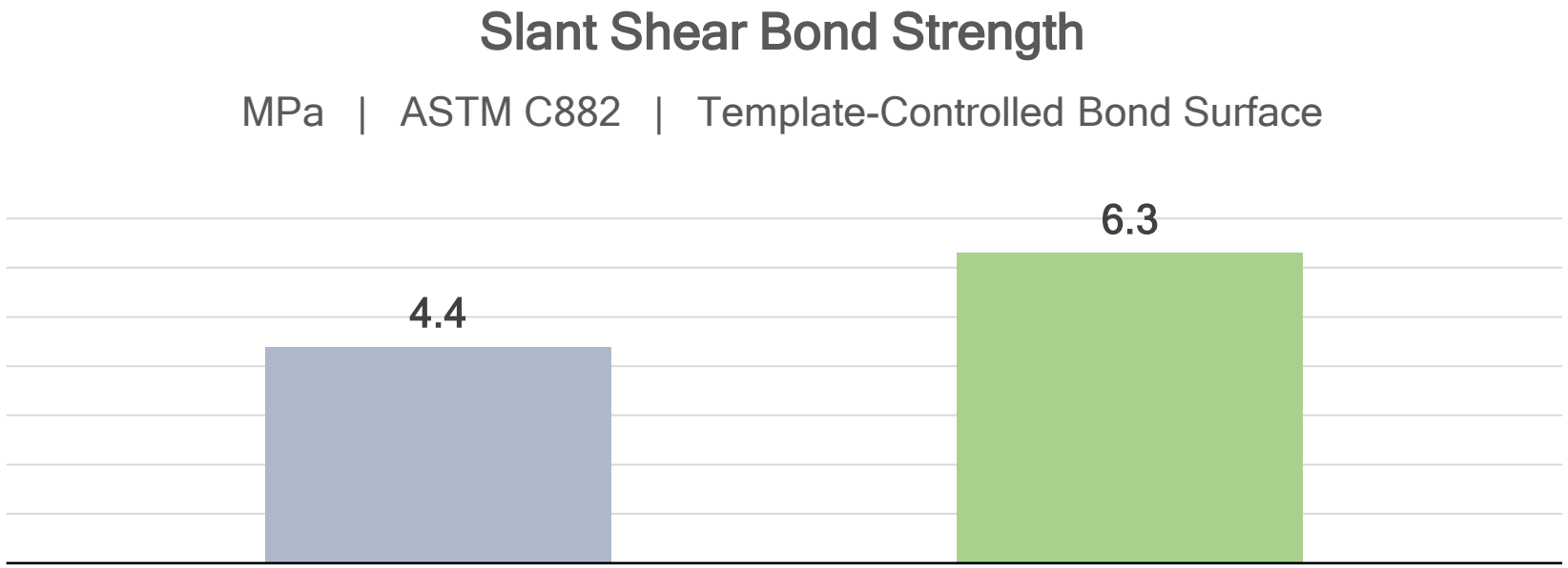
43% greater bond strength



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Carbon reduction using NFC

- Displacement of high-carbon ingredients
  - Polypropylene Fiber (cracking)
  - Steel Fiber (flexural strength)
- Improved durability
  - Increased time to replacement, reduced repair requirements (50% !?)
- Increased low-carbon supplementary cementitious materials enabled by NFC addition (e.g. fly ash)

Resolute Forest Products
- Senneterre lumber mill

collaborations welcome

PBI is actively seeking partners for NFC innovation and commercialization within performance-driven domains.

www.performancebiofilaments.com

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Questions?

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