Durability of Glass Fibre Reinforced Composites
- Experimental Methods and Results

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MEMC-VUB
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IBAC-RWTH

MEMC

CompTest 2004

Overview

- **Introduction**
  - **- Main project goals**
  - **- Goal of experimental program**

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  - **- Materials**
  - **- Testing methods and interpretation**

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- **Results and Discussion**
- **Conclusions**

Introduction

VUB-Brussels & RWTH Aachen

Projects:

Development of Durable Glass Fibre Reinforced Cementitious Composite

- Development of cement with neutral pH after hardening

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IPC (Inorganic Phosphate Cement)

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- **Modelling of mechanical behaviour**

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- Modelling durability

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IPC (Inorganic Phosphate Cement)

- Modelling of mechanical behaviour

- **Modelling durability**

Introduction

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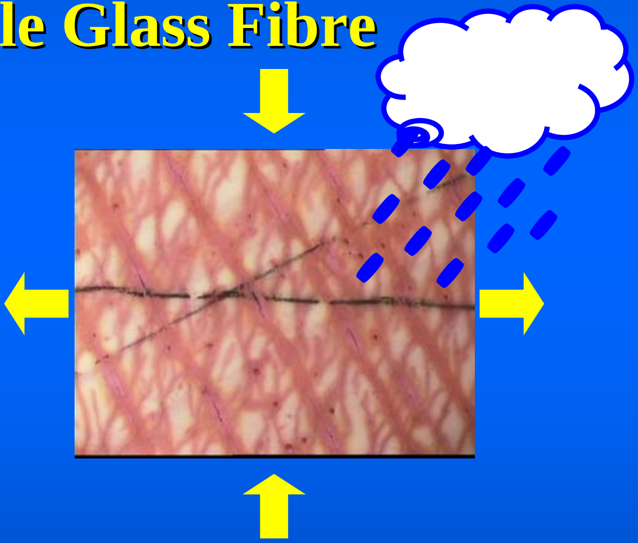
Project:

Development of Durable Glass Fibre Reinforced Concrete

macro-scale: combination of <u>measurement techniques</u>

series of experiments



- Modelling of mechanical behaviour

- Modelling durability

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Goal of experimental program

Durability of Fibre/Textile Reinforced concrete

- experimental setup
- damage mechanisms

Fibres are attacked:

Chemical degradation

Formation of reaction products in flaws

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Matrix is degraded:

Formation of matrix cracks

Chemical attack

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Fibres are attacked:
Chemical degradation
Formation of reaction products in flaws

Matrix is degraded:
Formation of matrix cracks
Chemical attack

Matrix-fibre interface is modified:
Formation of hydration products: embrittlement
Mechanical wear (cyclic load)

Goal of experimental program

Durability of Fibre/Textile Reinforced concrete

- experimental setup
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Function of

- **Materials**
- **Temperature**
- **Humidity**
- **Mechanical load**

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} Constant environmental loading (elevated RH and T)

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Goal of experimental program

Durability of Fibre/Textile Reinforced concrete

- experimental setup
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Function of

- **Materials**
- **Temperature**
- **Humidity**
- **Mechanical load**

Constant environmental loading
(elevated RH and T)

Repeated environmental loading
(wetting-drying & freezing-thawing)

Constant environmental load

Materials

-AR-glass fibres and OPC (Ordinary Portland cement, pH = 13,5)

-AR-glass fibres and IPC (Inorganic Phospate Cement)

-E-glass fibres and IPC (Inorganic Phospate Cement)

Constant environmental load: Accelerated Ageing

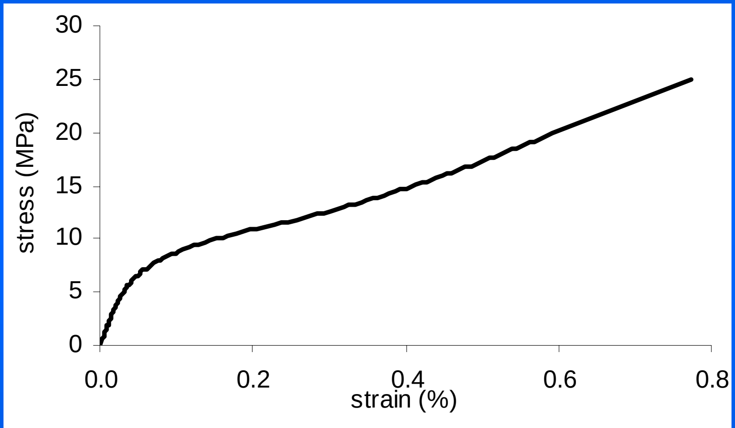
- water, 50°C

Cyclic environmental load

Materials

-E-glass fibres and IPC (Inorganic Phosphate Cement, pH = 7)

Series 1: no pre-loading



Cyclic environmental load: Accelerated Ageing

- wetting-drying (60 cycles)
- freezing-thawing (60 cycles)

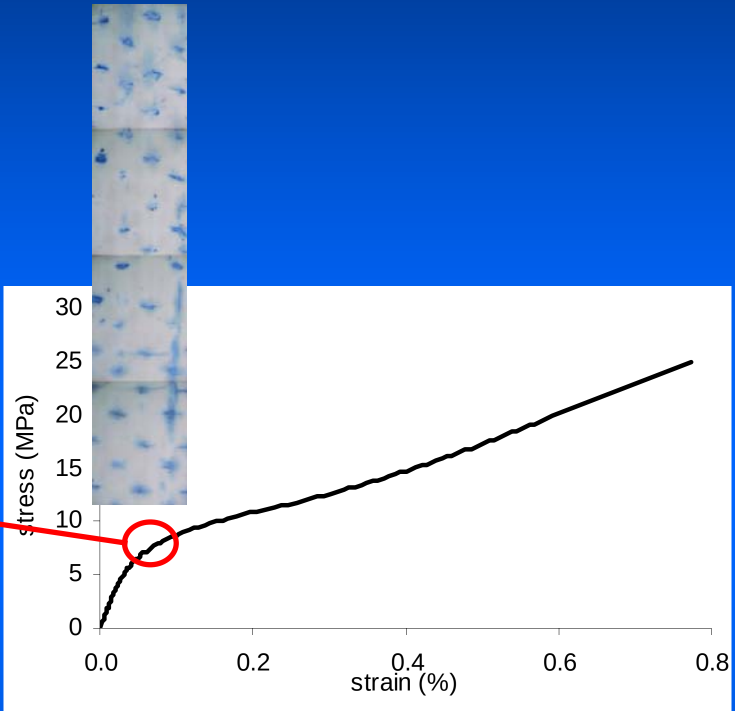
Cyclic environmental load

Materials

-E-glass fibres and IPC (Inorganic Phosphate Cement, pH = 7)

Series 1: no pre-loading

Series 2: multiple-cracking zone



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Cyclic environmental load

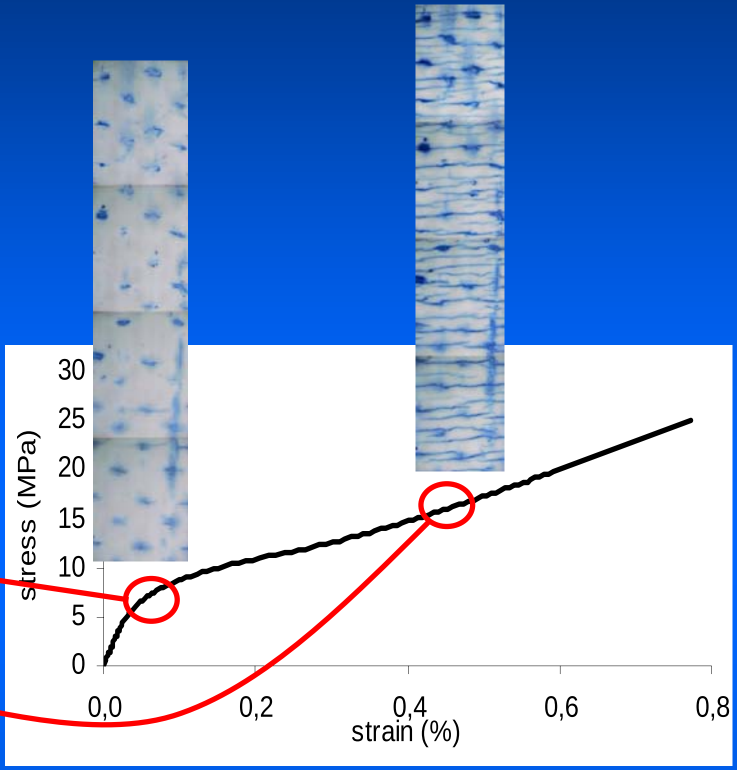
Materials

-E-glass fibres and IPC (Inorganic Phosphate Cement, pH = 7)

Series 1: no pre-loading

Series 2: multiple-cracking zone

Series 3: post-cracking zone



Cyclic environmental load: Accelerated Ageing

- wetting-drying (60 cycles)
- freezing-thawing (60 cycles)

Experimental program

After environmental loading (constant or cyclic)

Matrix cracking: microscope & camera

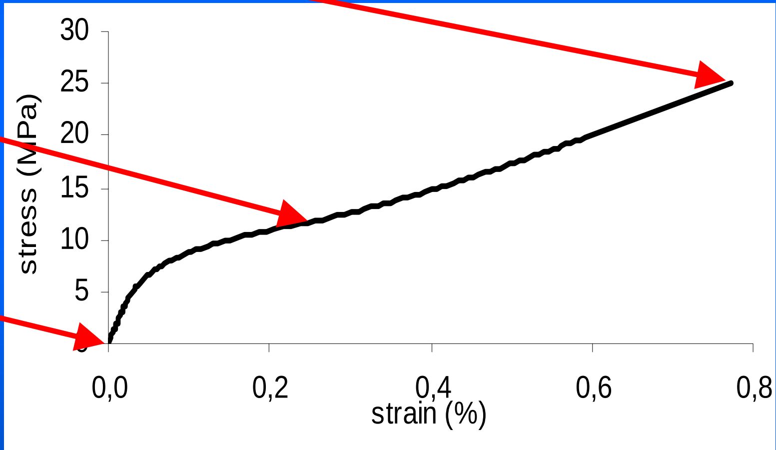
Experimental program

After environmental loading (constant or cyclic)

Matrix cracking: microscope & camera

Static loading

- Strength: fibre strength or matrix-fibre interface quality
- Post-cracking stiffness: fibre quality
- Pre-cracking stiffness: matrix quality



Experimental program

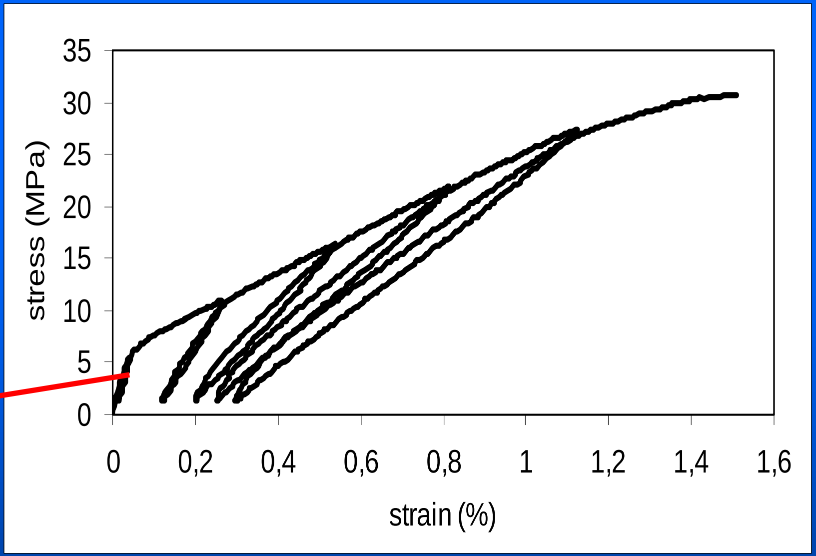
After environmental loading (constant or cyclic)

Matrix cracking: microscope & camera

Static loading

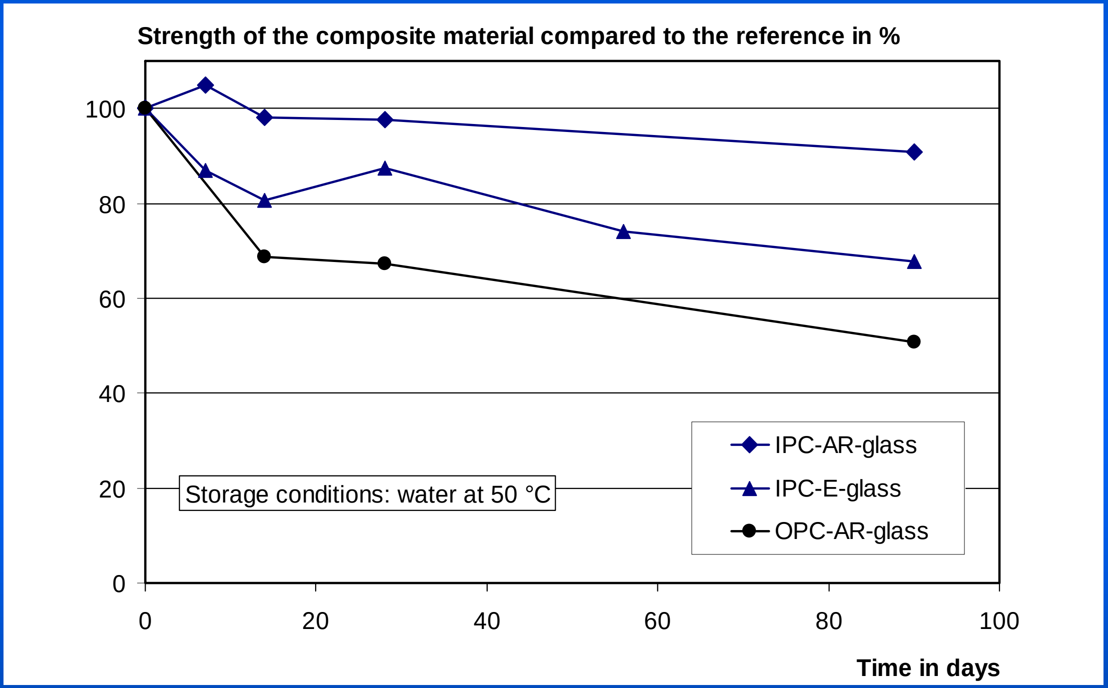
- Strength: fibre strength or matrix-fibre interface quality
- Post-cracking stiffness: fibre quality
- Pre-cracking stiffness: matrix quality

Interpretation cycles: matrix-fibre interface



Results: constant environmental loading

- tensile strength



OPC:

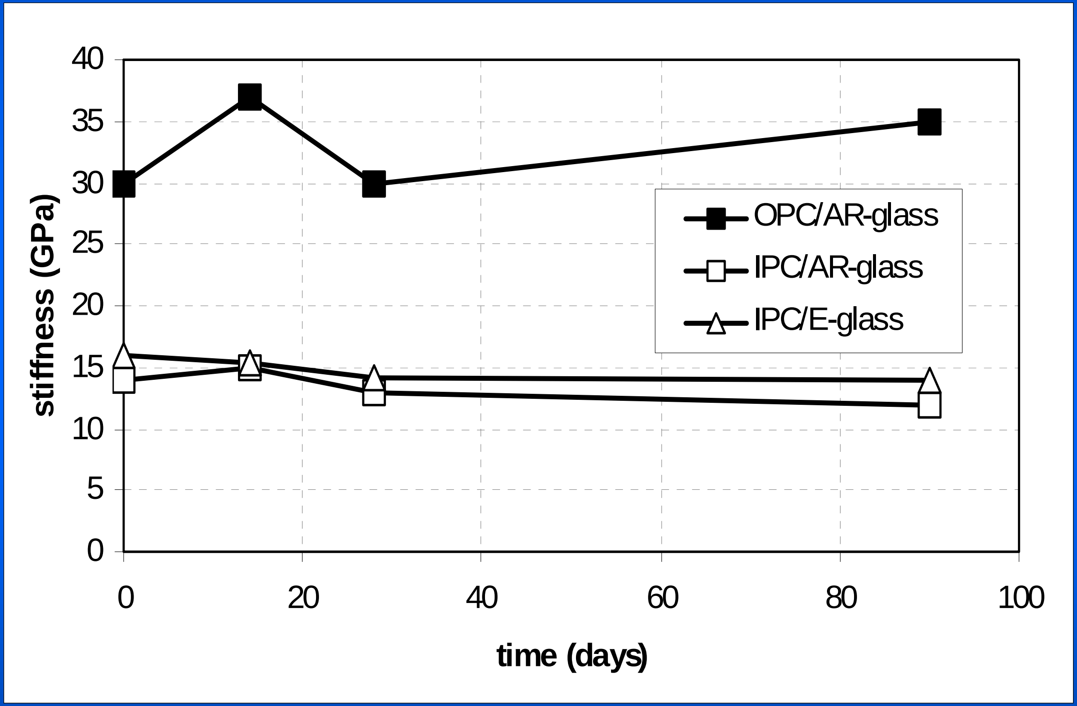
- Loss of strength: fibre attack

IPC:

- Less loss of strength

Results: constant environmental loading

Monotonic tensile loading: pre-cracking stiffness (E_{c1})



OPC:

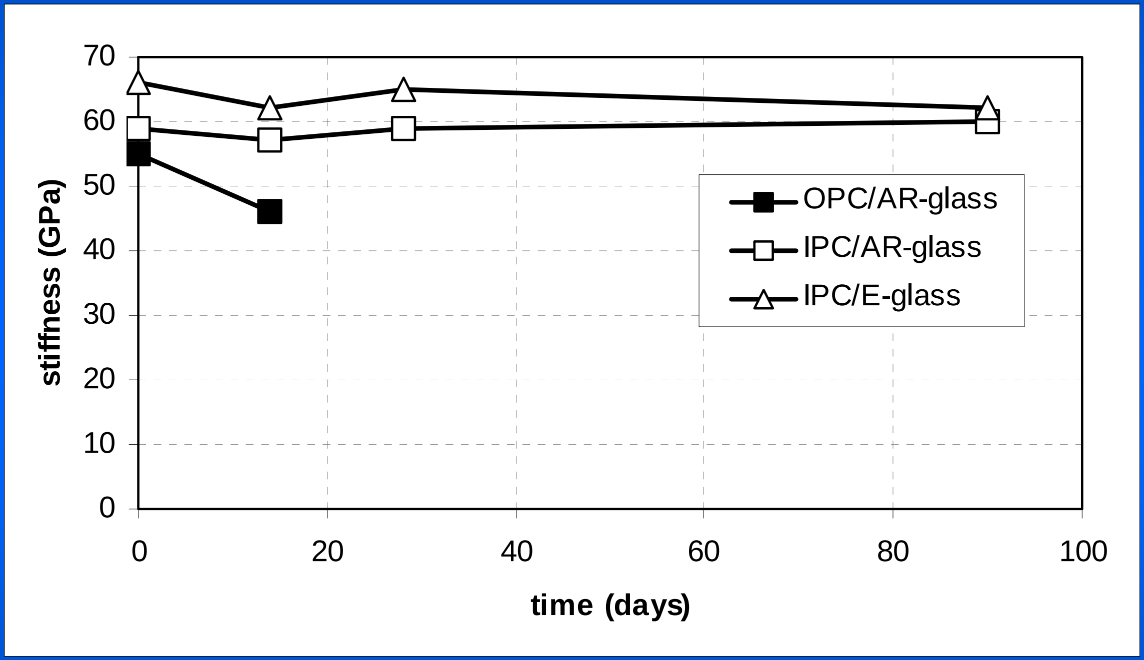
- Loss of strength: fibre attack
- Matrix stable

IPC:

- Less loss of strength
- Matrix stable

Results: constant environmental loading

<u>Monotonic tensile loading:</u> post-cracking stiffness



<u>OPC</u>:

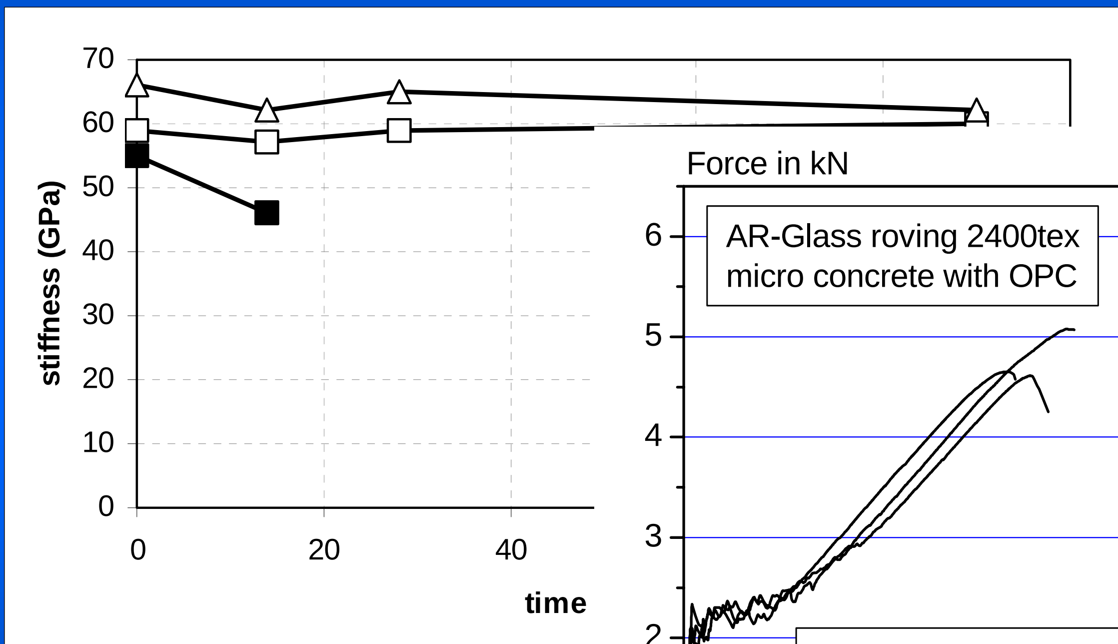
- Loss of strength: fibre attack
- Matrix stable
- <u>Ductility lost</u>

<u>IPC</u>:

- Less loss of strength
- Matrix stable
- <u>Fibres not attacked seriously</u>

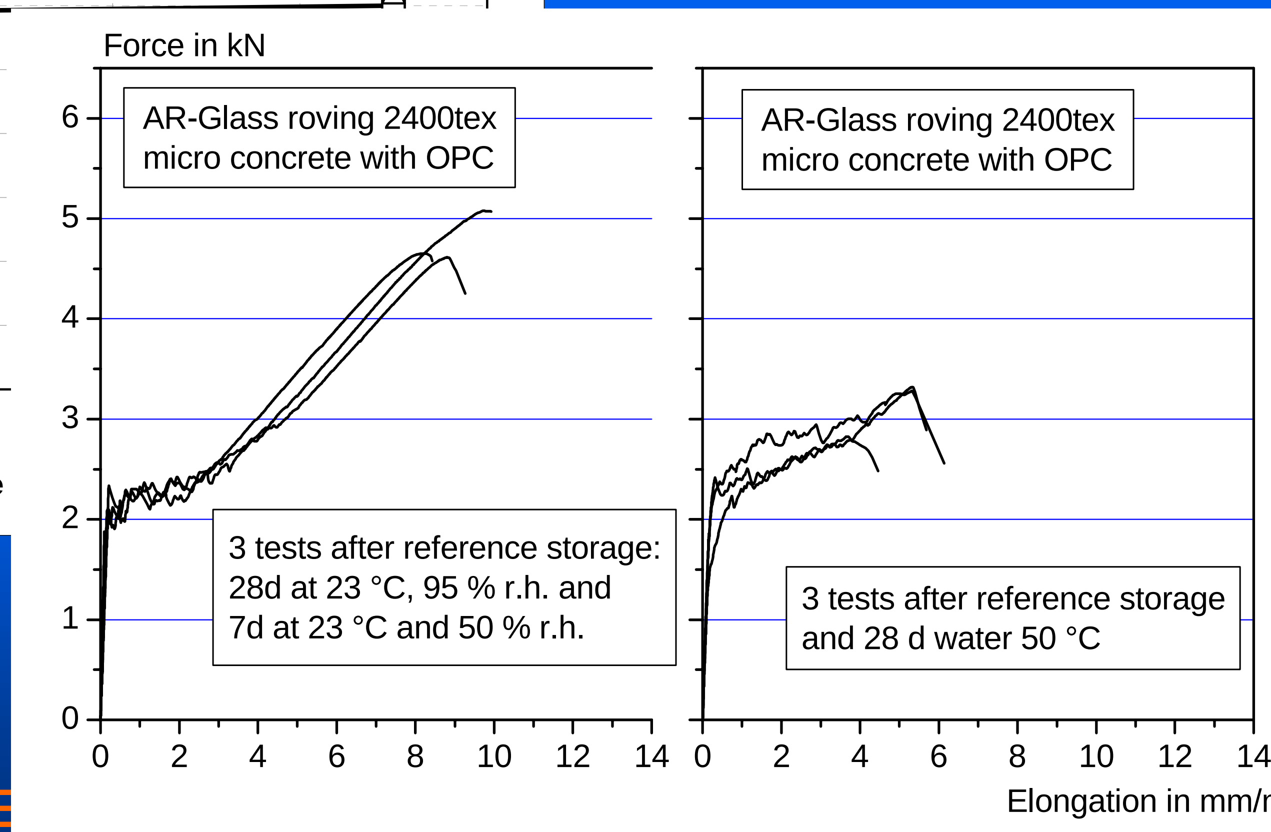
Results: constant environmental loading

Monotonic tensile loading: post-cracking stiffness (E_{III})



OPC:

- Loss of strength: fibre



Cyclic environmental load

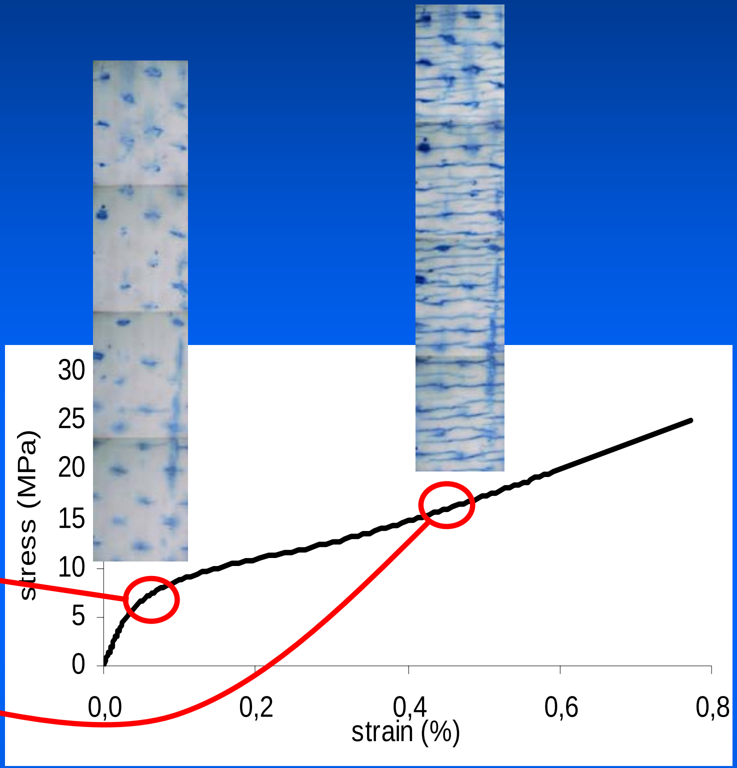
Materials

-E-glass fibres and IPC (Inorganic Phosphate Cement, pH = 7)

Series 1: no pre-loading

Series 2: multiple-cracking zone

Series 3: post-cracking zone

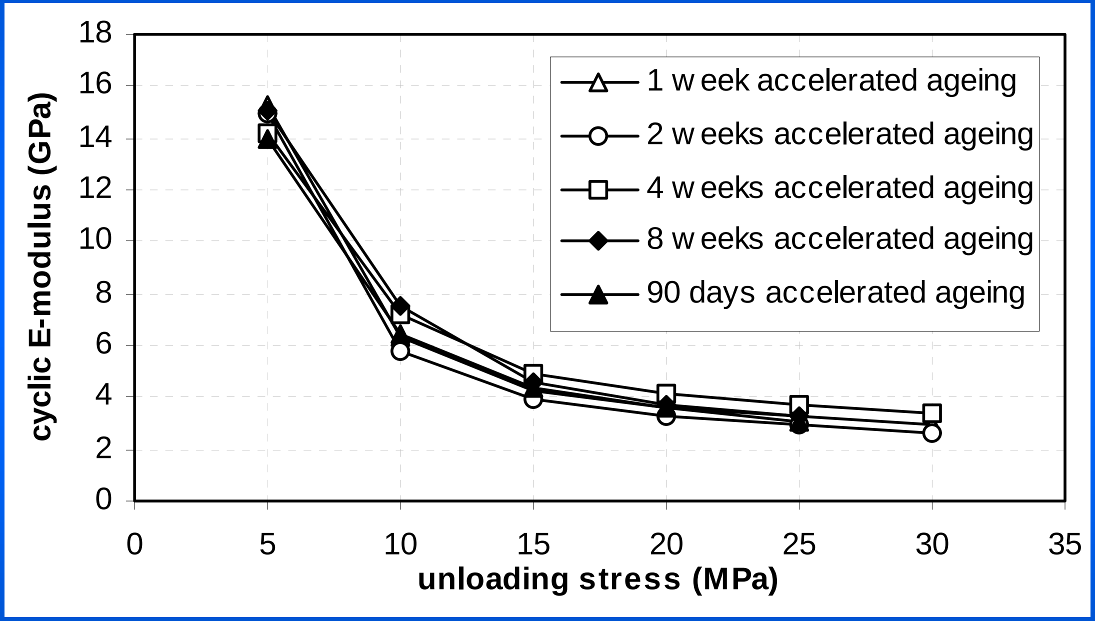


Cyclic environmental load: Accelerated Ageing

- wetting-drying (60 cycles)
- freezing-thawing (60 cycles)

Results: constant environmental loading

Cyclic tensile loading: matrix-fibre interface



OPC:

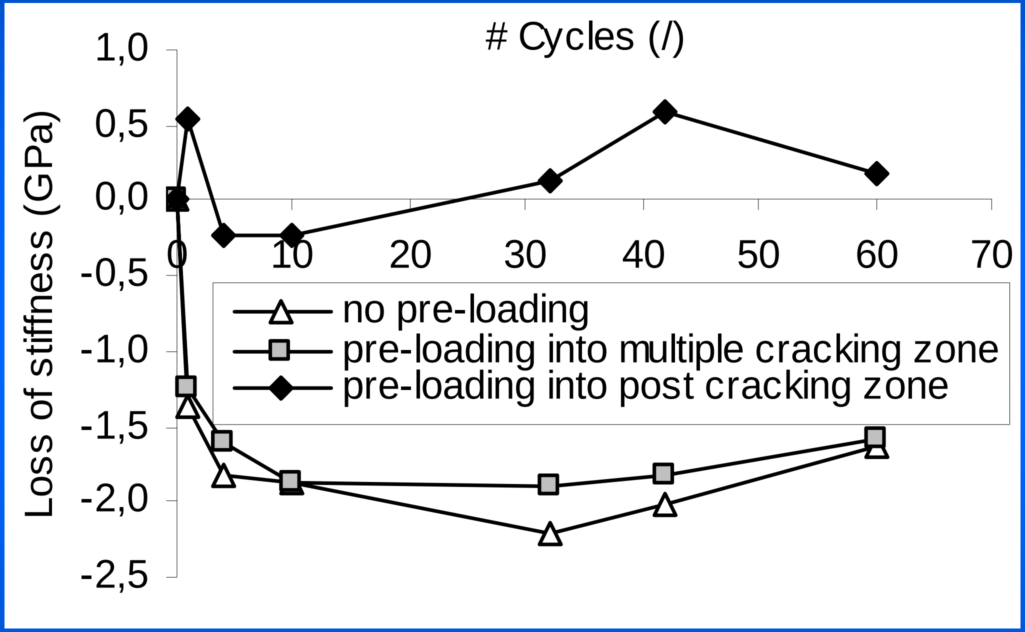
- Loss of strength: fibre attack
- Matrix stable
- Ductility lost

IPC:

- Less loss of strength
- Matrix stable
- Fibres not attacked seriously
- Interface stable

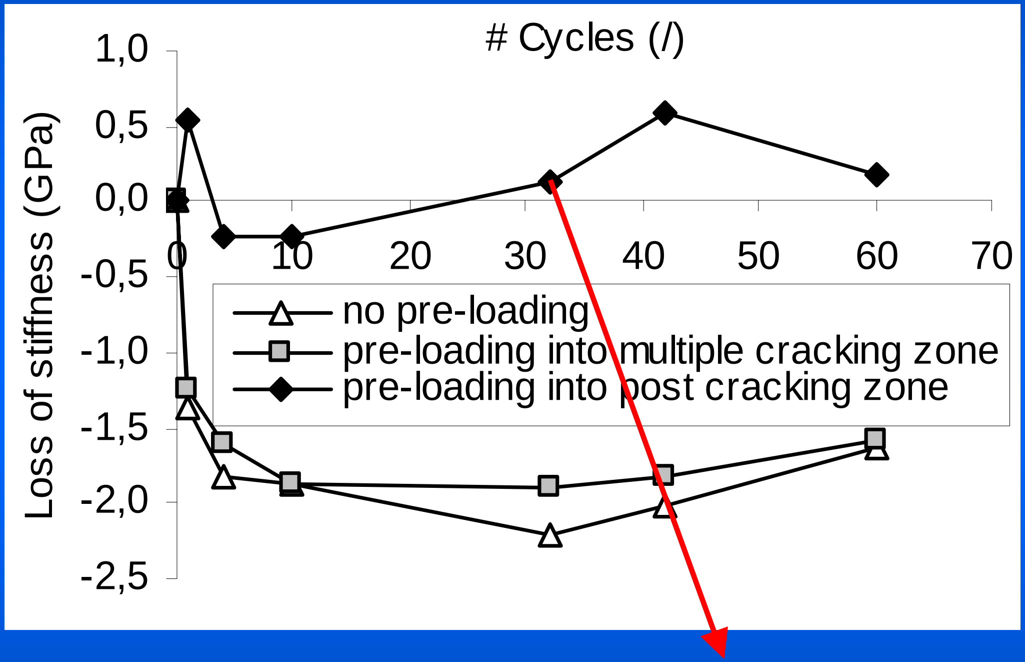
Results: repeated environmental loading

Freezing-thawing



Results: repeated environmental loading

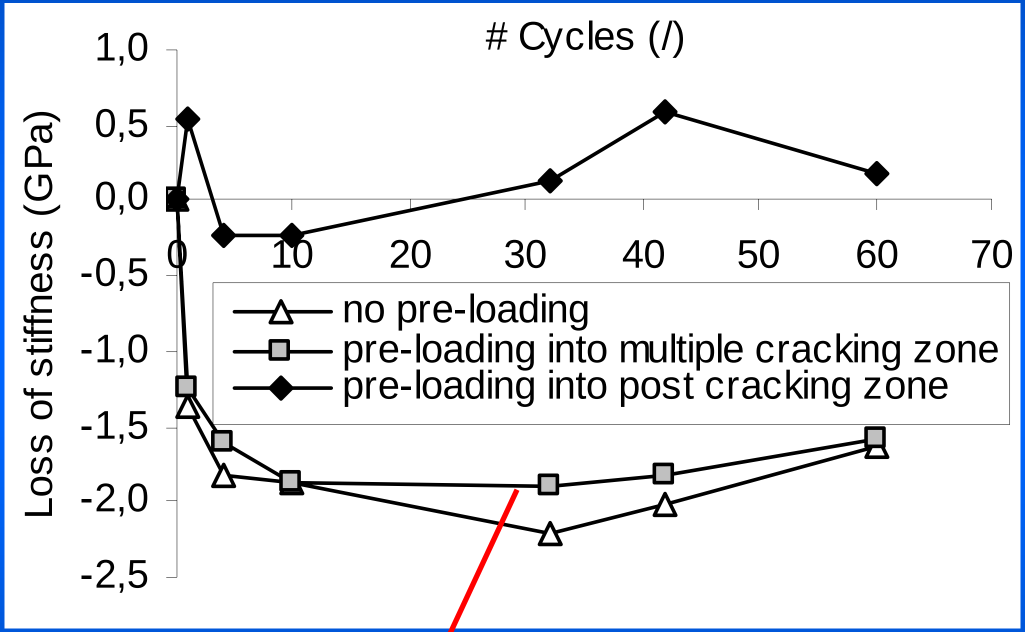
Freezing-thawing



- Pre-loading into post-cracking zone: no extra damage mechanism

Results: repeated environmental loading

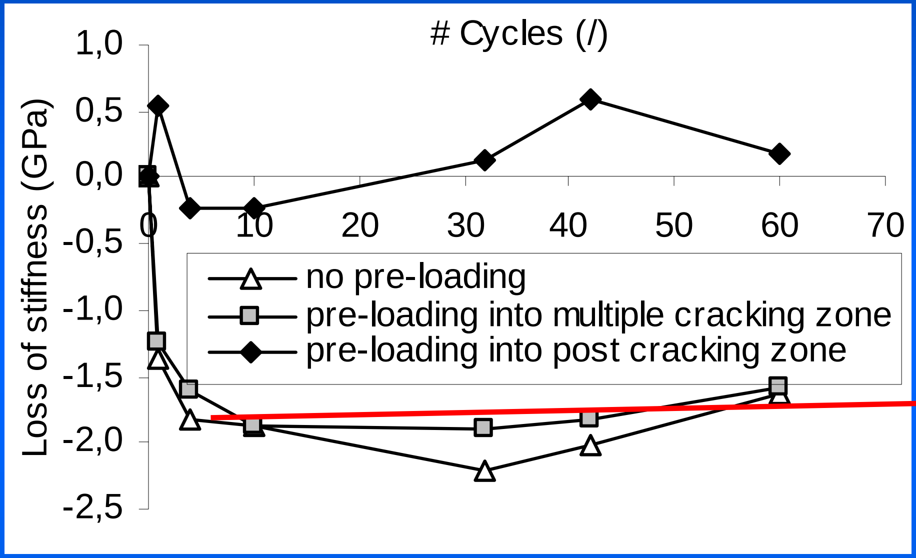
Freezing-thawing



- Pre-loading into post-cracking zone: no extra damage mechanism
- No or small pre-loading: damage (matrix cracking?) first cycles

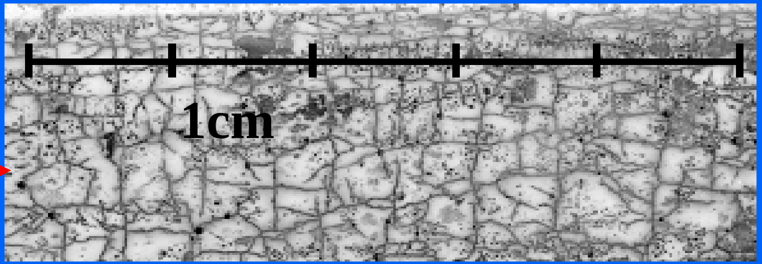
Results: repeated environmental loading

Freezing-thawing



First cycles: matrix cracking

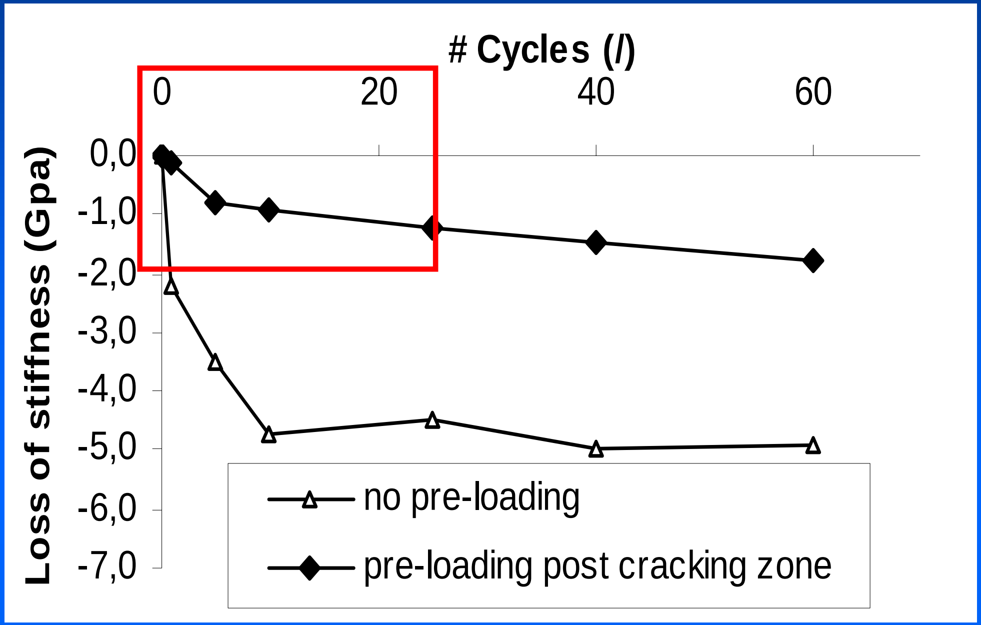
Later: stabilisation



- •Random alignment cracking
- •No large internal stresses due to fibres

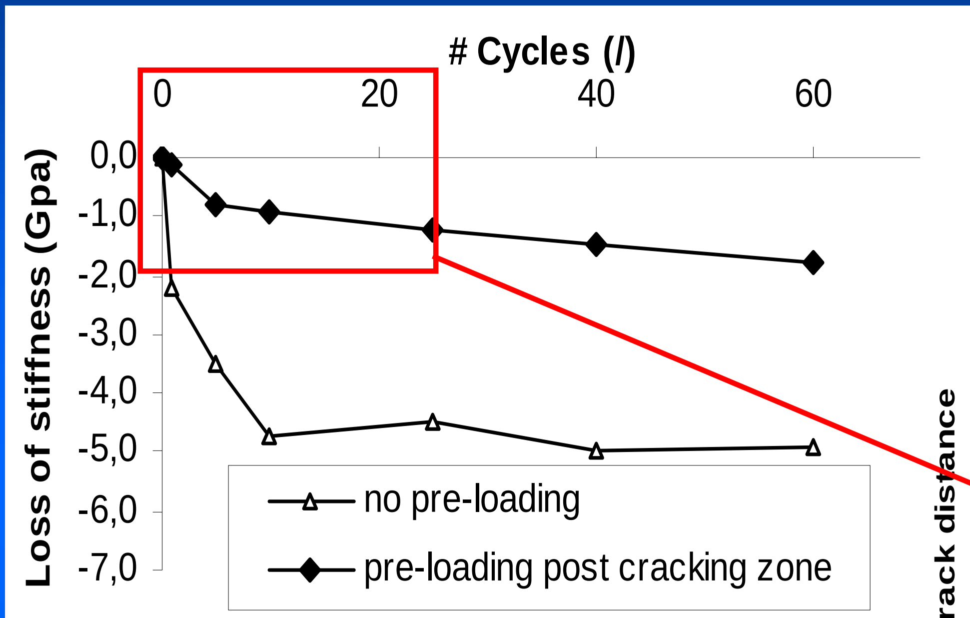
No loss of strength: no damage to fibres

Results: repeated environmental loading



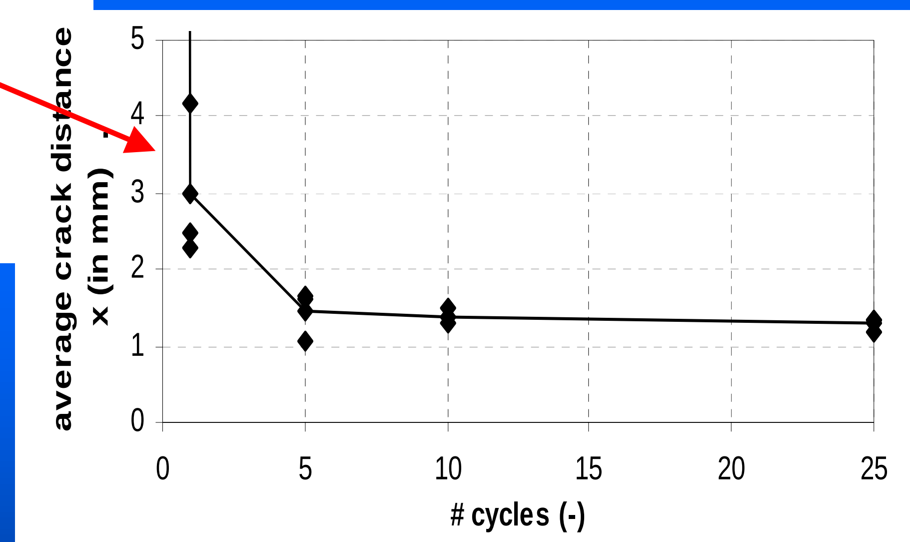
Wetting-drying

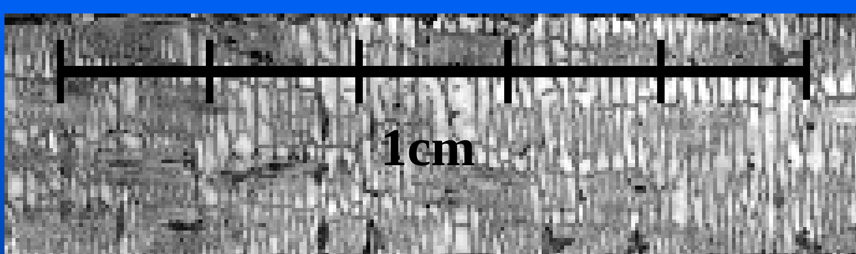
Results: repeated environmental loading



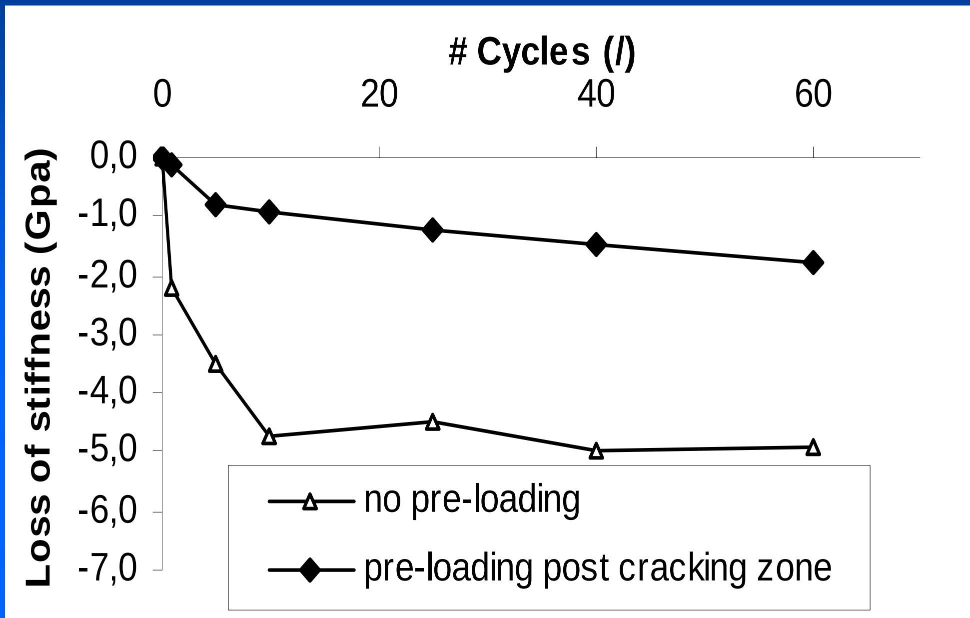
Wetting-drying

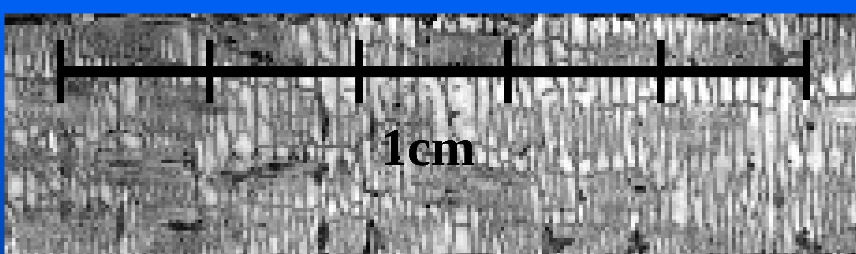
- first cycles matrix cracking
- later other damage mechanism





Results: repeated environmental loading

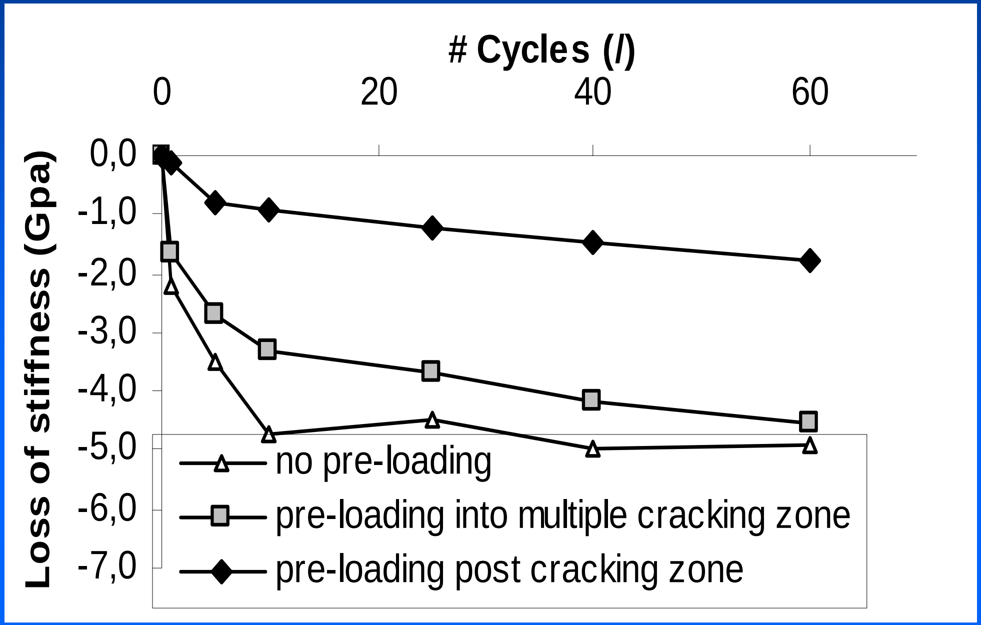




<u>Wetting-drying</u>

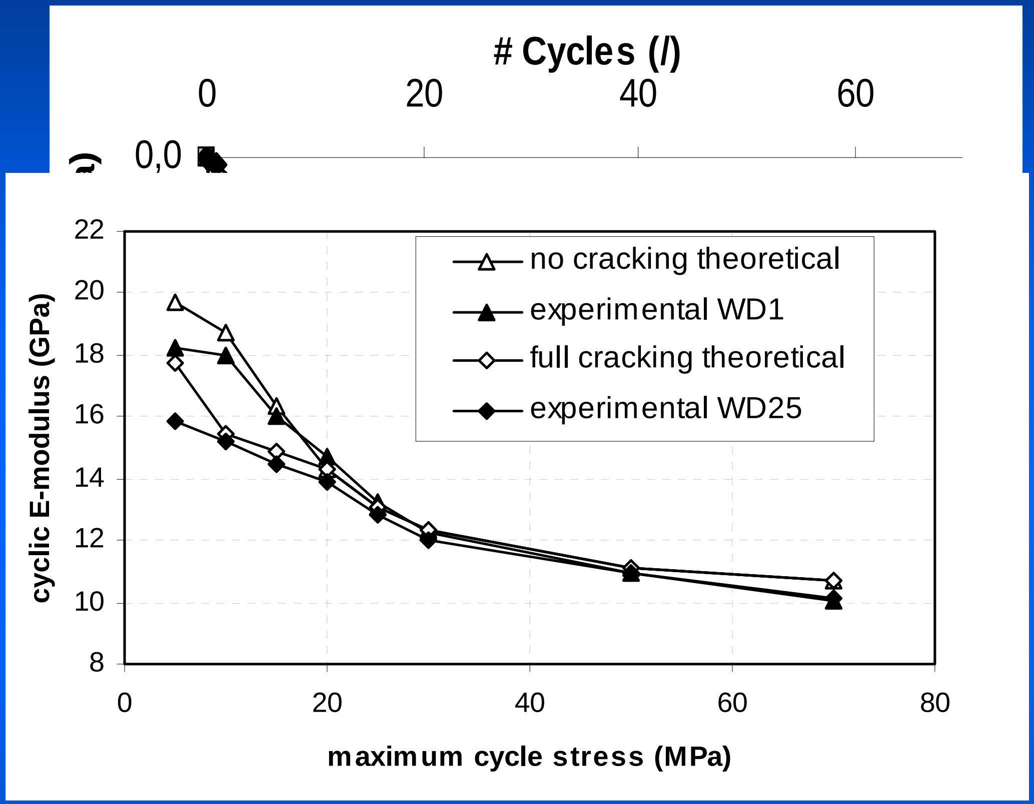
- first cycles matrix cracking
- later other damage mechanism
- cracks aligned and perpendicular to fibres: internal stresses due to presence of fibres

Results: repeated environmental loading



- first cycles matrix cracking
- later other damage mechanism
- cracks aligned and perpendicular to fibres: internal stresses due to presence of fibres
- no evolution strength: fibres not attacked

Results: repeated environmental loading



- first cycles matrix cracking
- later other damage mechanism
- cracks aligned and perpendicular to fibres: internal stresses due to presence of fibres
- no evolution strength: fibres not attacked
- cyclic loading: matrix-fibre interface wear due to cyclis loading

Conclusions

Constant environmental loading:

Cyclic environmental loading:

Conclusions

Constant environmental loading:

- pH has considerable influence on fibre strength

Cyclic environmental loading:

Conclusions

Constant environmental loading:

- **pH has considerable influence on fibre strength**
- **IPC prevents low durability due to chemical attack**

Cyclic environmental loading:

Conclusions

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Cyclic environmental loading:

- **Freezing thawing: fibres prevent early fracture**

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Cyclic environmental loading:

- **Freezing thawing: fibres prevent early fracture**
- **Same fibres can provoke damage due to wetting-drying**

Conclusions

Constant environmental loading:

- pH has considerable influence on fibre strength
- IPC prevents low durability due to chemical attack

Cyclic environmental loading:

- Freezing thawing: fibres prevent early fracture
- Same fibres can provoke damage due to wetting-drying
  - First WD cycles: matrix cracking
  - Later: matrix-fibre interface degradation

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