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POLYTECHNIQUE
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Monitoring of the creep and the relaxation behaviour of concrete since setting time, part 2 : tension

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Aix en Provence
Tuesday May 29, 2012

Background

Introduction

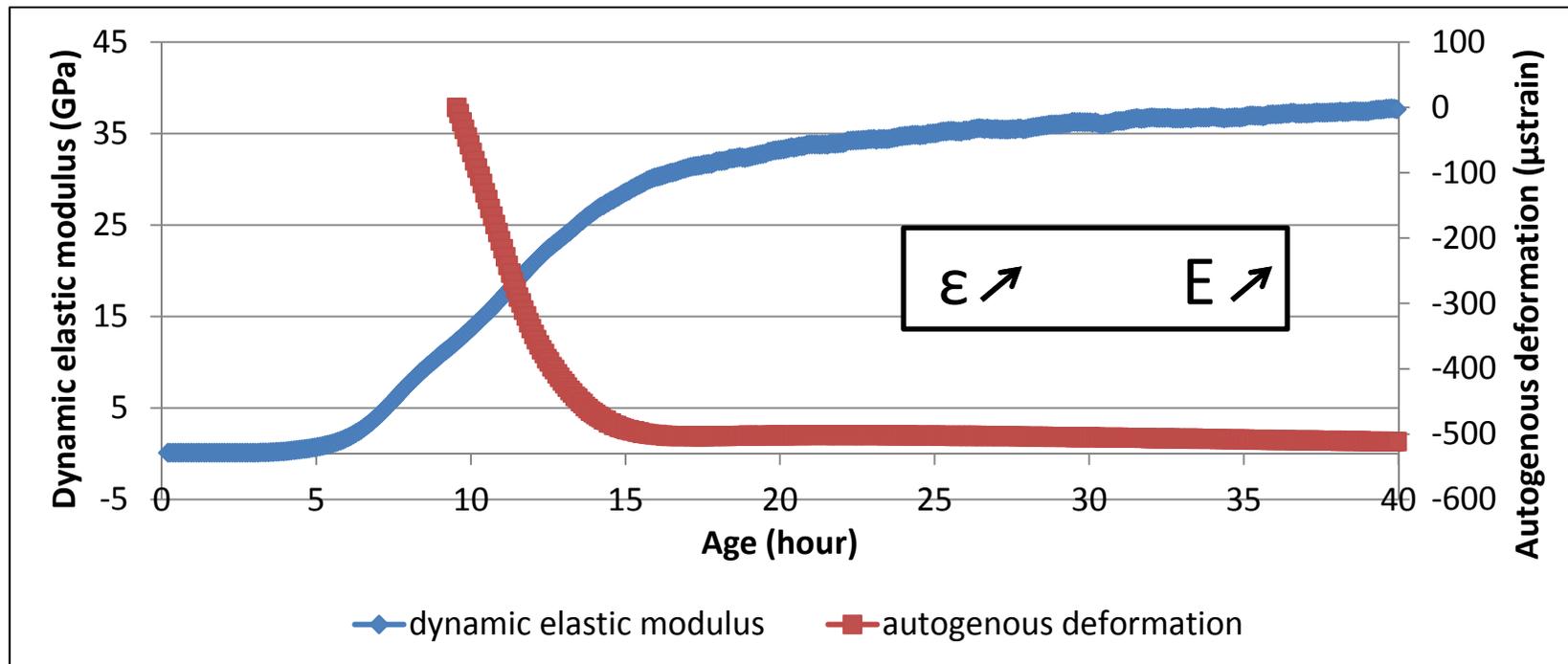
Test setup

Results

Conclusion

Perspectives

- Early age behaviour of concrete has a impact on the durability of concrete structures.
- During few hours after setting, mechanical and chemical properties of the concrete evolve very quickly.



Background

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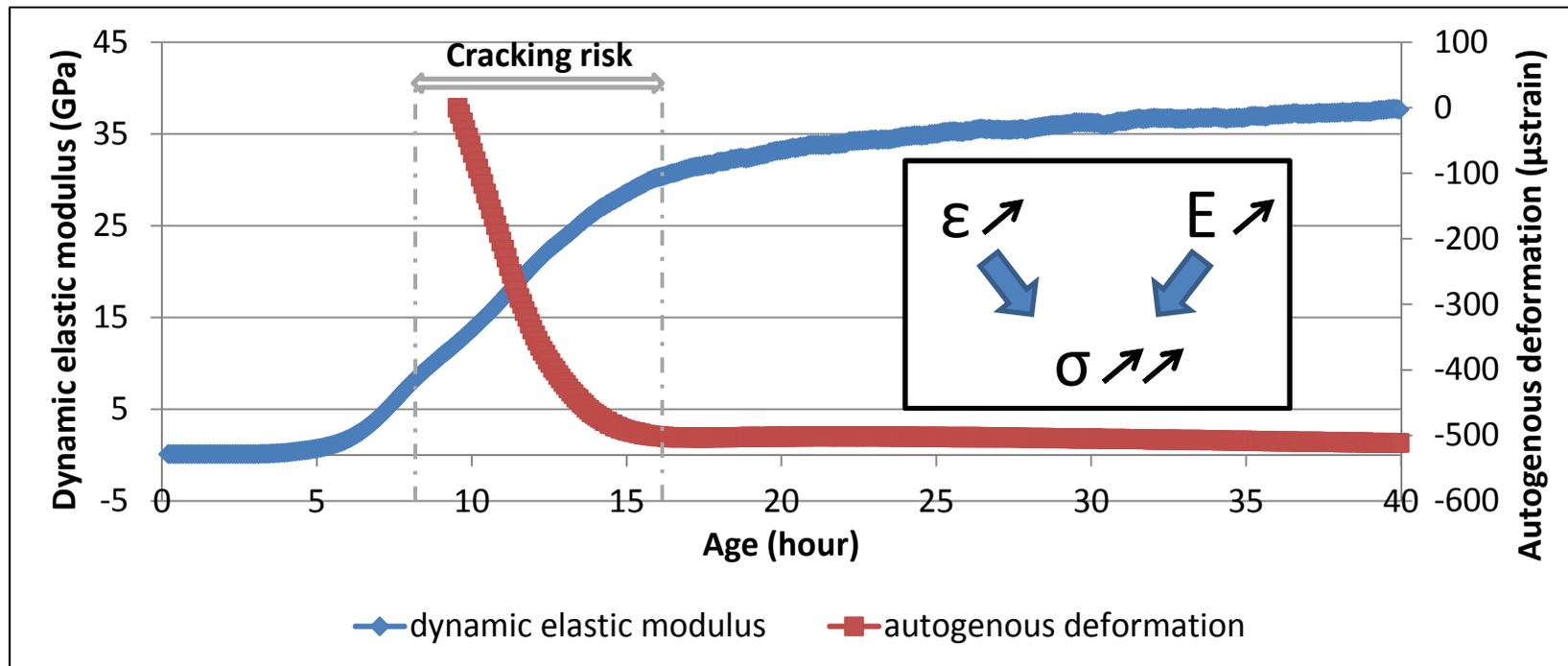
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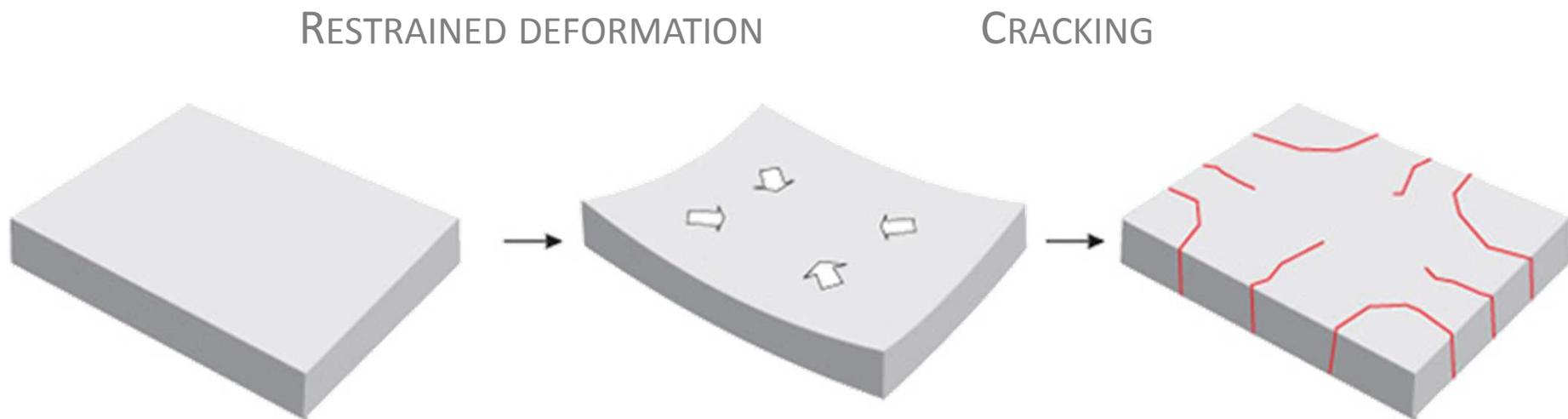
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Perspectives

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- Autogenous deformation
- Drying shrinkage
- Thermal deformation

Elastic response
AND
Creep / relaxation

Background

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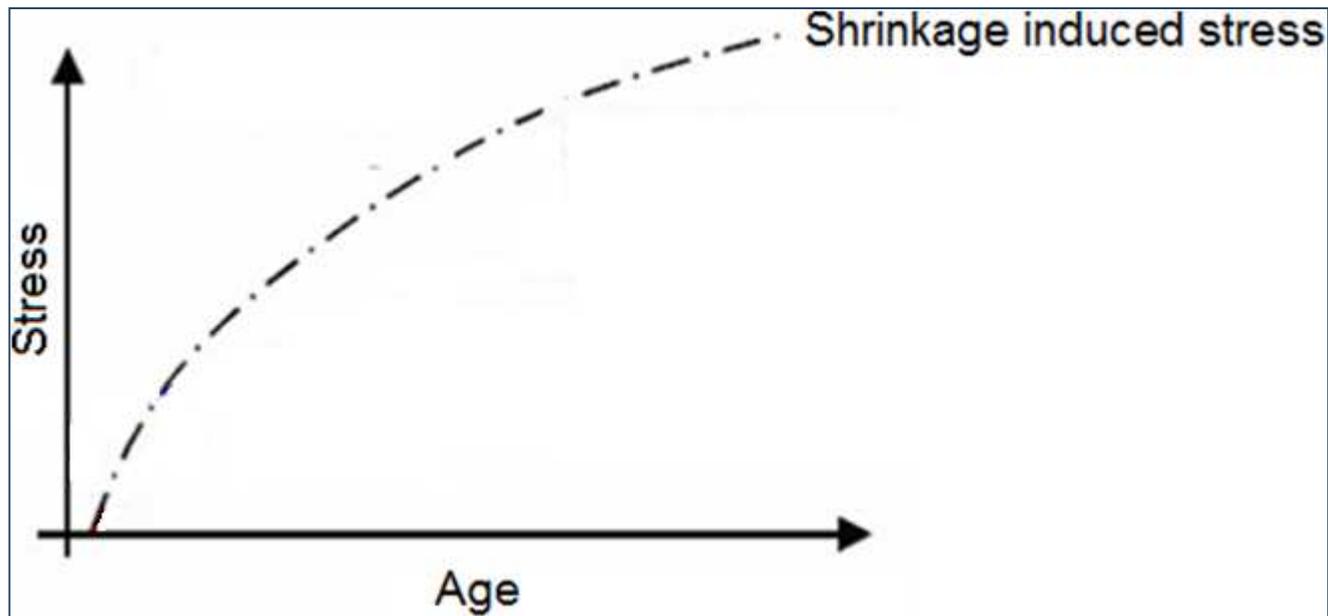
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Perspectives

- Early age behaviour of concrete has a impact on the durability of concrete structures.
 - Cracking risk due to restrained shrinkage



Background

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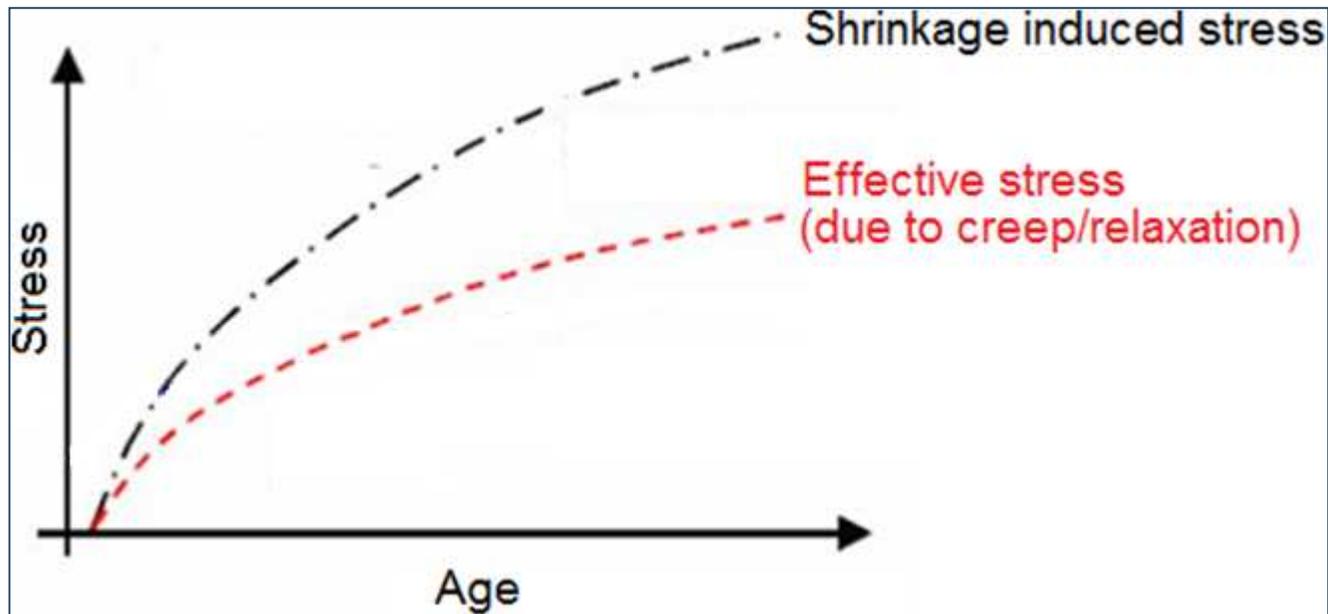
Test setup

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Background

Introduction

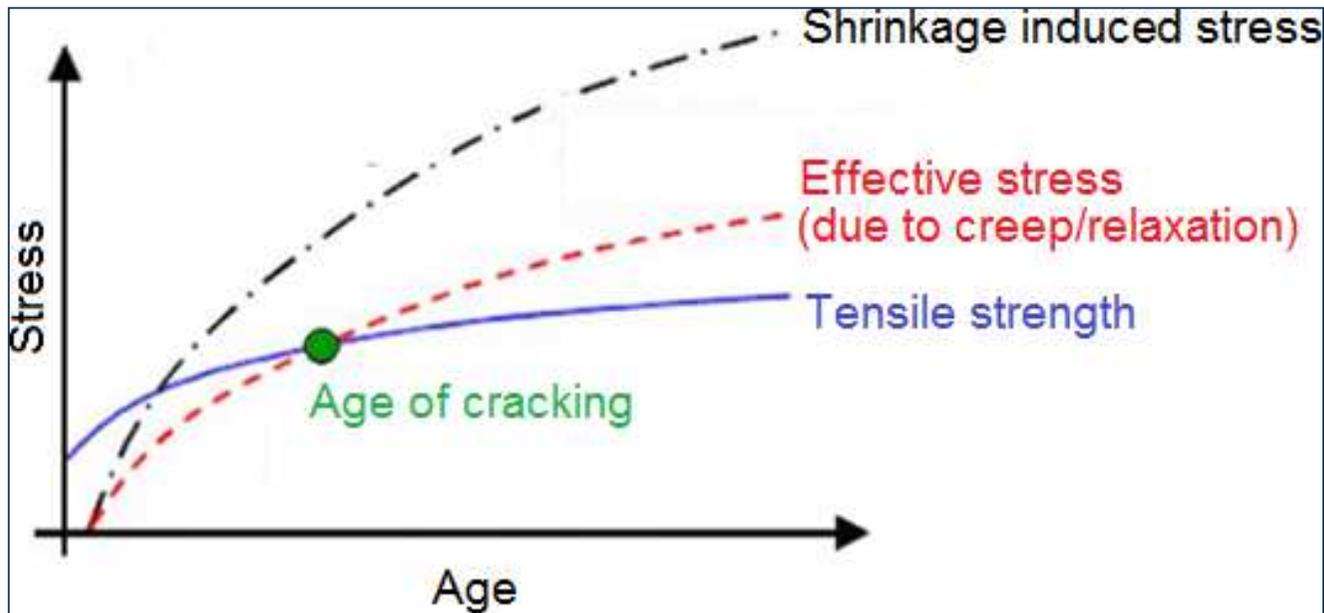
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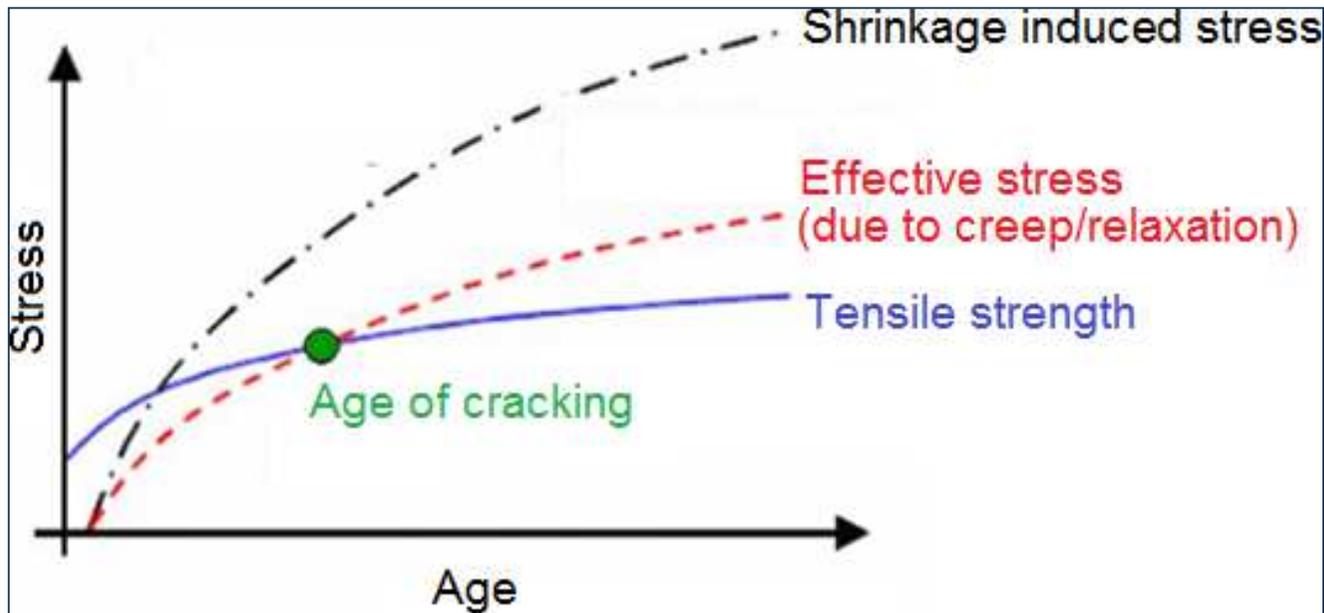
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Necessity to know the evolution of the parameters involved

Summary

- Test setup
 - Experimental tools
 - Protocol of loadings
- Results and discussion
- Conclusion
- Perspectives

Experimental tools

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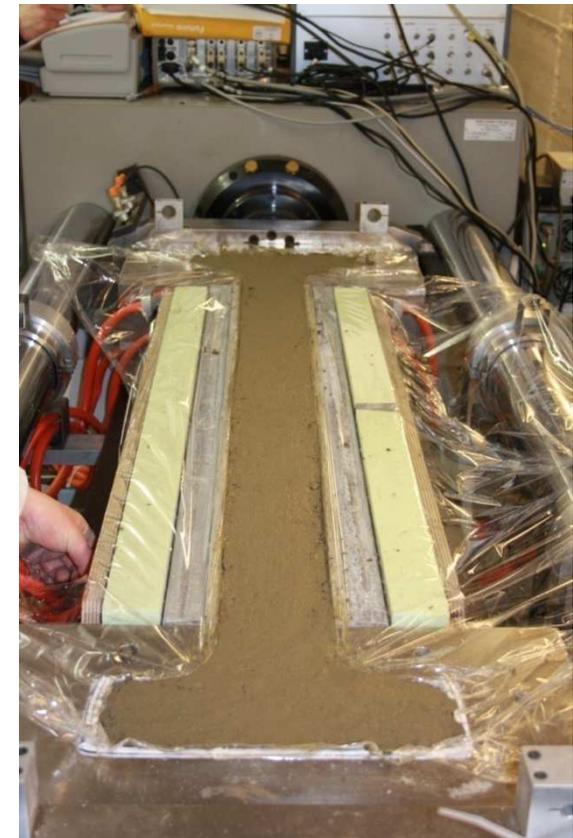
Results

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Perspectives

TSTM (Temperature Stress Testing Machine)

- Linear horizontal device
- 400 kN compression/traction jack
- Computer controlled
- Dog bone shape
 - Length = 1.3 m
 - Section = 100 x100 mm²
- Fixed and mobile heads
- Surrounded by a plastic film
 - Autogenous conditions
- Displacement sensors without contact
 - 75 cm spacing
- Thermal regulation
- Twin mould



Experimental tools

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Fixed head



Mobile head



Experimental tools

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Experimental tools

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Test setup

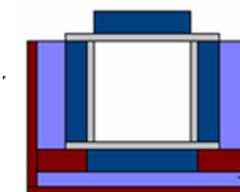
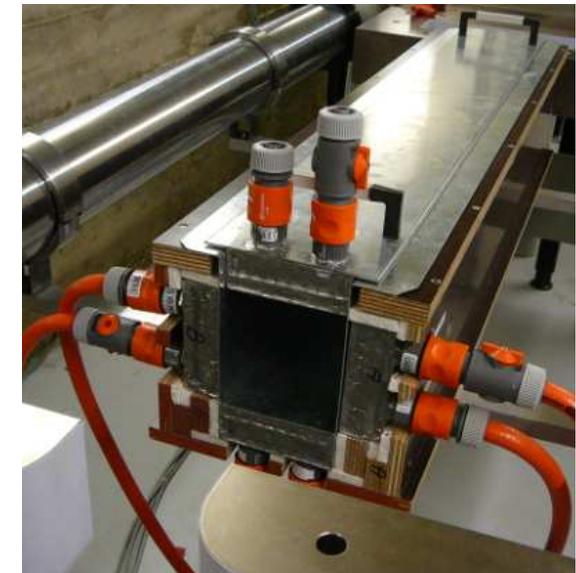
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Legend

- Aluminum
- Thermal regulation
- Isolation
- Wood

Experimental tools

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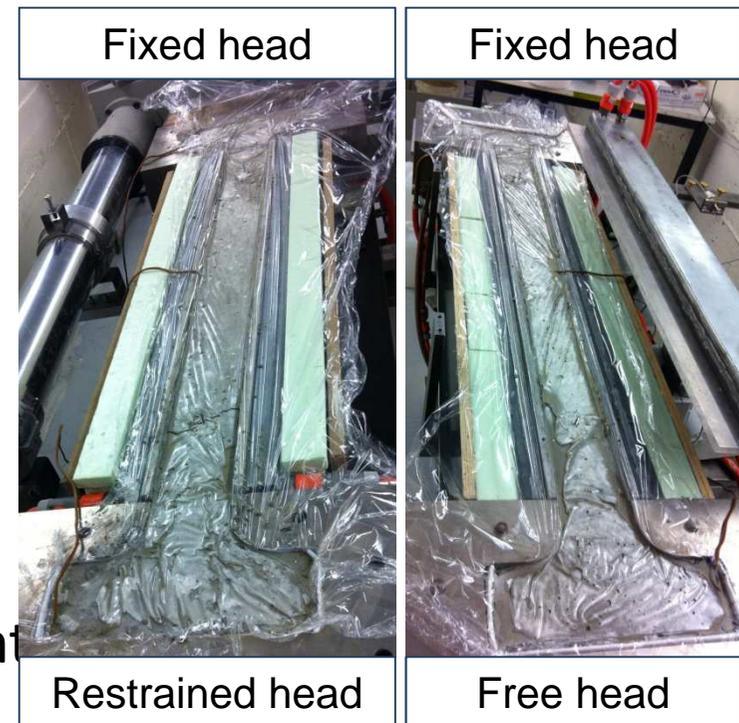
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Experimental tools

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Experimental tools

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Experimental tools

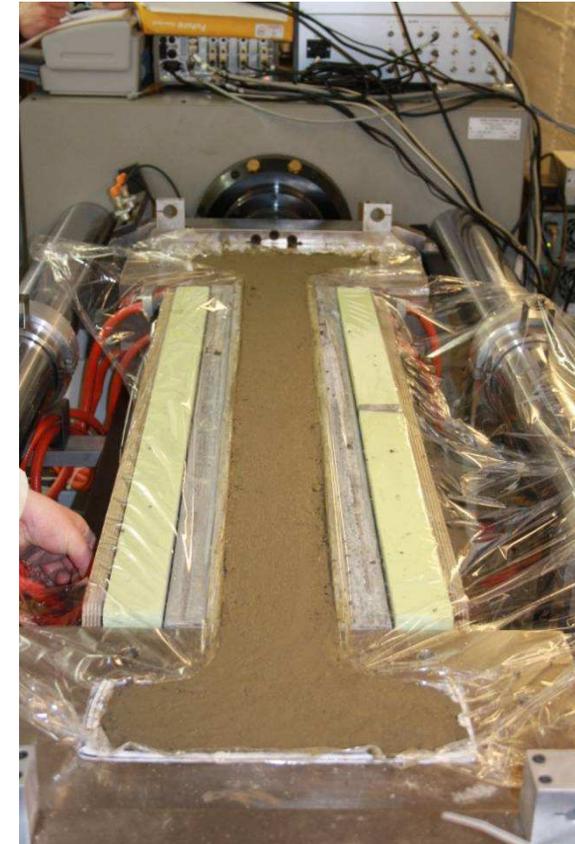
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TSTM (Temperature Stress Testing Machine)

- Technical possibilities
 - Tension / compression
 - Sealed / unsealed conditions
 - Control according to:
 - Force
 - Displacement in the extremities
 - Displacement in the span
 - Various temperature
 - Multiple stress levels
- Tests
 - Shrinkage (free)
 - Creep in tension/compression
 - Relaxation in tension/compression
 - Restrained shrinkage
 - E modulus



Protocol of loadings

Introduction

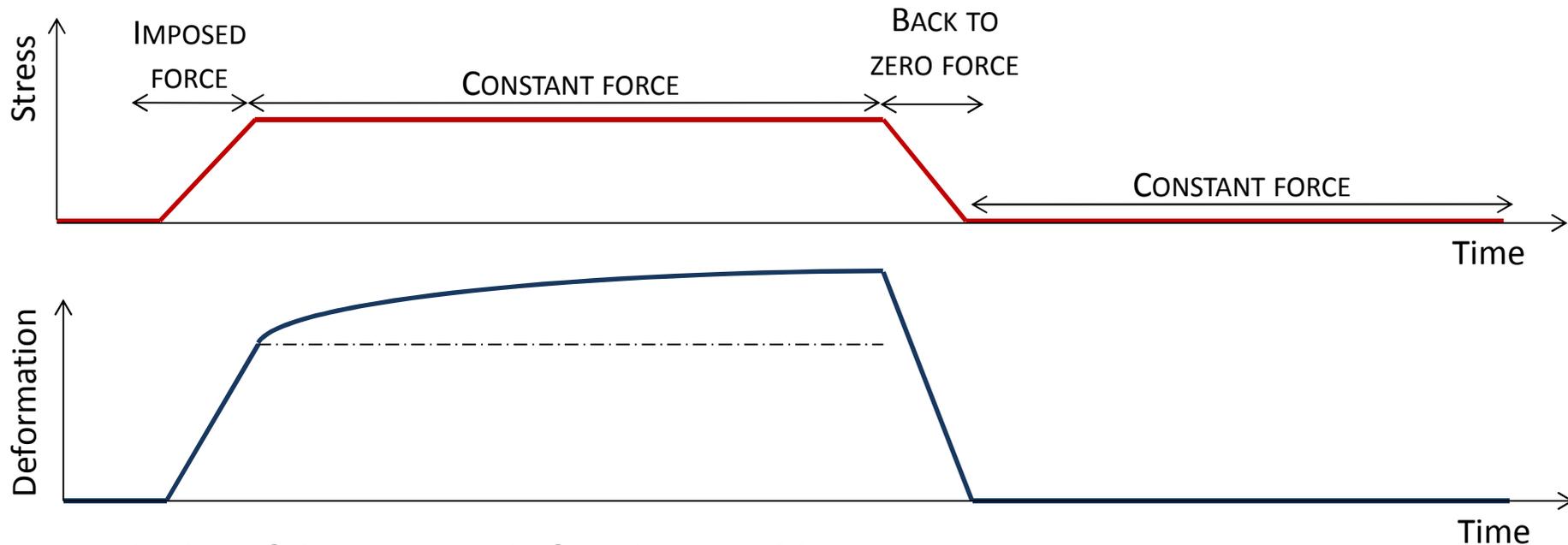
Test setup

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Evolution of the creep at early age



Beginning of the test = end of setting = 7H00

Loading = 40% of the strength in tension

Duration of the cycle = 30 min

Duration of loading = 5 min

Protocol of loadings

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Test setup

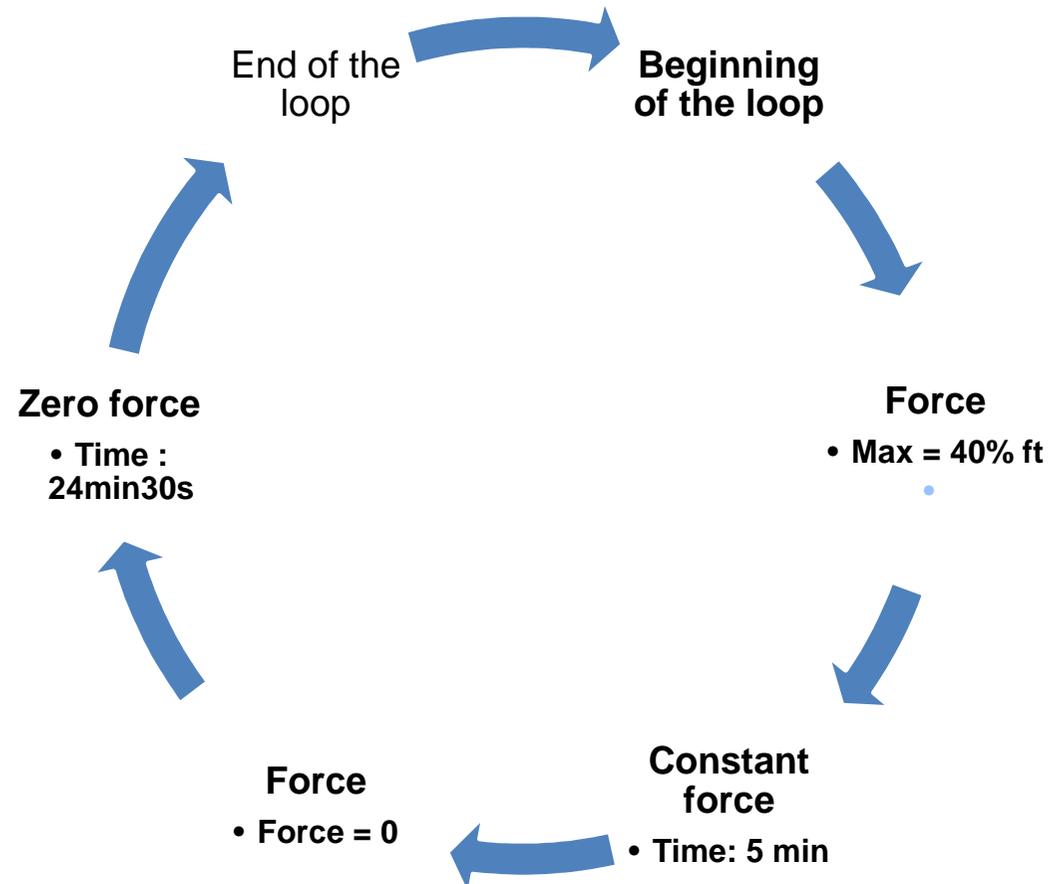
Results

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Evolution of the creep at early age

- Definition of the **Young's modulus** evolution during the increase of deformation.
- Definition of the **creep function** when the deformation is constant.



Protocol of loadings

Introduction

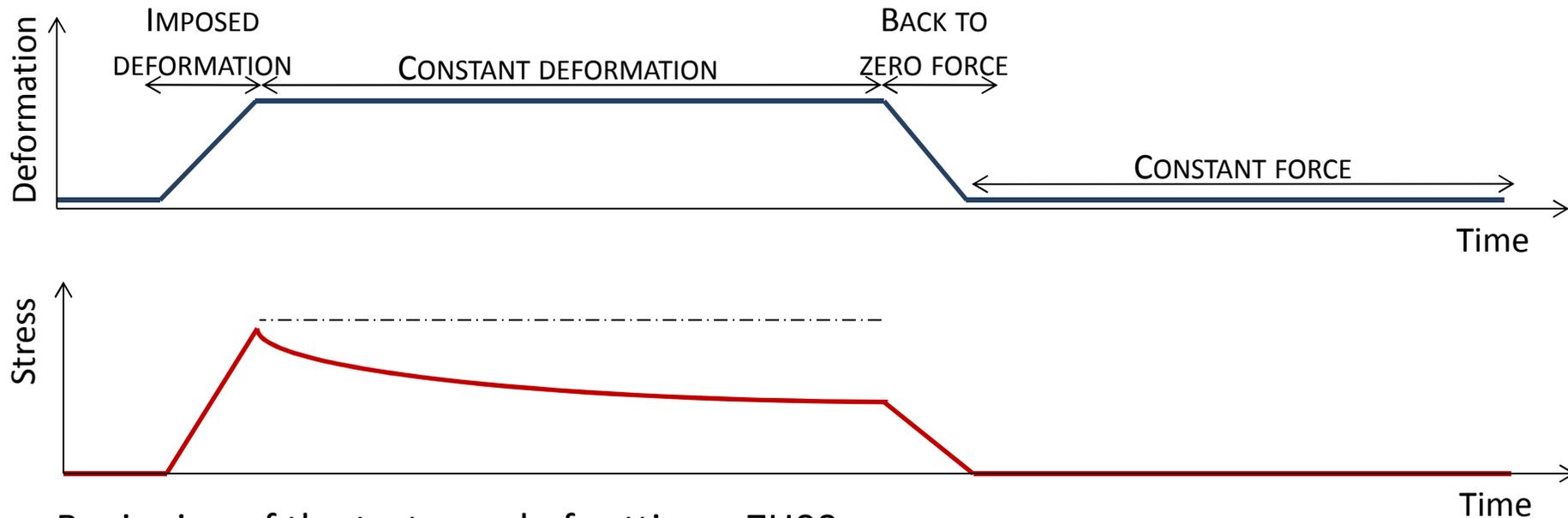
Test setup

Results

Conclusion

Perspectives

Evolution of the relaxation at early age



Beginning of the test = end of setting = 7H00

Loading = 40% of the strength in tension and 20% of the strength in compression

Duration of the cycle = 30 min

Duration of loading = 5 min

Alternation between tension and compression

Protocol of loadings

Introduction

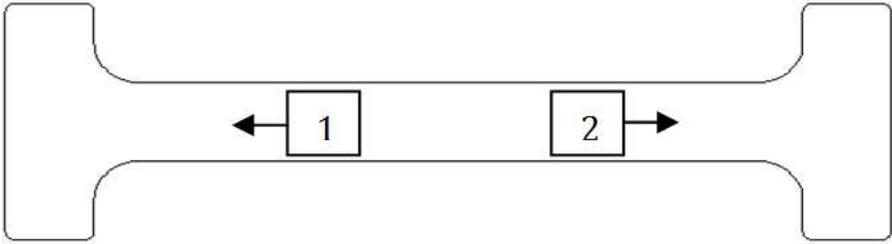
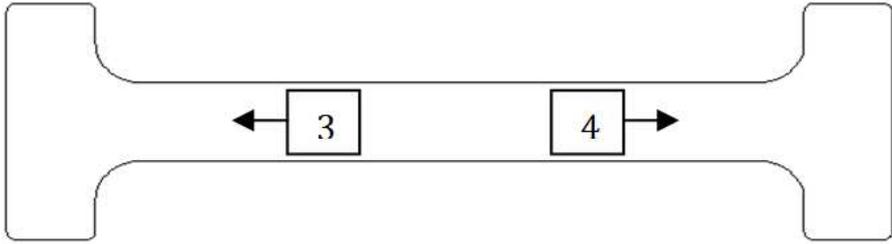
Test setup

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Evolution of the relaxation at early age

	<p>Mould 1 : $\frac{S1 + S2}{750 \text{ mm}} = \epsilon_e + \epsilon_c + \epsilon_{th} + \epsilon_s$</p>
	<p>Mould 2: $\frac{S3 + S4}{750 \text{ mm}} = \epsilon_{th} + \epsilon_s$</p>

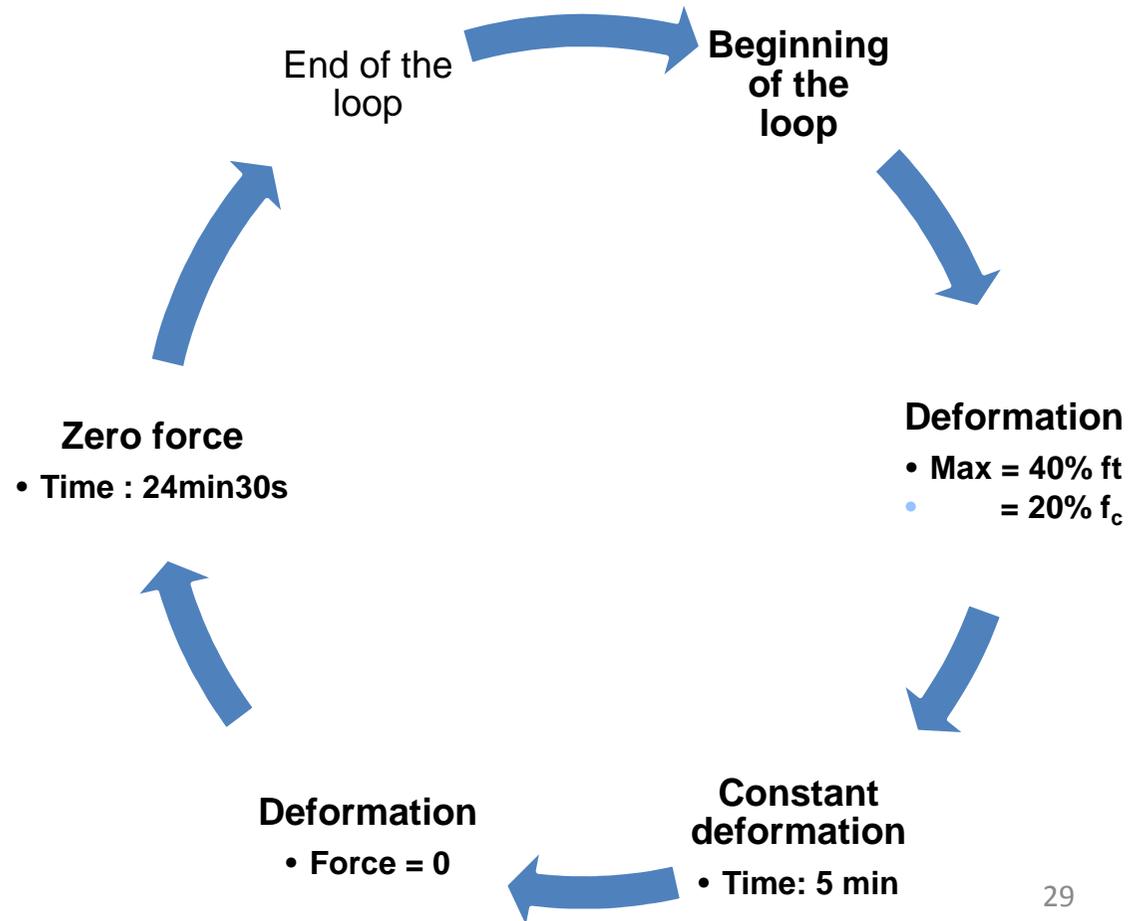
TSTM device is controlled by $(S1+S2)-(S3+S4)$ which corresponds to creep and elastic deformations.

Protocol of loadings

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Evolution of the relaxation at early age

- Definition of the **Young's modulus** evolution during the increase of deformation.
- Definition of the **relaxation function** when the deformation is constant.



Protocol of loadings

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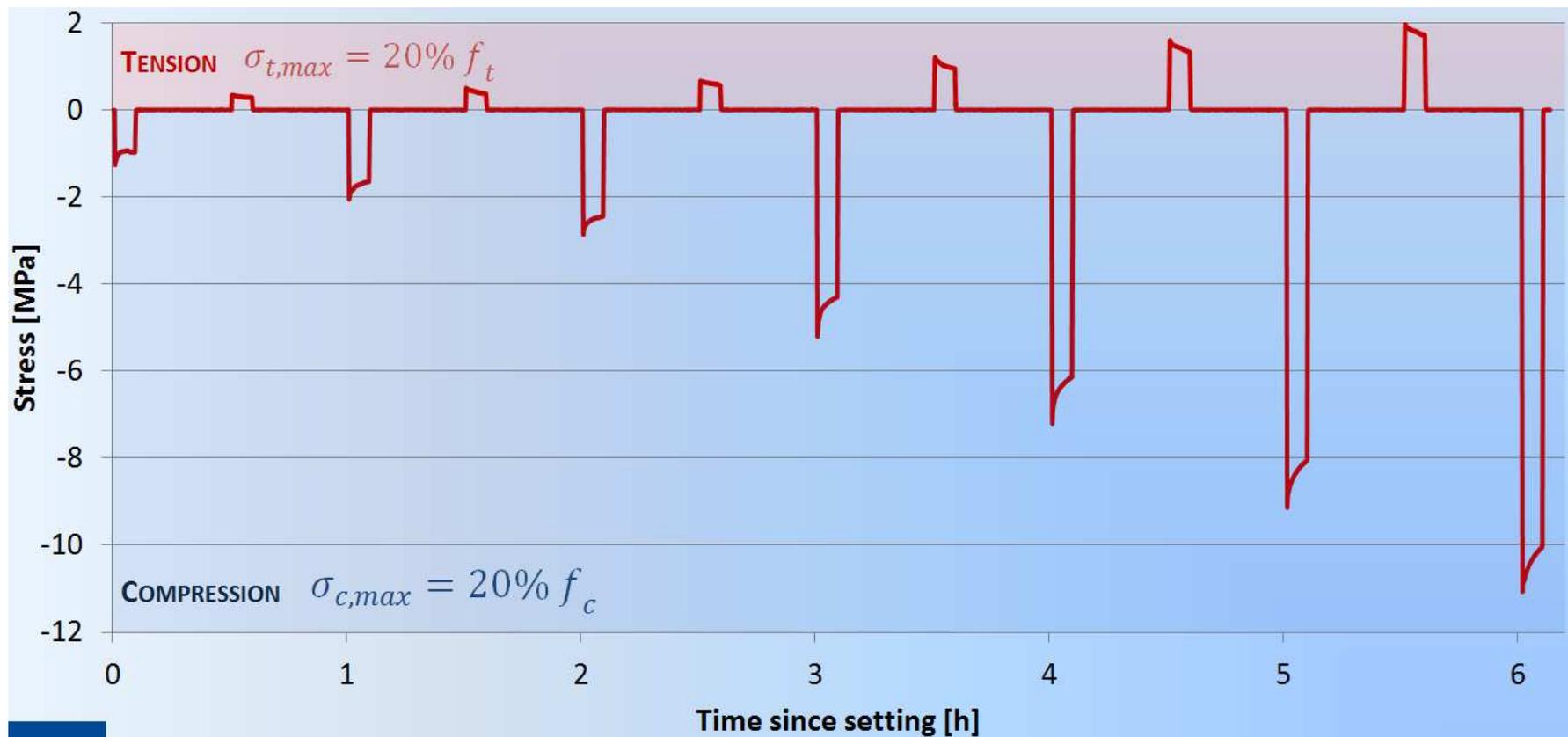
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Evolution of the relaxation at early age



Young's modulus

Introduction

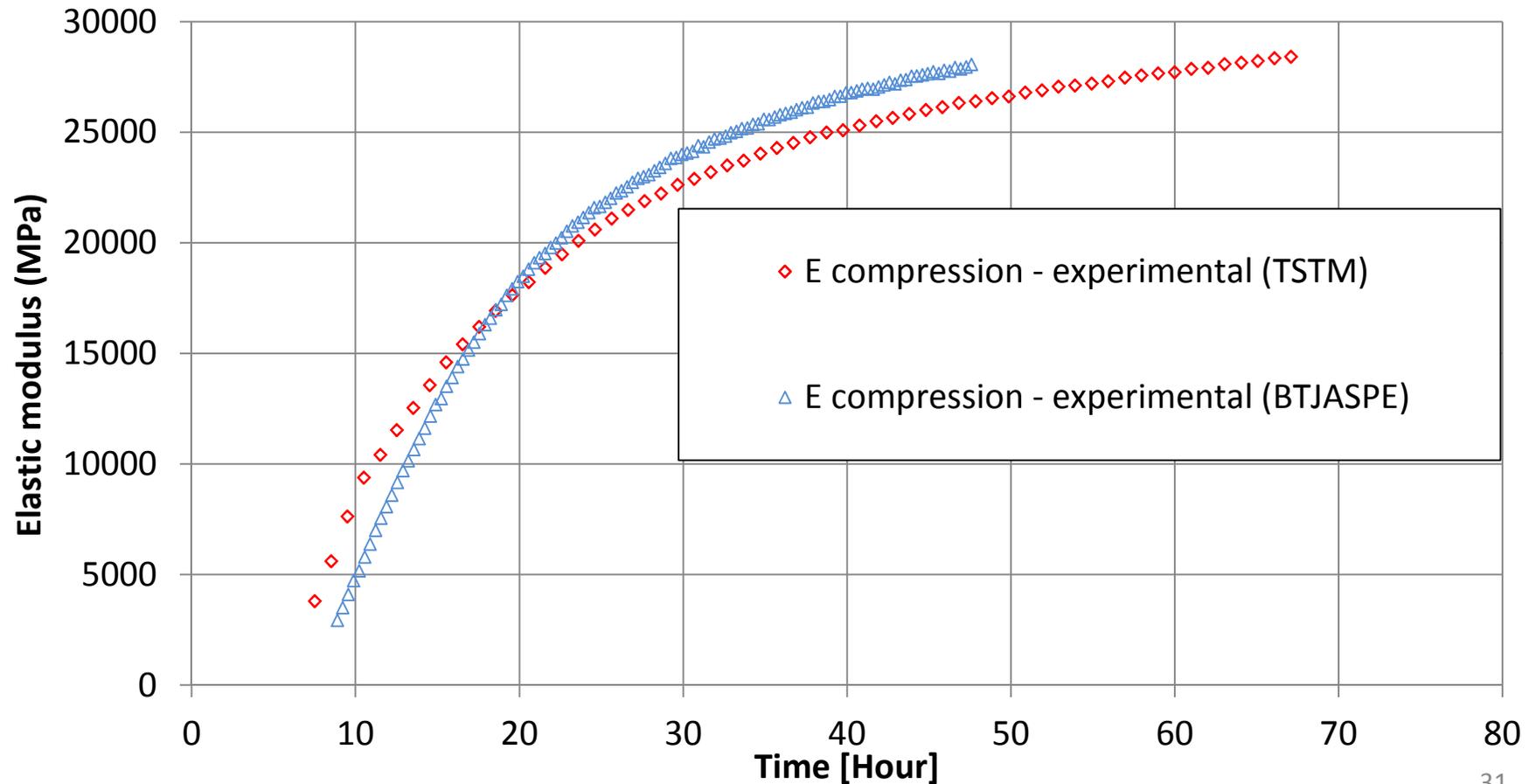
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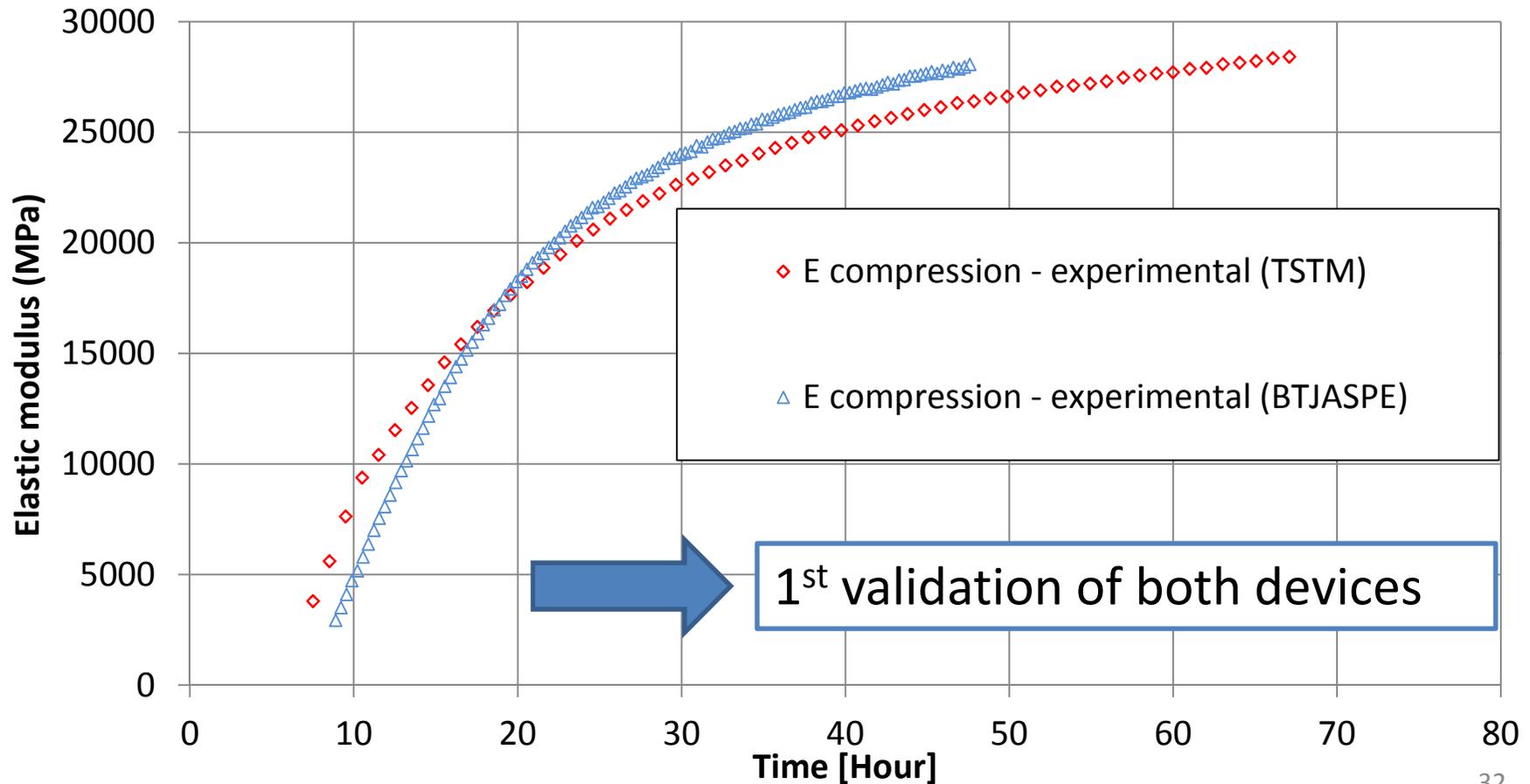
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Young's modulus

Experimental measurements



Typical relaxation records

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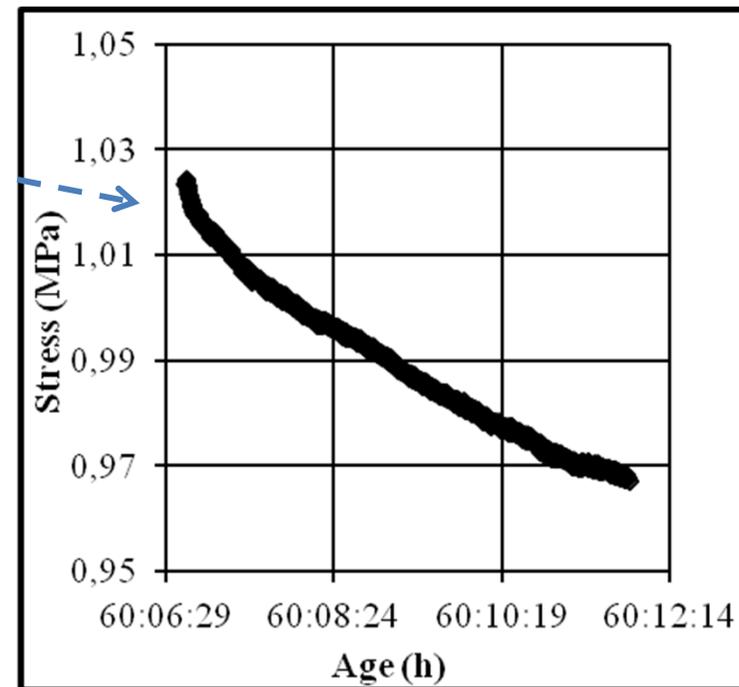
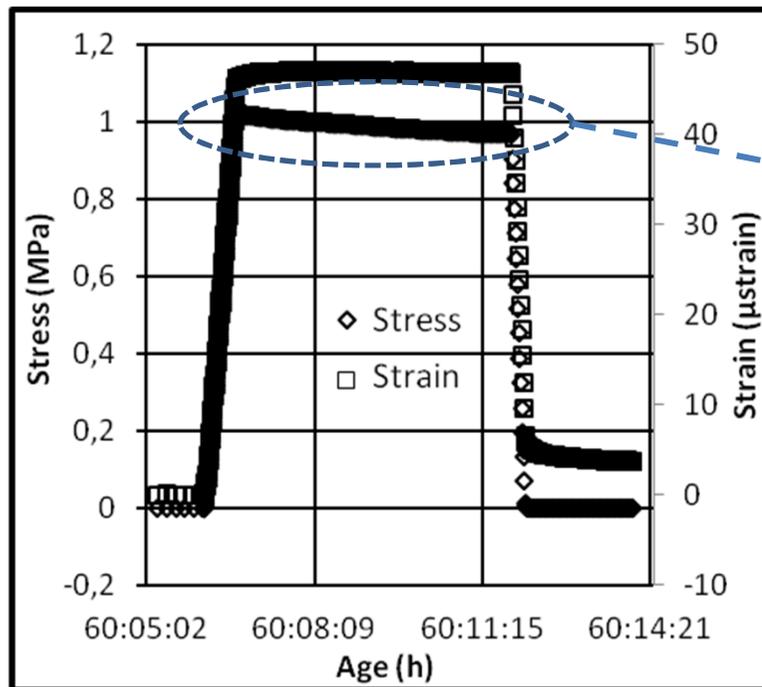
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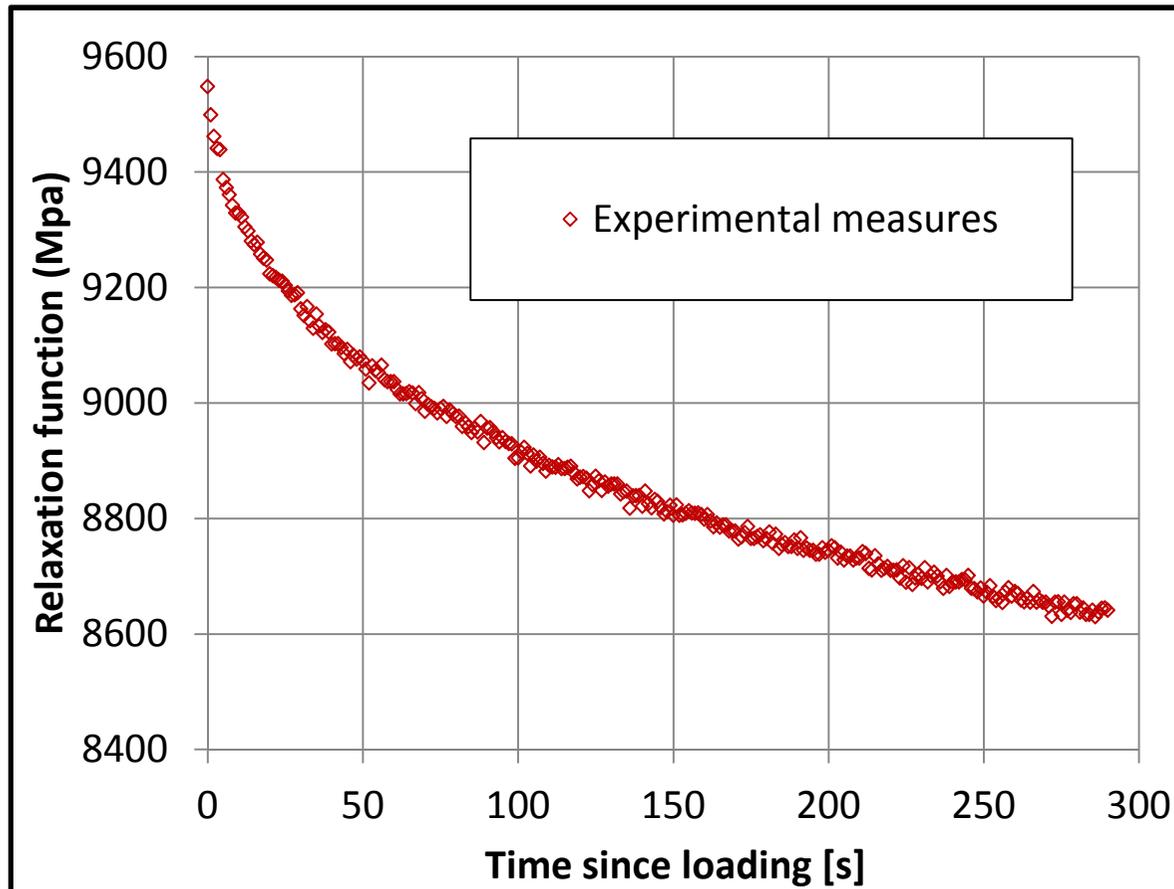
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Fitting of experimental results

-Multiple Maxwell's chains



Typical relaxation records

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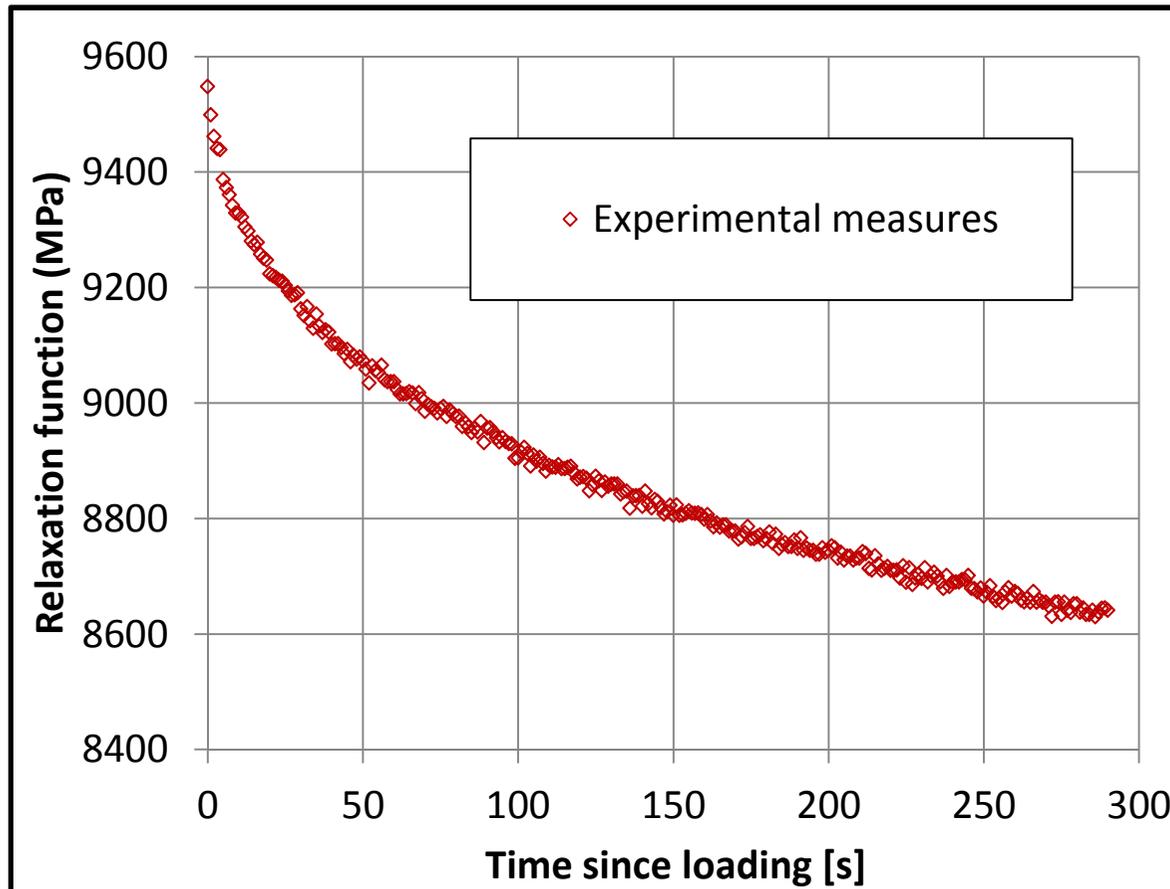
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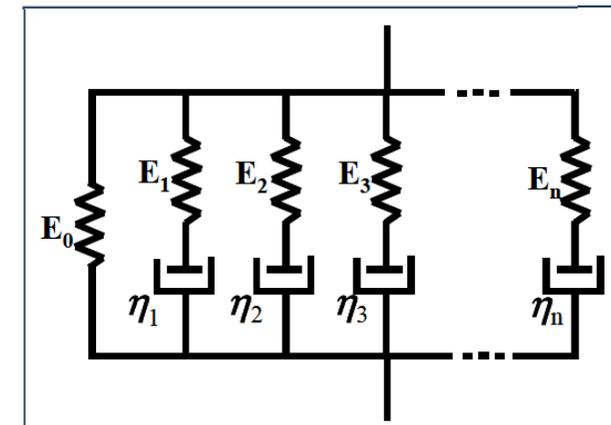
Perspectives

Fitting of experimental results

-Multiple Maxwell's chains



$$R(t, t') = E_0 + \sum_{\mu=1}^N E_{\mu} \cdot e^{-\frac{(t-t')}{\tau_{\mu}}}$$



(Huynh Kim Long, 2005)

$$\tau_{\mu} = 10^{\mu-1} \tau_1 \quad (\mu = 1, \dots, n)$$

$$\eta_{\mu}(t) = \tau_{\mu} E_{\mu}(t)$$

(Bazant, 1978)

Typical relaxation records

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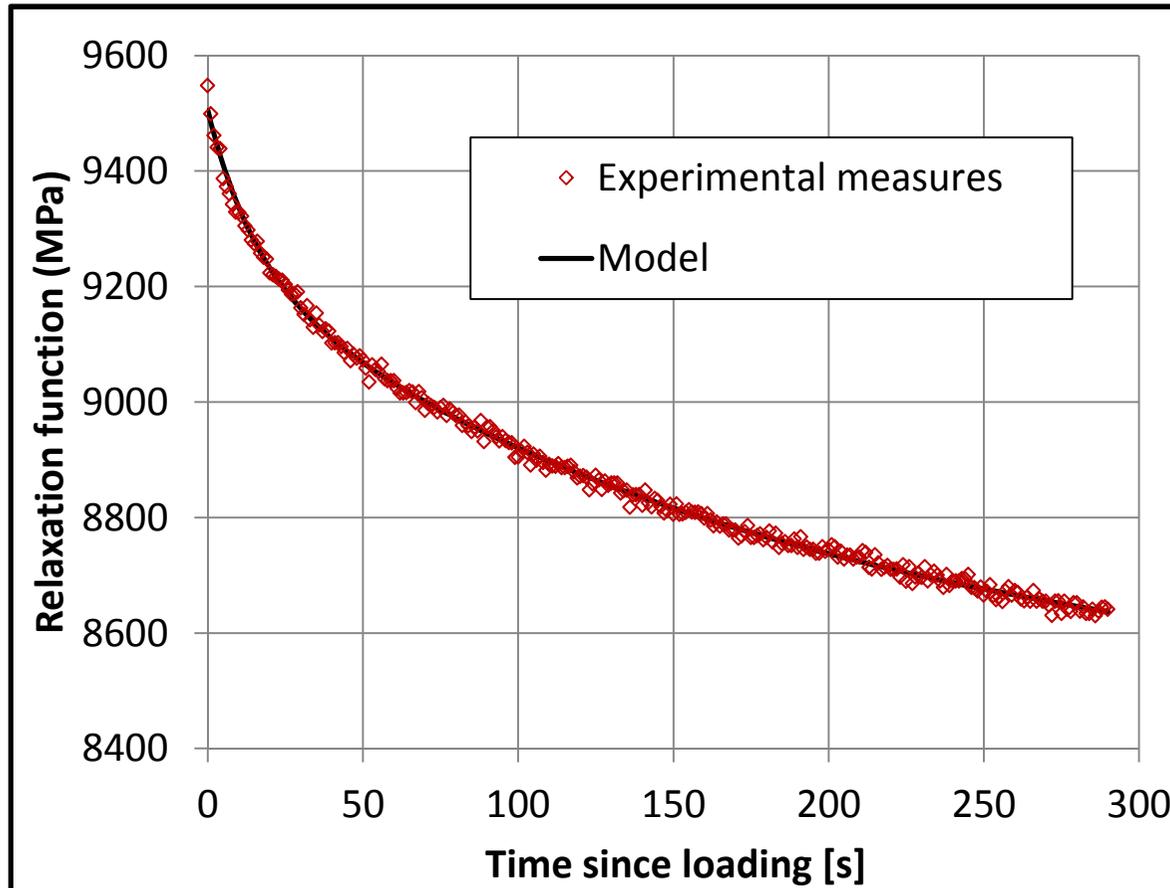
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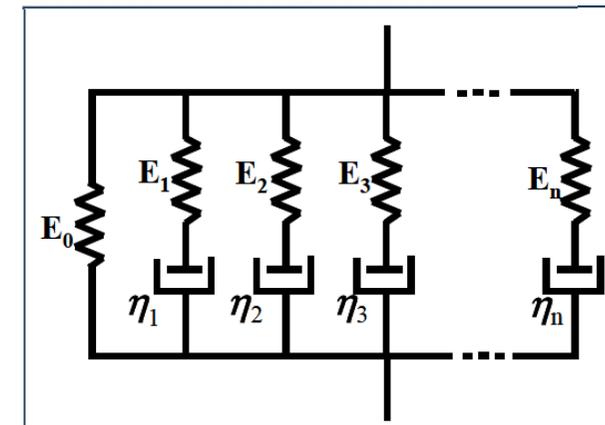
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Typical relaxation records

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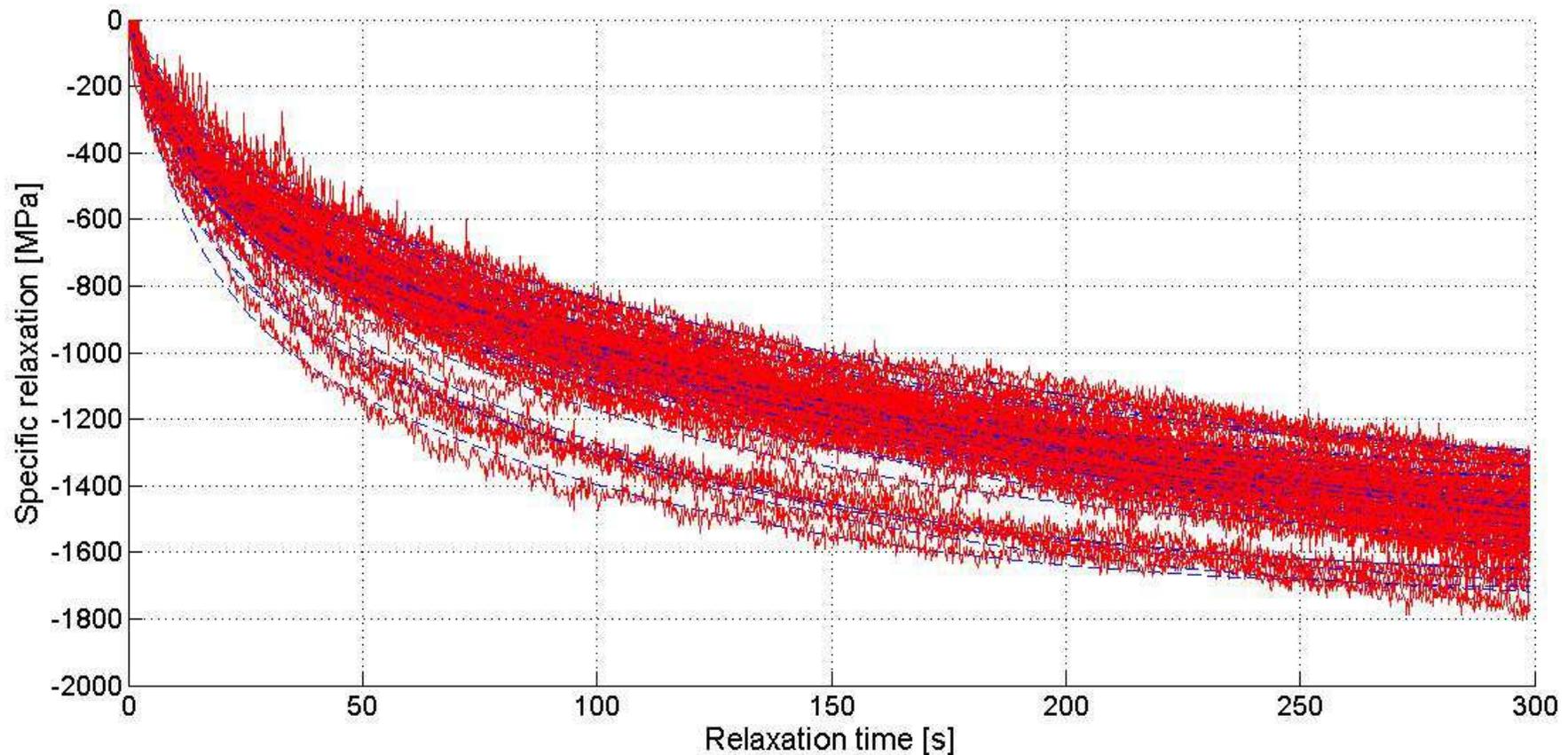
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Fitting of experimental results - tension



Typical relaxation records

Introduction

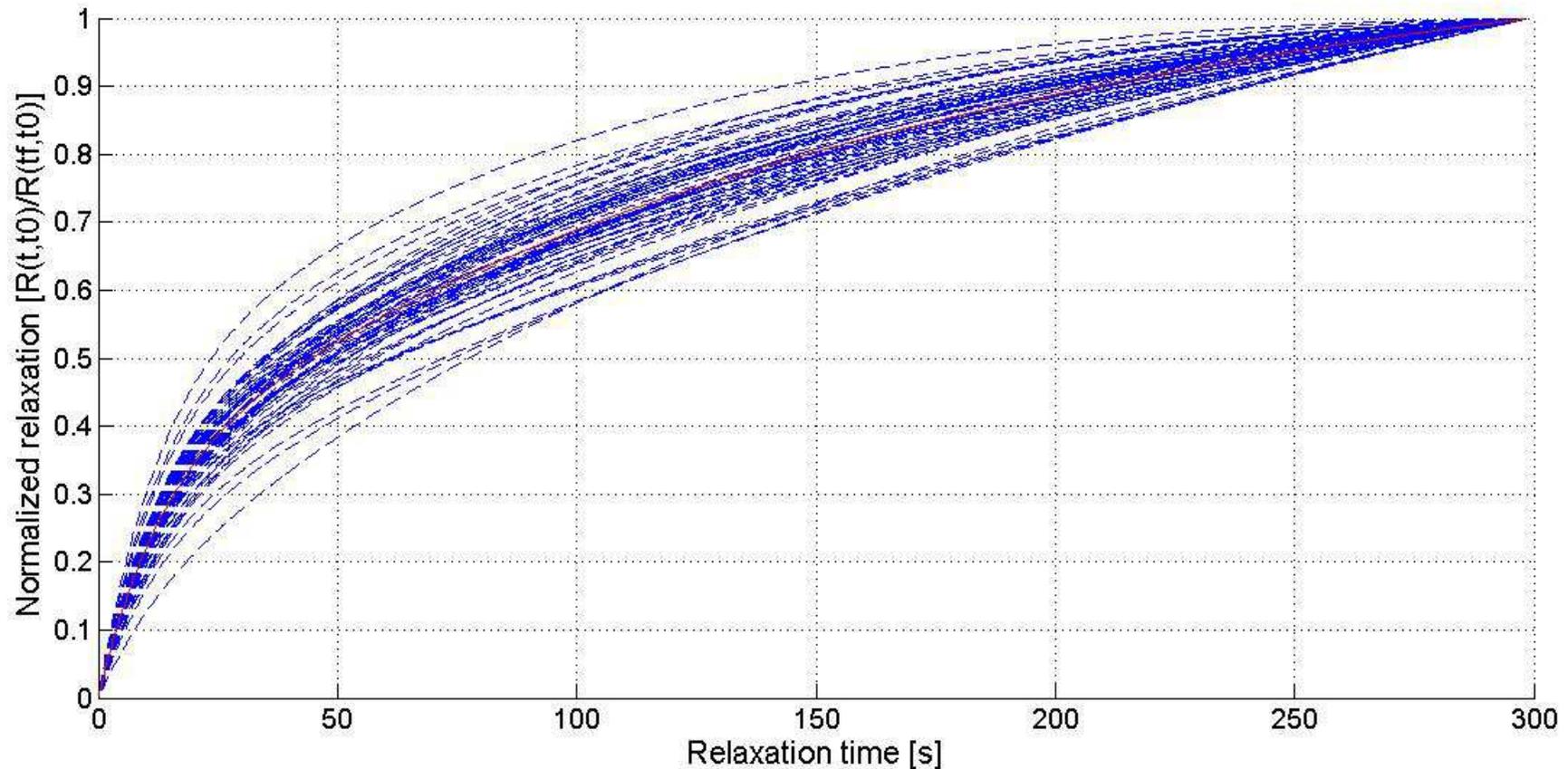
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Superimposed curve of the relaxation in tension



Typical relaxation records

Introduction

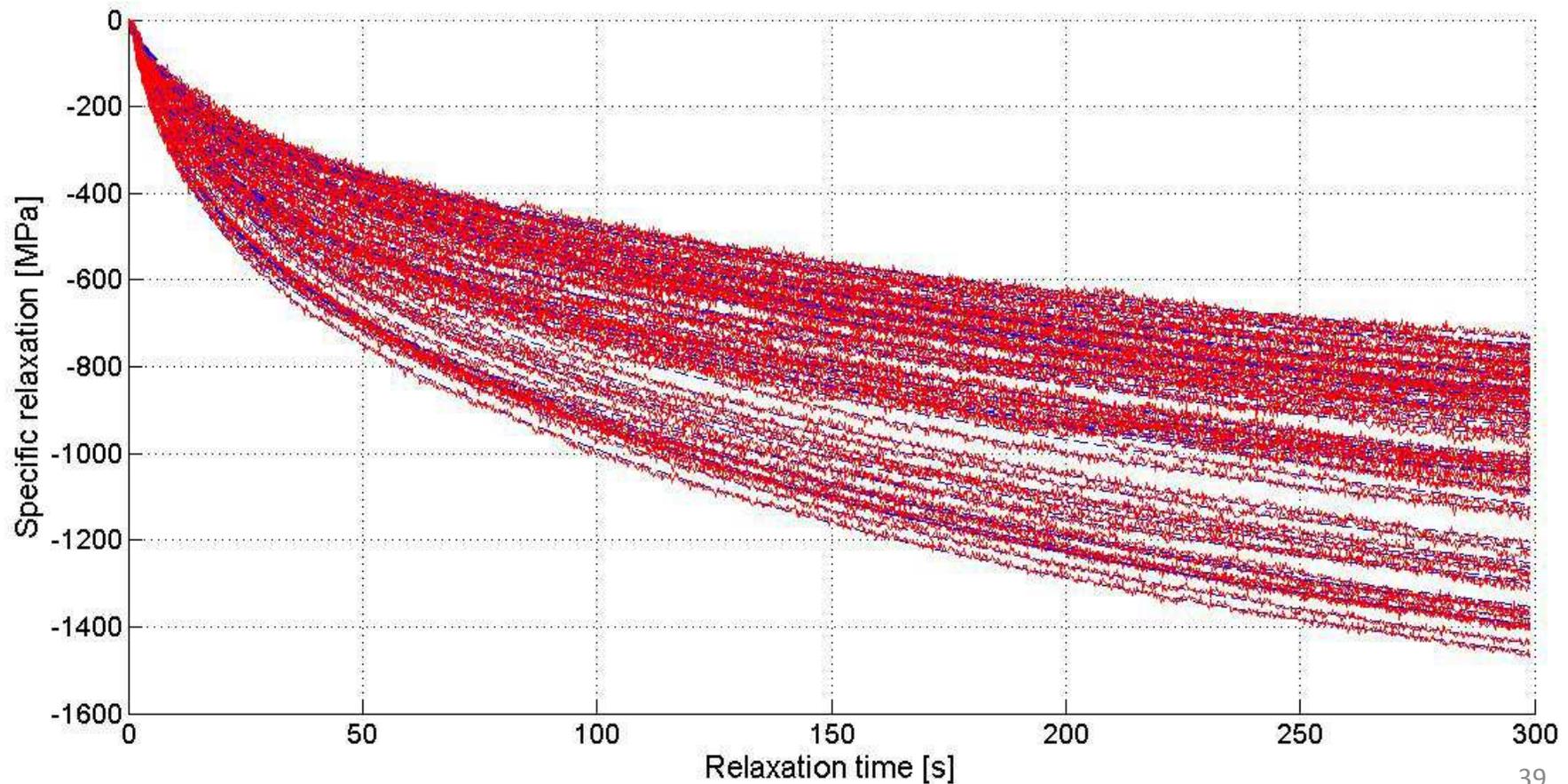
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Fitting of experimental results - compression



Typical relaxation records

Introduction

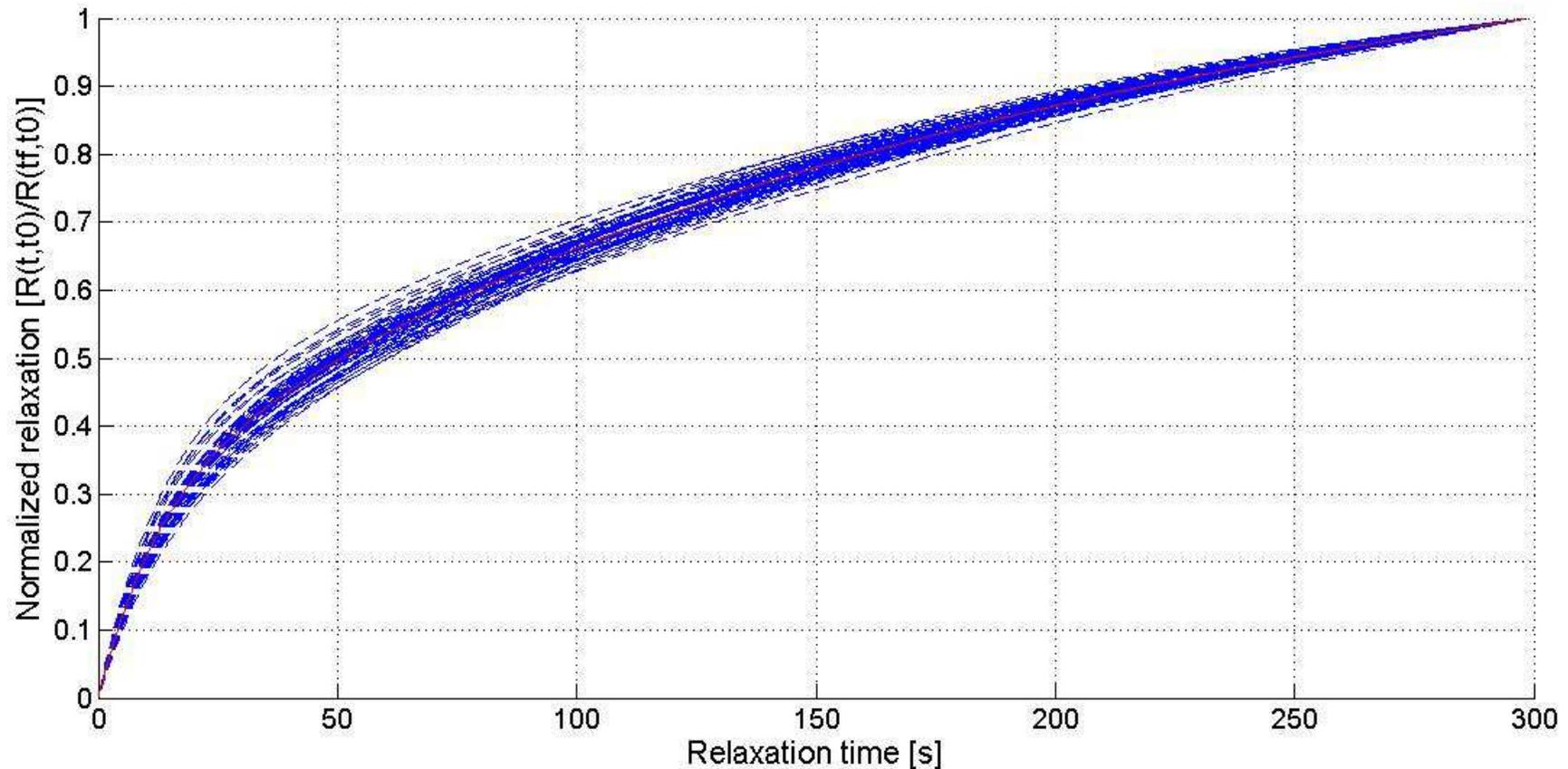
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Superimposed and normalized curves in compression



Typical relaxation records

Introduction

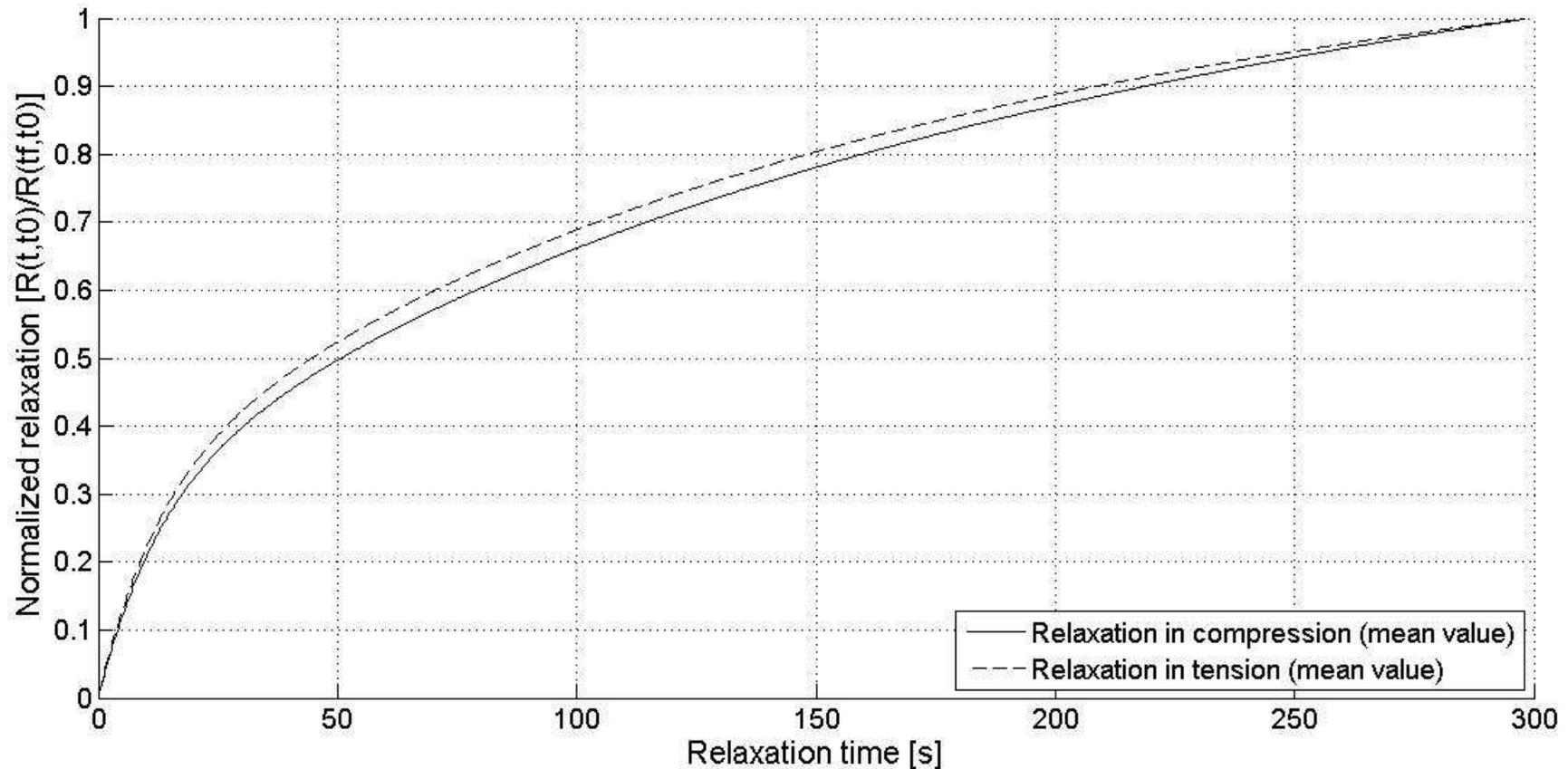
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Superimposed and normalized curves in compression



Typical creep records

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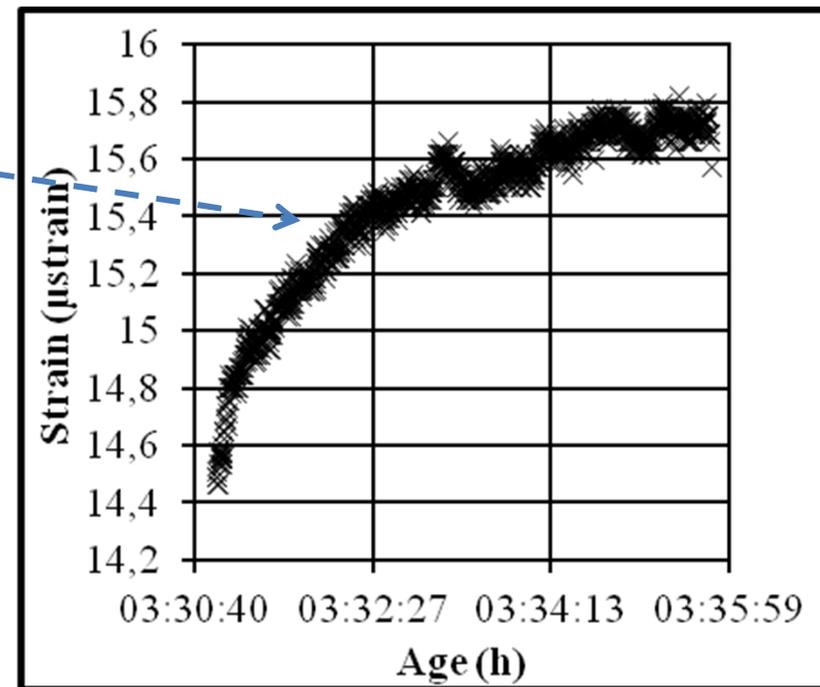
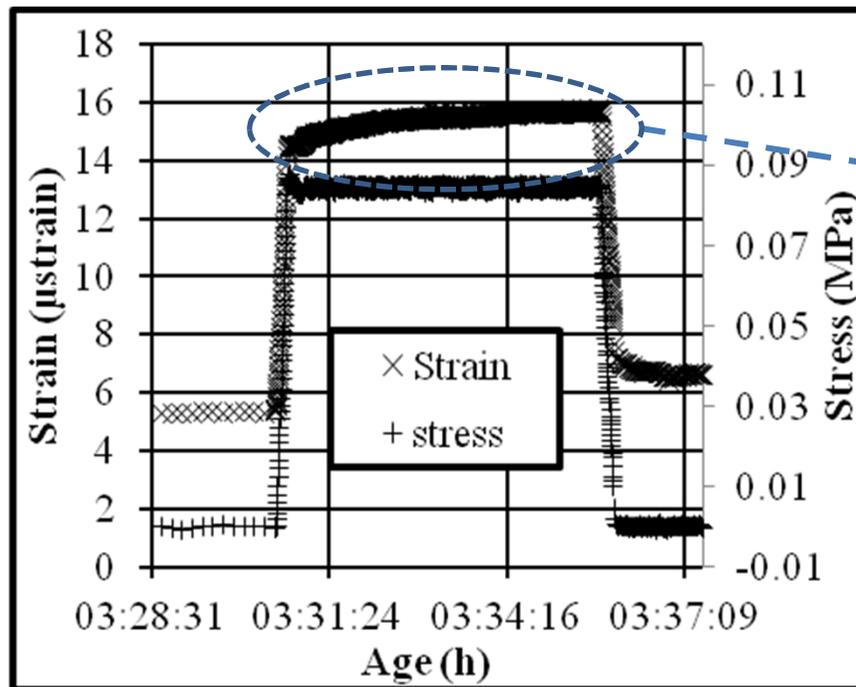
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Typical creep records

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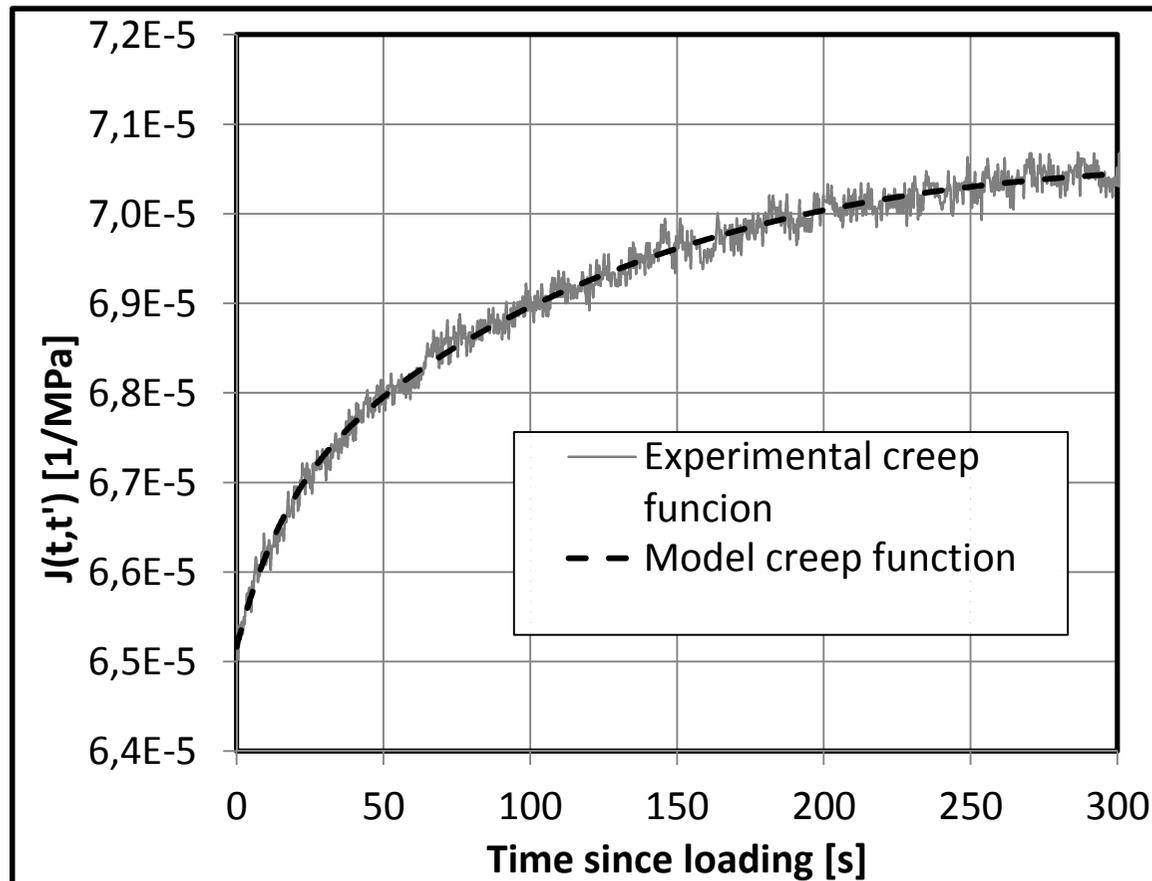
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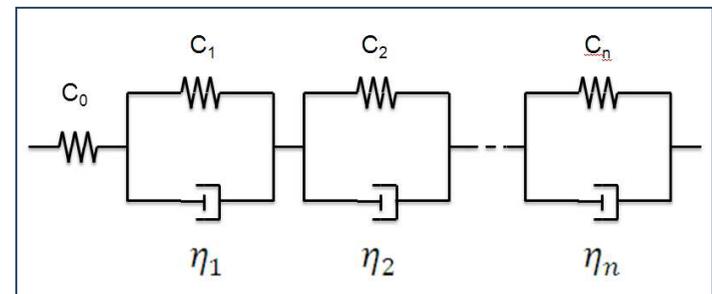
Perspectives

Fitting of experimental results

-Multiple Kelvin-Voigt's chains



$$J(t, t') = \sum_{\mu=1}^N \frac{1}{C_{\mu}(t')} \left(1 - e^{-\frac{(t-t')}{\tau_{\mu}}}\right)$$



$$\tau_{\mu} = 10^{\mu-1} \tau_1 \quad (\mu = 1, \dots, n)$$

$$\eta_{\mu}(t) = \tau_{\mu} E_{\mu}(t)$$

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Typical creep records

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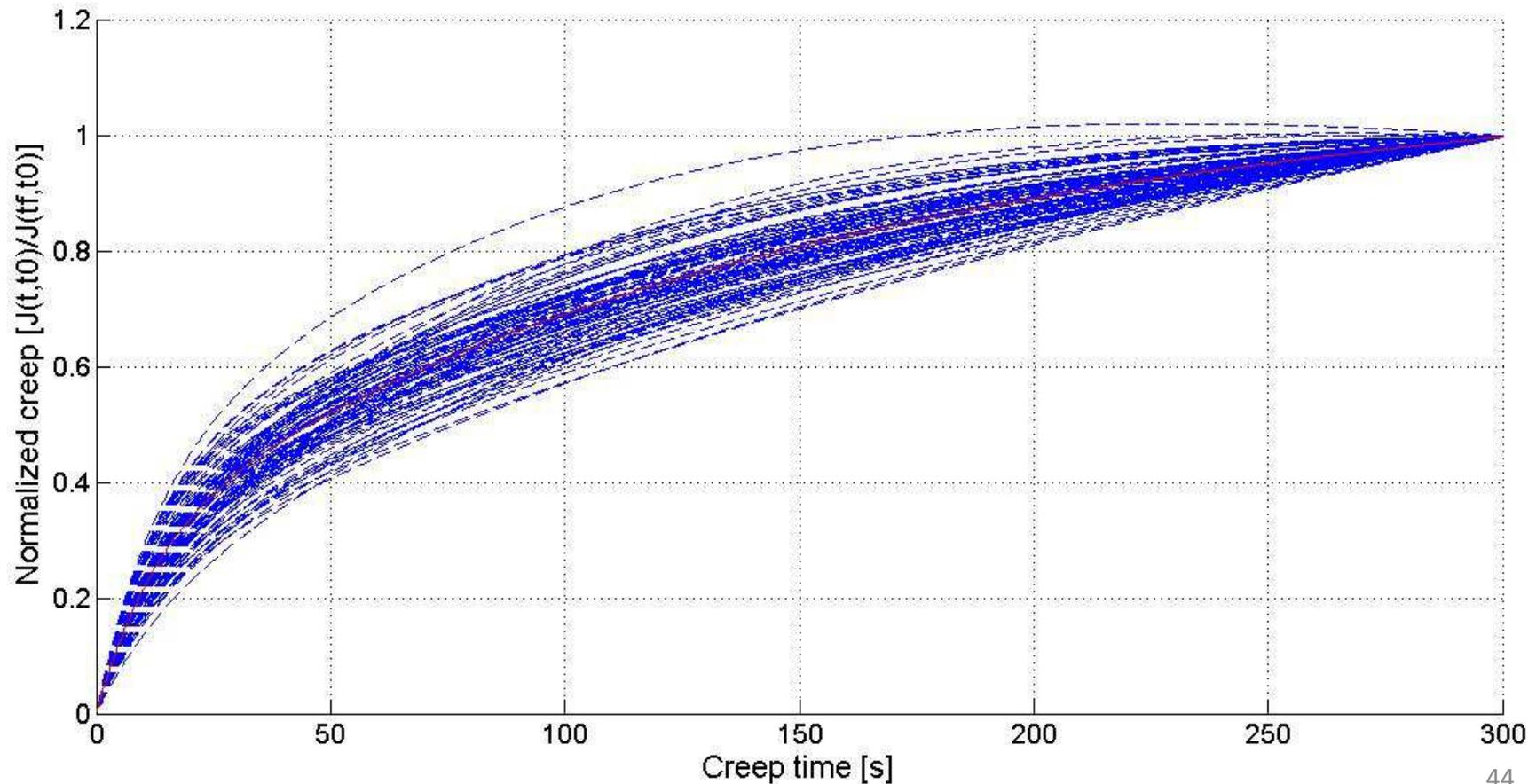
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Superimposed and normalized curve in tension



Typical creep records

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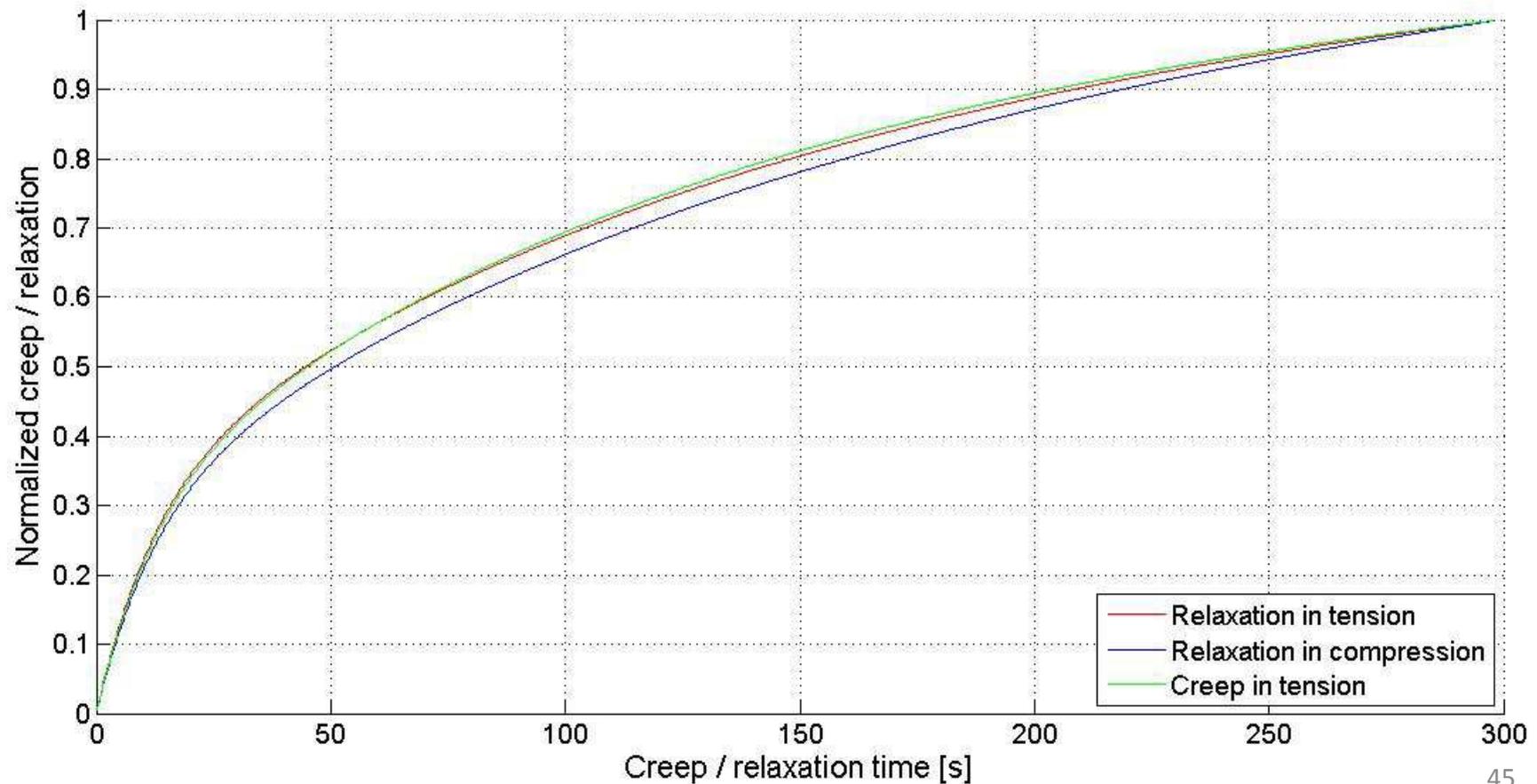
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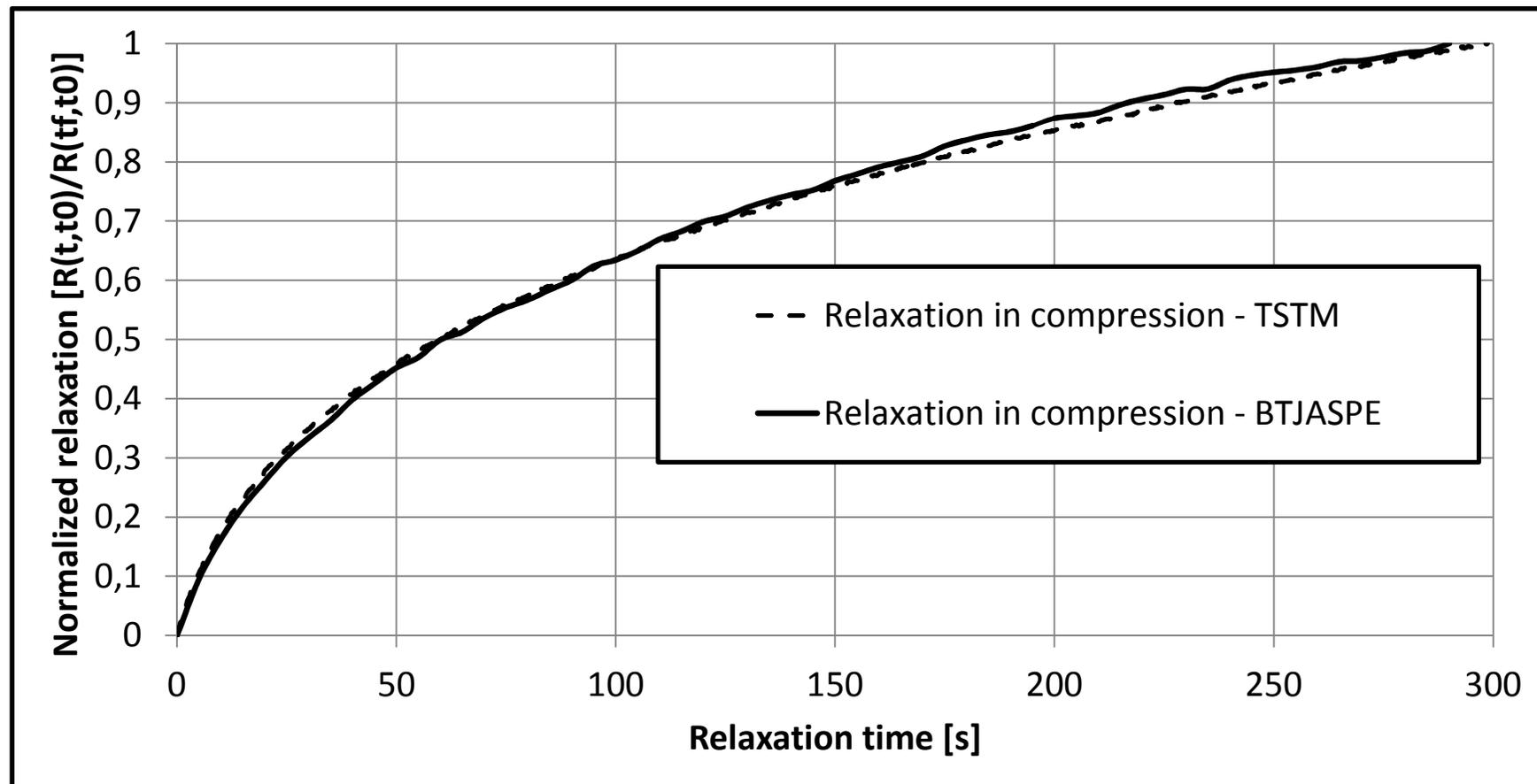
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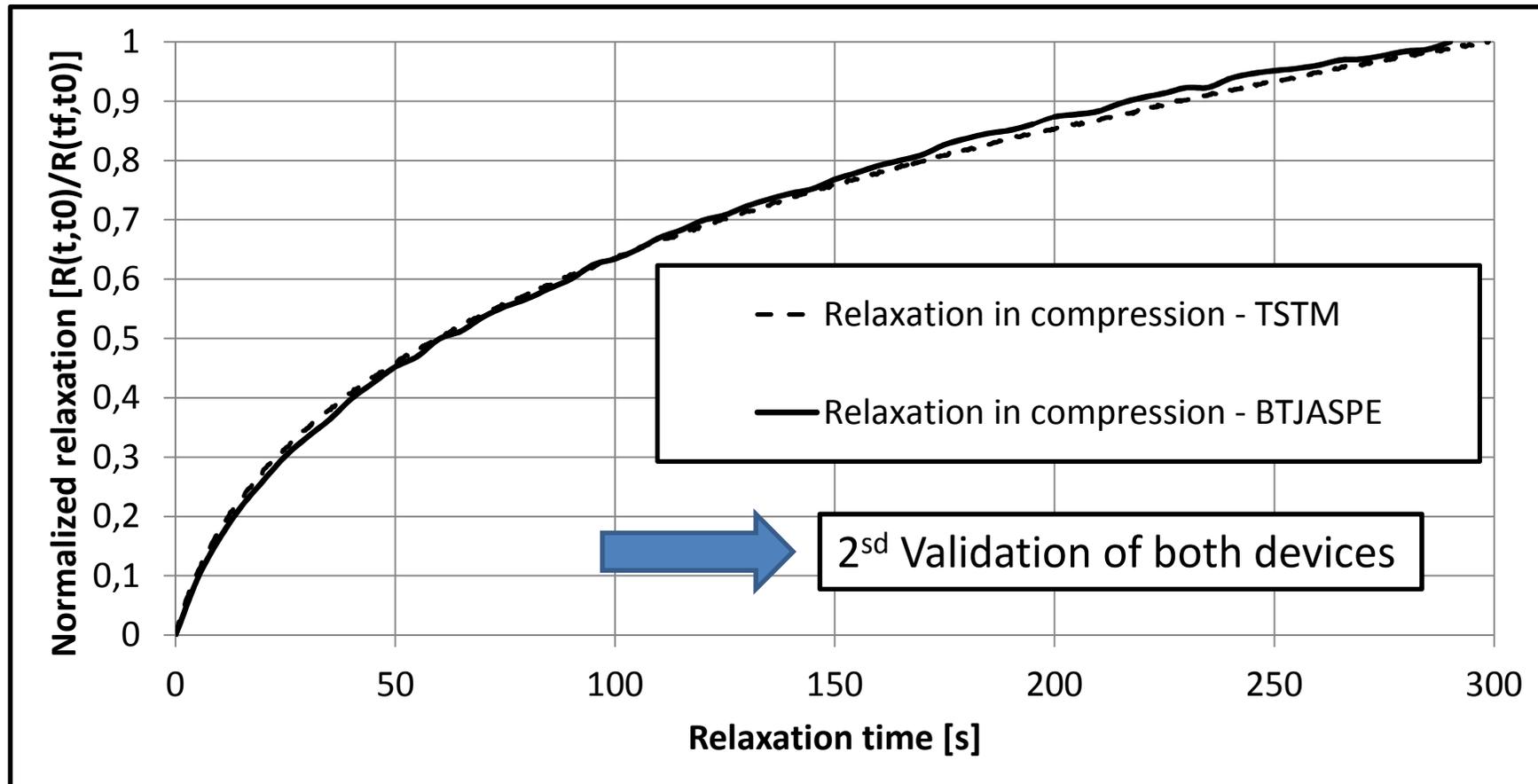
Superimposed and normalized curve



Comparison between TSTM and BTJASPE results



Comparison from TSTM and BTJASPE results



Conclusion

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- A new experimental methodology is used to define the evolution of Young's modulus, creep coefficient and relaxation coefficient in tension and compression since setting time.
- The kinetic of the creep and the relaxation are similar in tension and compression (Normalized curves are superimposed) at early age.
- Excellent agreement between TSTM and BTJASPE device by the comparison of both results.
- Creep and relaxation results were obtained for a short duration of loading (5 min) and for limited level of loadings.

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- Study of longer duration of loading
- Modelling of amplitude of the creep and the relaxation
- Repeatability and other concretes
- Validation on any loading histories
- Taking into account:
 - the maturity
 - The temperature
 - The stress level (40% - 60% - 80%)
 - The creep recovery
- Transition between creep and relaxation
- Drying creep?
- Come back to null deformation for relaxation cycle
- Study of transversal displacement in TSTM device for 3D modelling



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