

Fatigue properties and Selfhealing of bituminous pavement materials

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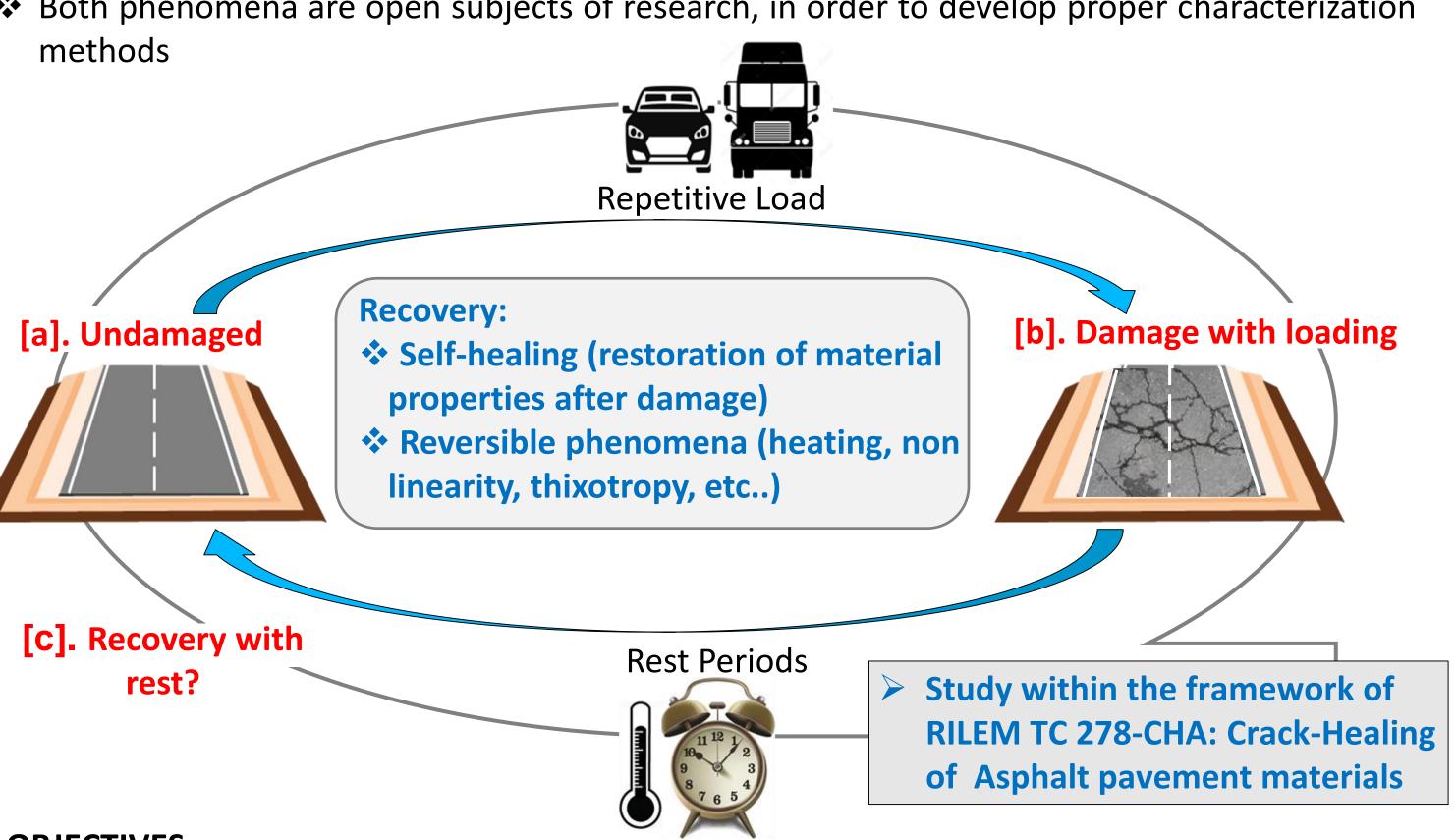
Laboratoire de Tribologie et **Dynamique** des **Systèmes** 

**UMR 5513** 



# Context and objectives

- ❖ Fatigue and self-healing of road materials are key aspects of pavement durability
- ❖ Both phenomena are open subjects of research, in order to develop proper characterization



#### **OBJECTIVES**

**Grant by:** 

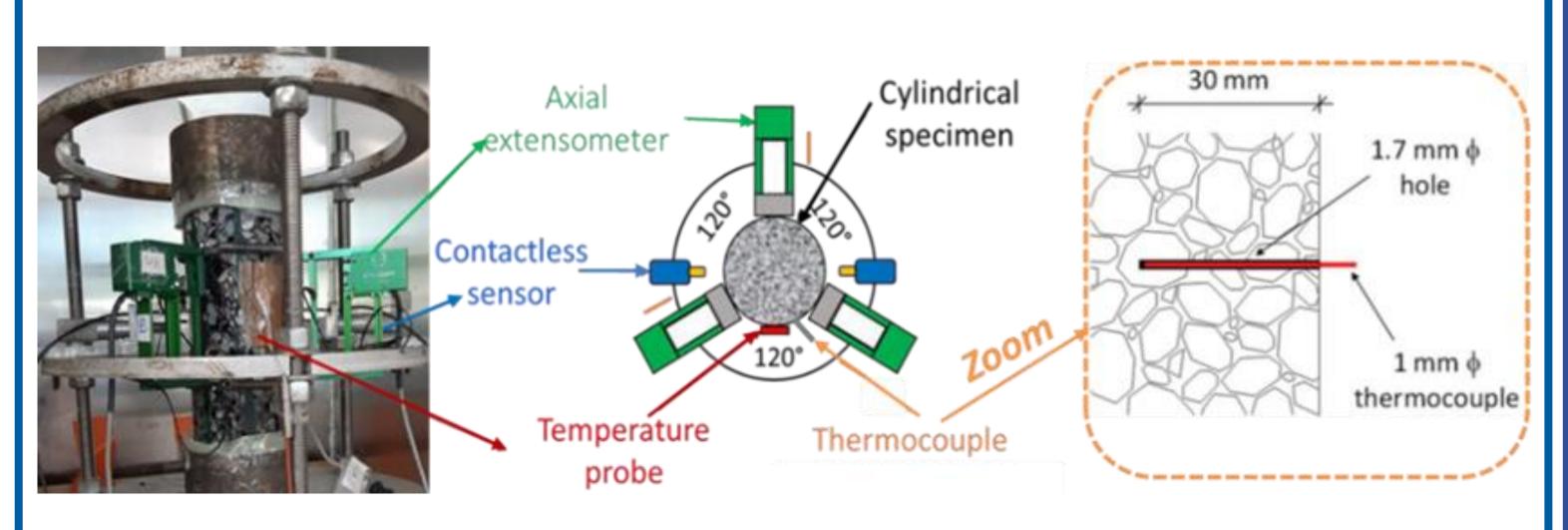
Petroleum Technology

Development Fund

Development of laboratory test procedure proposed by ENTPE to evaluate damage and recovery of bituminous materials:

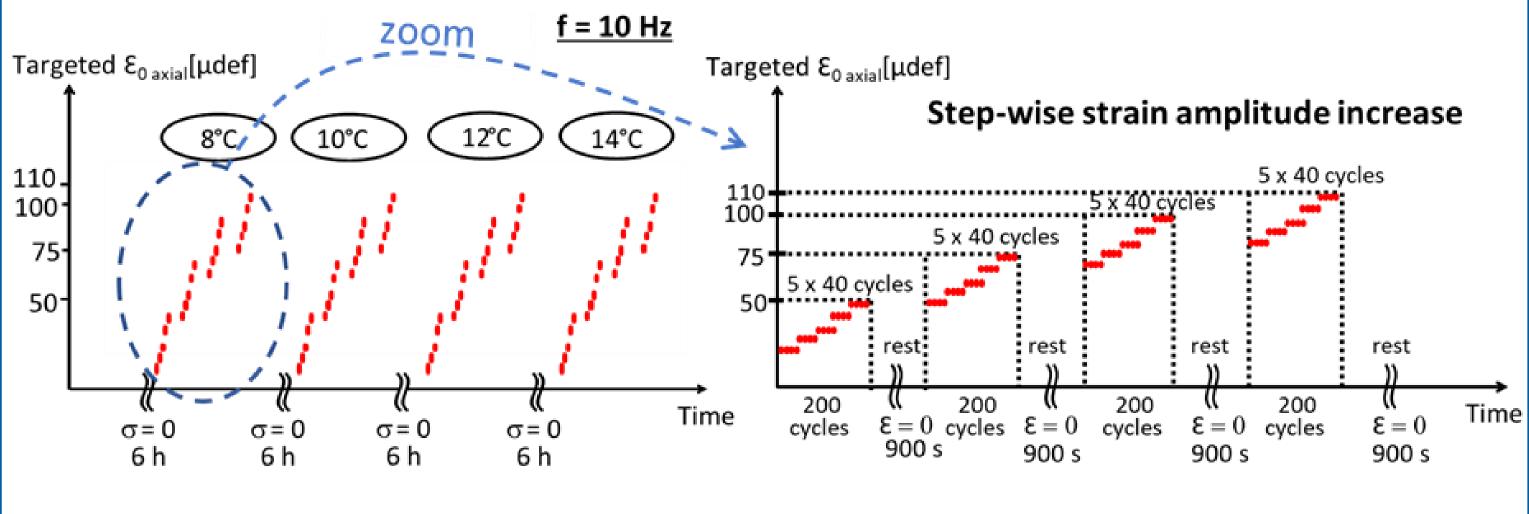
- Evaluating repeatability of test procedure within RILEM framework
- Improving test procedure (rest periods up to 48 h)
- Studying evolution of 3D properties (complex Poisson's ratio) during load and rest periods

## Experimental equipment, procedure and materials



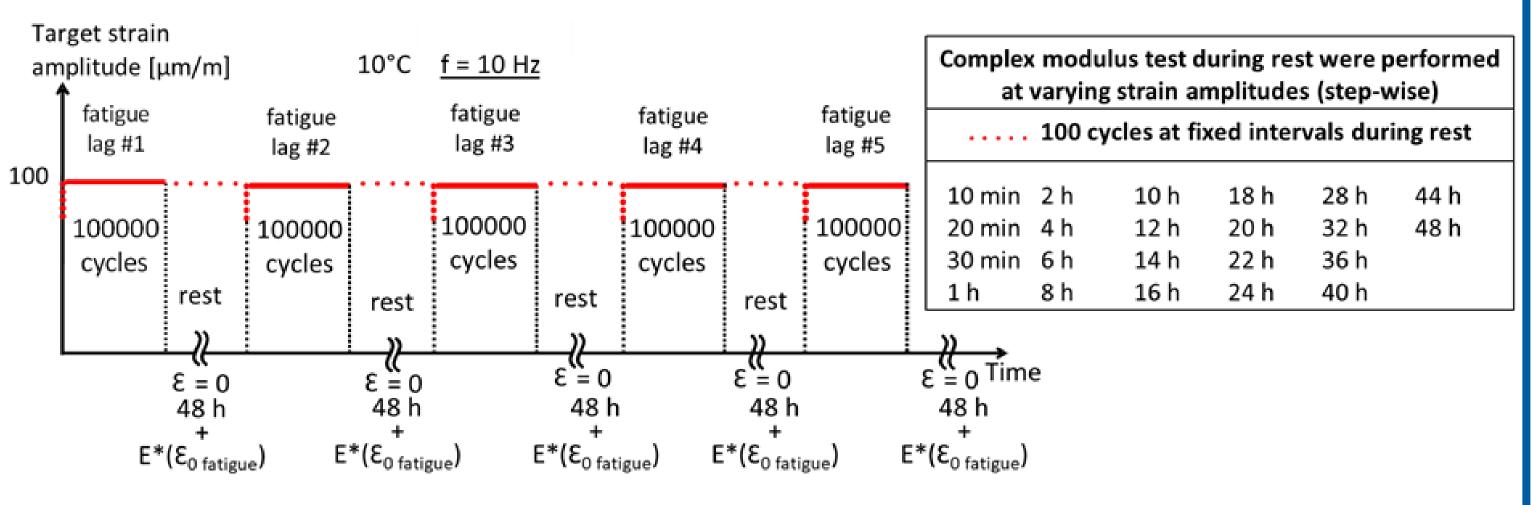
**1**st step: Complex modulus tests at varying strain amplitude and temperature

**Effects of strain amplitude (non-linearity)** and temperature on  $|E^*|$ ,  $\phi_E$ ,  $|v^*|$ ,  $\phi_v$ 



**2**nd step: Fatigue tests with rest periods

#### **Effects of cyclic loading and** rest on $|E^*|, \phi_E, |v^*|, \phi_v$



#### Materials tested

3 mixtures with 3 different binders and same grain size distribution (8 samples for each mixture, provided by Univ. Gustave Eiffel).

Base binder	Α	В	C (Modified)
Binder pen. (1/10 mm)	49	80	N/A
Binder content	6.6 %	6.6 %	6.6 %

#### **Examples of results obtained ❖** Variation of |E\*| with strain amplitude and temperature (undamaged conditions) $|E^*|$ at 0 $\mu$ m/m 10000 $|E^*|$ at 110 $\mu$ m/m **M** 8000 <u> </u> 6000 $R^2 = 0.976$ 8.8° C ◆ 11.4° C ▲ 13.8° C ■ 15.6° C 4000 First & last cycles of each strain level deleted 2000 20 40 100 120 Strain amplitude, ε (μm/m) **Binder A mixture:** 1.0E+04 sample 4 $\times 0 \,\mu\text{m/m}$ values obtained **७** 9.0E+03 50 μm/m from non-linearity • 75 μm/m <u>envelopes</u> 8.0E+03 ▲ 100 μm/m $|E^*|(\varepsilon,T)=b_E(\varepsilon)T+|E_{0^{\circ}C}^*|(\varepsilon)$ ■ 110 µm/m 7.0E+03 b<sub>E</sub> **Increasing strain 当** 6.0E+03 amplitude $R^2 = 0.999$ 5.0E+03 $R^2 = 0.999$ 14 10 T [° C] **❖** Variation of |E\*| during fatigue and rest periods. 100000 cycles 100000 100000 2h 46' cycles 100000 cycles 9000 100000 2h 46' cycles 2h 46' cycles 2h 46' Unrecovered Unrecovered 2h 46' Unrecovered 8000 Unrecovered Cyclic effect Unrecovered Cyclic effect (reversible) Cyclic effect (reversible) Cyclic effect (reversible) <u>\*</u> 7000 Temperature Cyclic effect (reversible) Temperature I Effect (reversible) (reversible) Temperature **1** fect (reversible 48h rest Effect (reversible Temperature 6000 Temperature 48h rest Effect (reversible) Incr. strain amplitude Effect (reversible) fatigue lag #i < • Const. strain amplitude $\varepsilon = 100 \, \mu \text{m/m}$ 48h rest ★ E<sup>\*</sup><sub>100μm/m,T0,0 cycles, lag 1</sub> 48h rest 5000 200000 600000 800000 400000 Time (Sec.) **Binder A mixture:** 100000 100000 12.0 sample 4 100000 100000 100000 cycles cycles cycles 2h 46' cycles 2h 46' cycles Internal 2h 46' 11.5 2h 46' 2h 46' Surface 11.0 10.5 48 h 48 h 48 h 48 h 48 h 10.0 200000 800000 400000 600000 -Sample 1 Time (Sec.) -Sample 2 Quantification of unrecovered $|E^*|$ variations for binder A mixture -Sample 3 -Sample 4 **§** 12% 11.04% 10.33% -Sample 5 total 8.06% 8.28% 7.20% 8.55% 5.79% 7.20% 4.19% |/∆|E³ 3.80% 3.33% 3.72% 2.19% 3.26% 3.50% 2.19% 2.34% 2.20% 1.48% 1.46% 1.60% 0% Fatigue lag #2 Fatigue lag #1 Fatigue lag #3 Fatigue lag #4 Fatigue lag #5

### Partial conclusions and ongoing work

- Isolation and estimation of reversible and irreversible variations of material properties during fatigue and rest
- About 90% (or more) of total variations observed during each fatigue tests are completely reversible (not permanent damage)
- Ongoing analysis on norm and phase angle of complex modulus and complex Poisson's ratio.