Characterization of interface between bituminous layers under shear loading cycles using 2T3C apparatus

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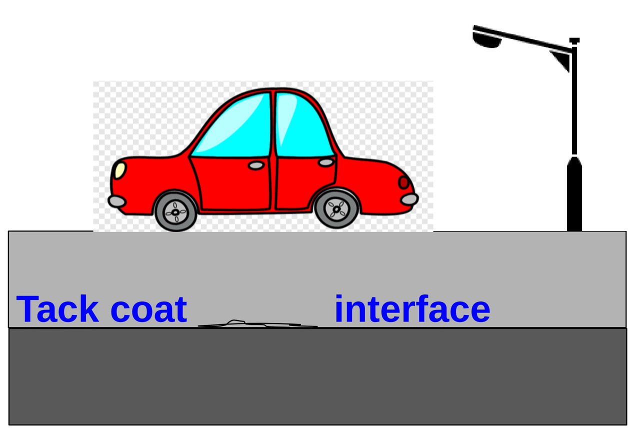
Context and objectives



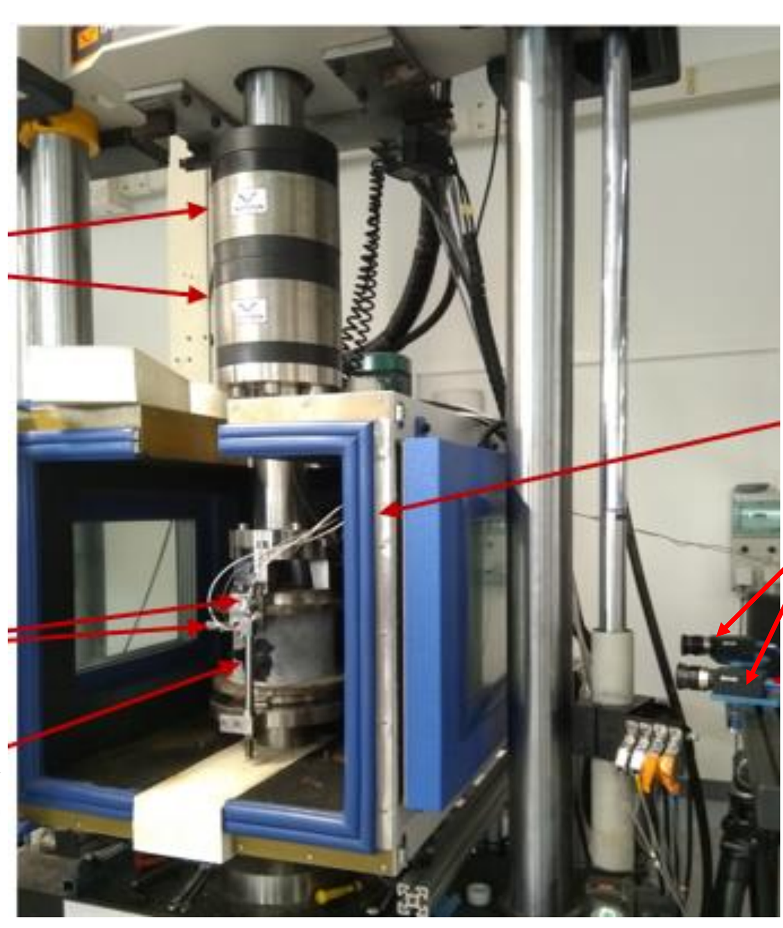
French design method (NF P 98-86 2019) considers bituminous layers either bonded or fully unbonded

In reality, the bonding capacity of tack coat reduce progressively during its service life

Better understanding about the mechanical behaviors of the interface and better design method for sustainable pavements → Less maintenance; Better performances

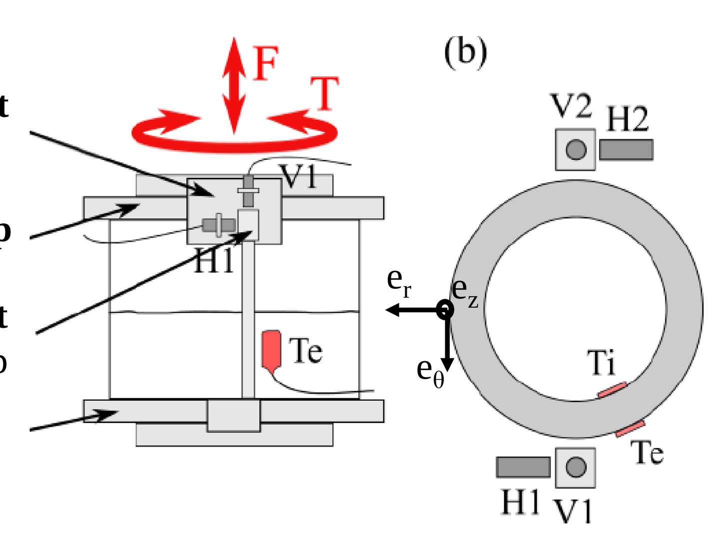
OBJECTIVE: characterize interface between bituminous layers under shear loading in Linear Viscoelastic (LVE) and fatigue domains by using 2T3C (Torsion/Traction/…) apparatus developed at ENTPE (Attia, 2020)

2T3C (Torsion/Tension/Compression on Hollow Cylinder) apparatus for interface study



- Max axial force: ±100 kN
- Max torque: ±2 kN.m
- Max loading freq.: 10 Hz

2 cameras in each side (2 opposite sides)
- Max sampling frequency 35fps
- Pixel size 70 µm
- Measurement resolution 0,7 µm



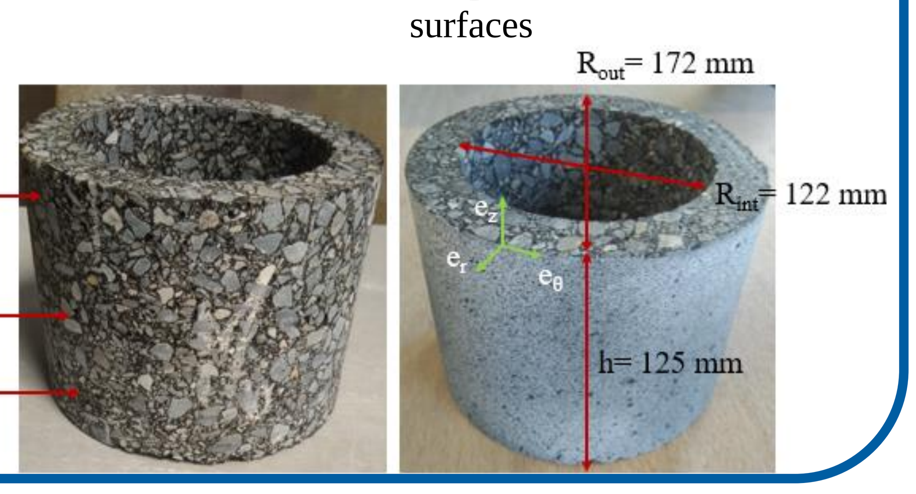
H1, H2: Horizontal non-contact sensors
- measure global axial displacement

V1, V2: Vertical non-contact sensors
- measure global torsional displacement

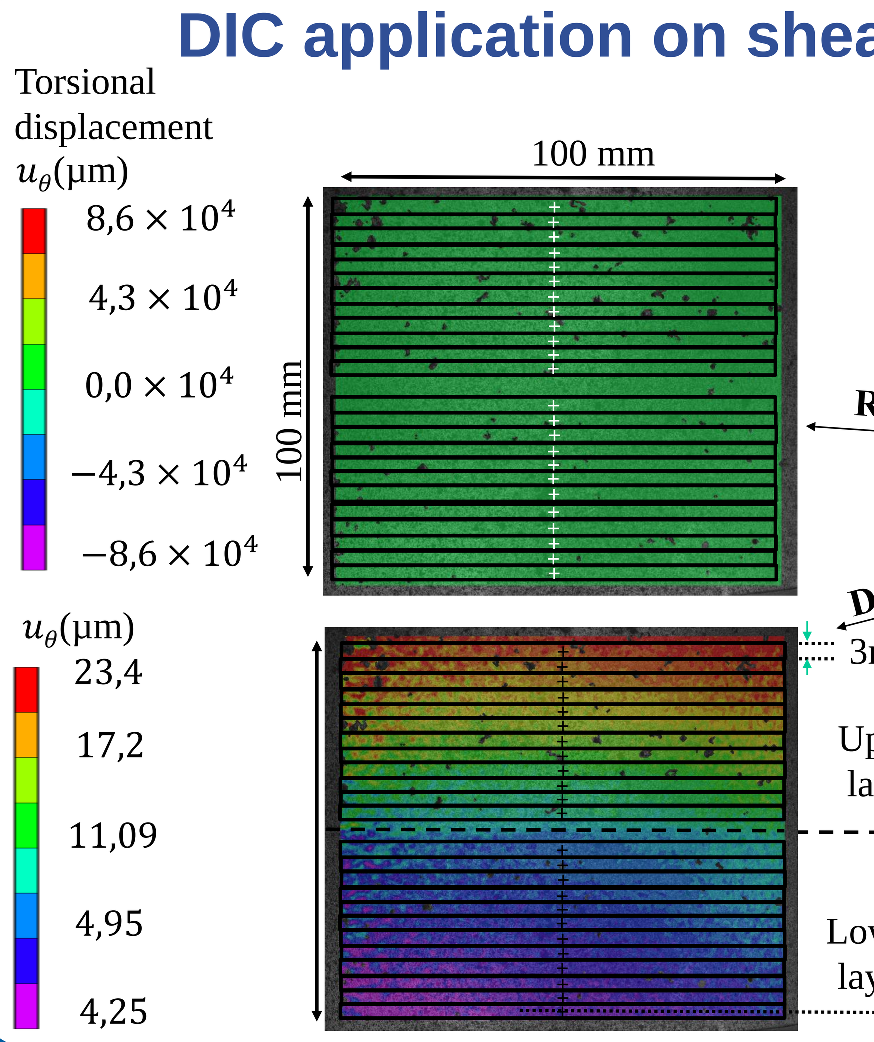
Ti,Te: Temperature sensors (PT 100)
- Measure temperature on sample's inner and outer surfaces

Sample: Double-layer hollow cylinder
- Height: 125mm
- Internal diameter (R_{int}): 122mm
- External diameter (R_{ext}): 172mm

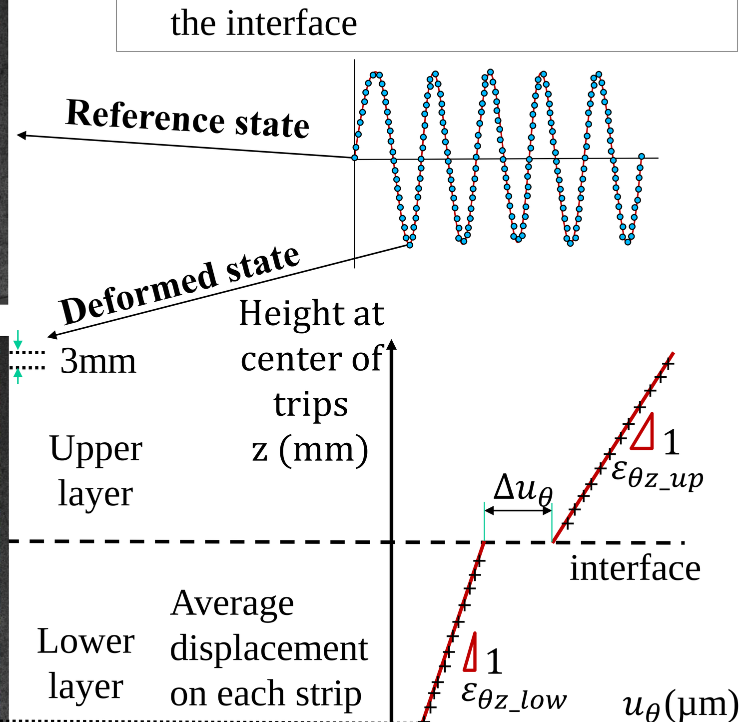
Advantage: Stress and strain fields ≈ homogeneous



DIC application on shear loading cycles



- Shear strain $\varepsilon_{\theta z}$ of each layer obtained via linear regression of dispacement u_θ in z
- Displacement gap Δu_θ obtained at the interface

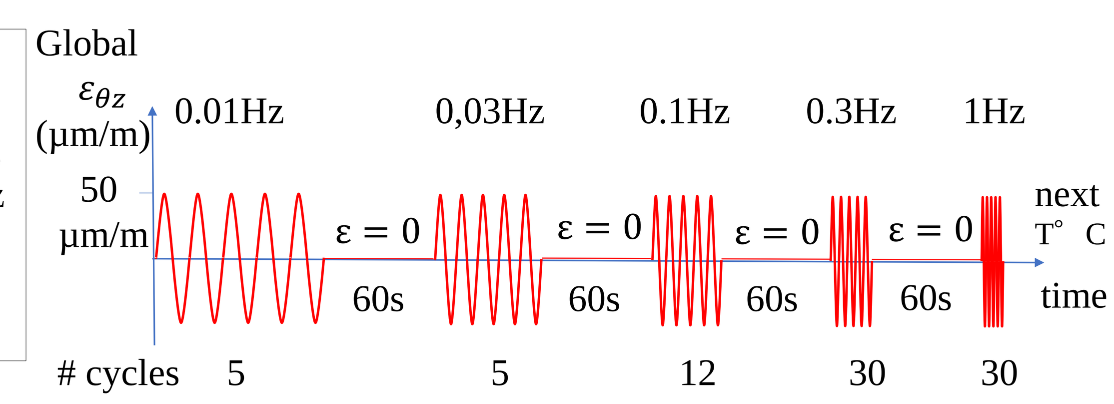


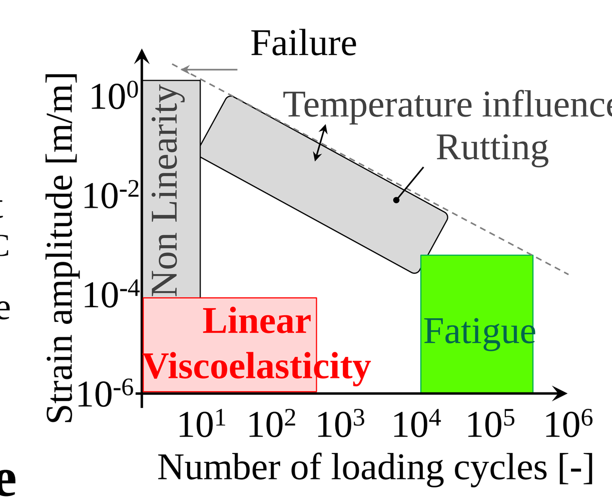
Test procedure for complex shear modulus and fatigue

$$\varepsilon_{\theta z\_global} = \frac{u_{\theta vertical\_sensors} \times R_{ext}}{2 \times h_{sample} \times R_{sensors}}$$

Shear complex modulus test

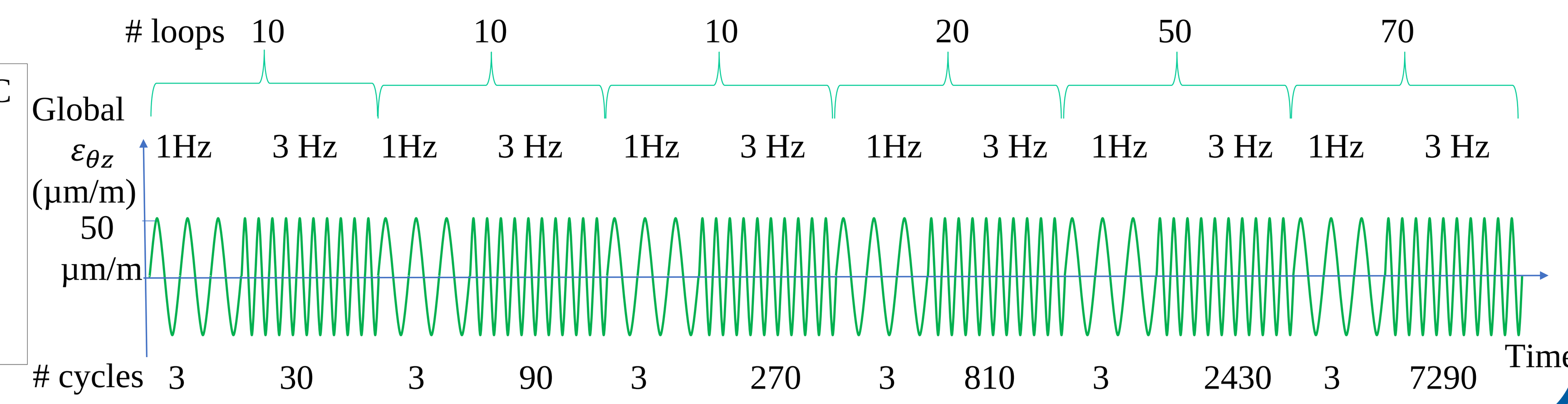
- Temperatures: 0, 10, 20, 30, 40°C
- Frequencies: 0.01, 0.03, 0.1, 0.3, 1Hz
- Global strain magnitude (whole sample): 50µm/m





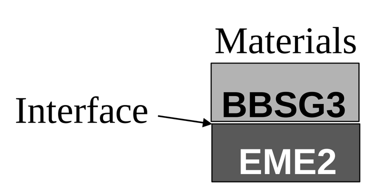
Fatigue test in shear loading mode

- Temperature: 10°C
- Frequencies: 1, 3Hz (no picture taken at 3Hz)
- Global strain amplitude (whole sample): 50µm/m



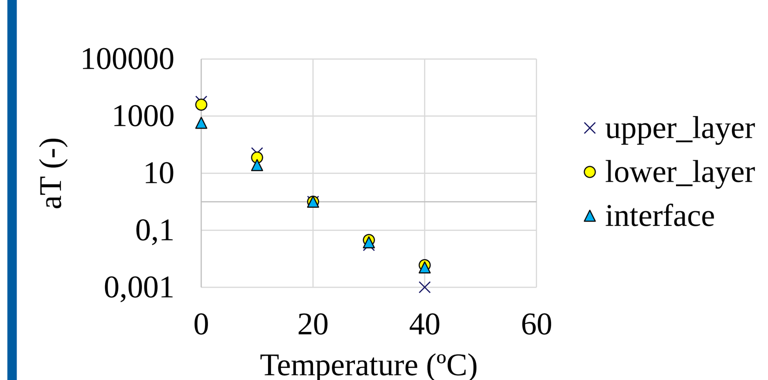
Results for shear complex modulus and fatigue tests

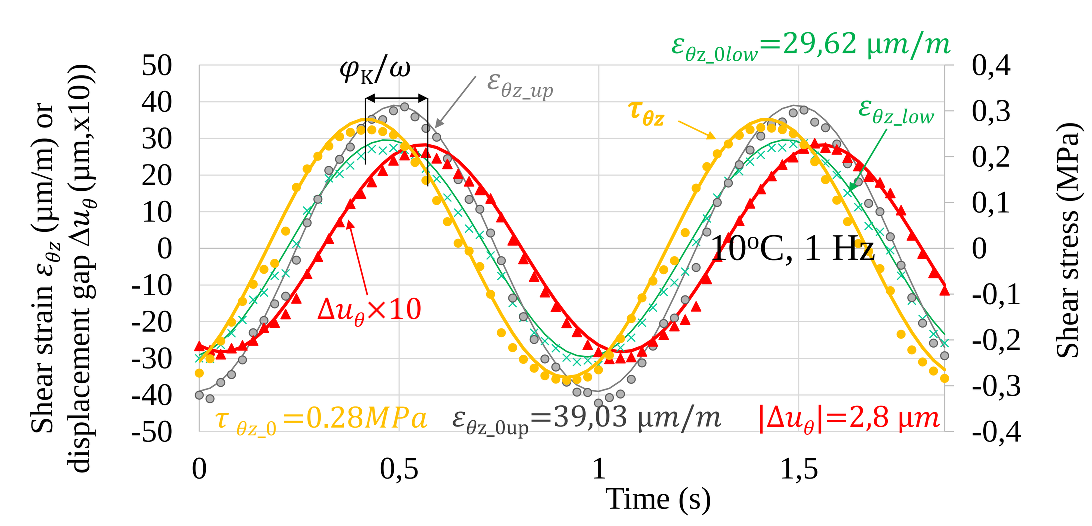
Example of shear complex modulus for layers and shear stiffness at interface

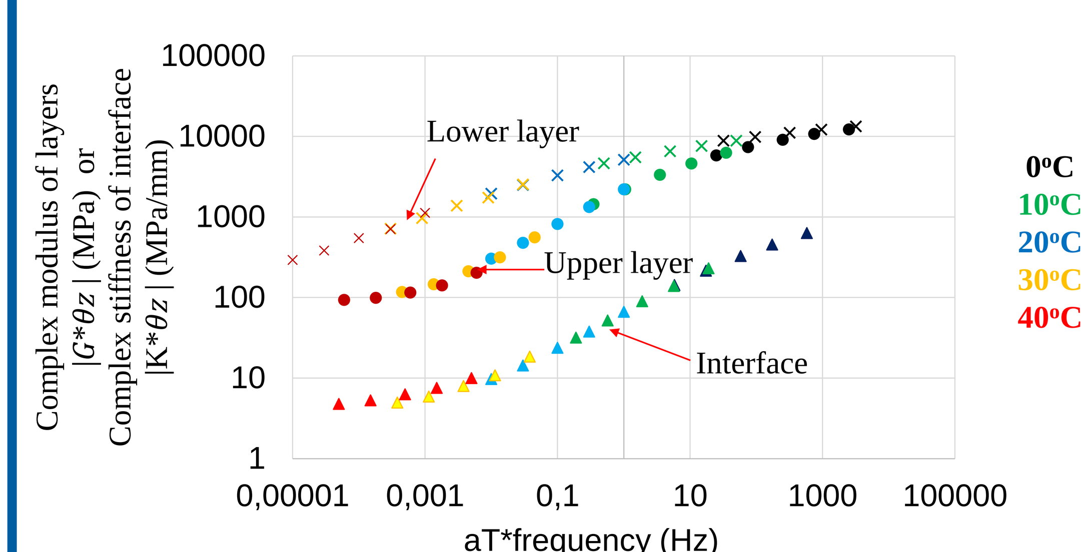


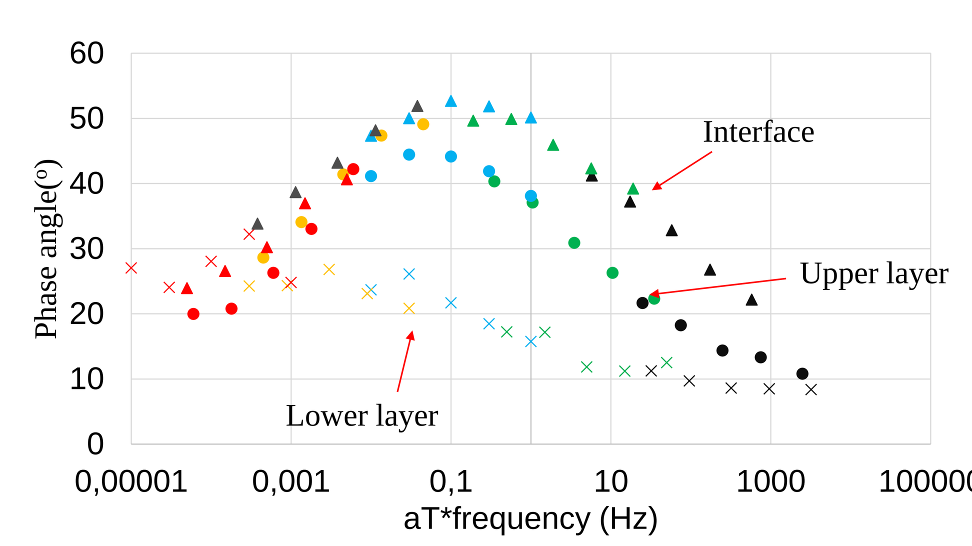
$$\tau_{\theta z} = \frac{3T}{2\pi \times (R_{ext}^3 - R_{int}^3)};\ G_{\theta z}^* = \frac{\tau_{\theta z\_0}}{2\varepsilon_{\theta z\_0}} e^{i\varphi_G} = |G_{\theta z}^*| e^{i\varphi_G};\ K_{\theta z}^* = \frac{\tau_{\theta z\_0}}{\Delta u_{\theta\_0}} e^{i\varphi_K} = |K_{\theta z}^*| e^{i\varphi_K}$$

Where $\tau_{\theta z}$: shear stress
T : torsion

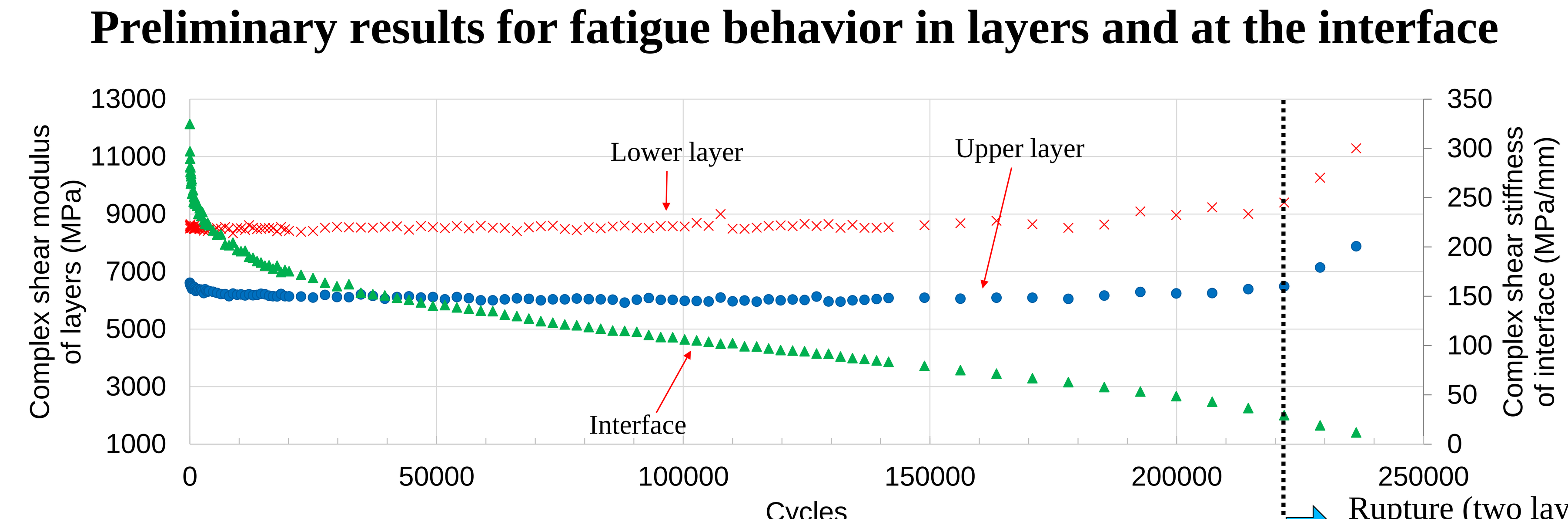




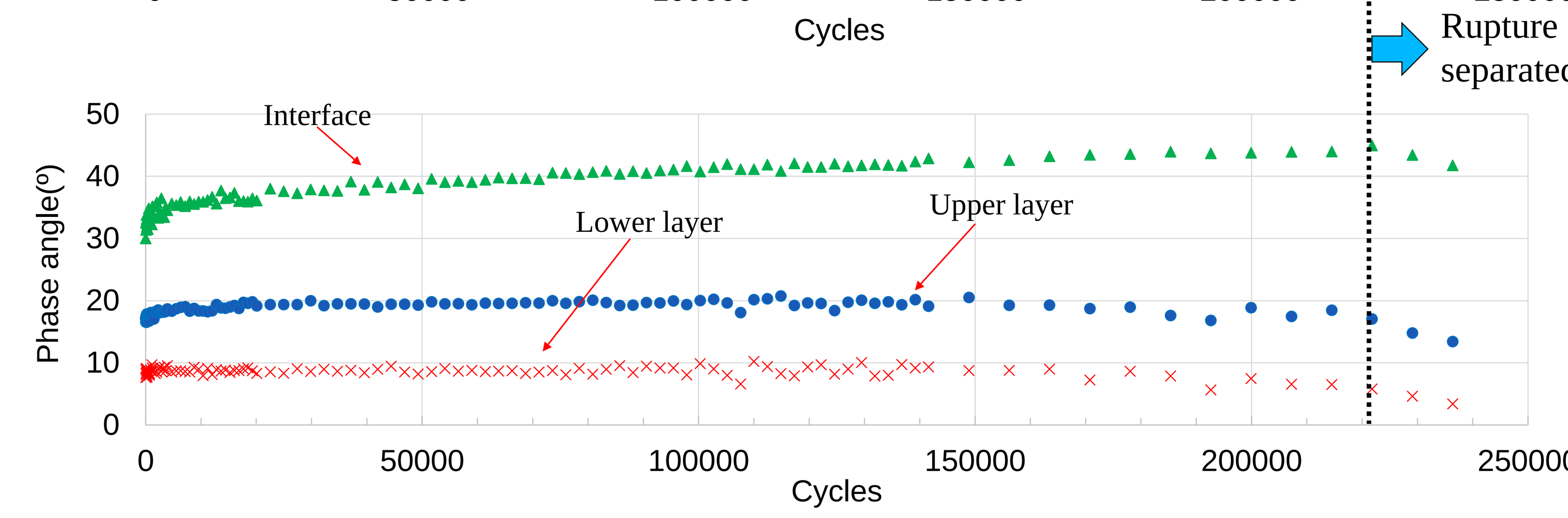




Preliminary results for fatigue behavior in layers and at the interface



Rupture (two layers separated at the interface)



Conclusions

- 2T3C apparatus abilities: sinusoidal torsion (or/and tension/compression) on interface
  - homogeneous stress and strain fields in layers
  - homogeneous stress and displacement fields at the interface
- From "complex modulus" tests : mechanical behavior at the interface is viscoelastic
- From preliminary fatigue results : fatigue failure appears at the interface rather than in layers

Perspectives

- Develop suitable fatigue critiria for the interface
- Study interface properties in high strain domain

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