ADDENDUM to GRANULAR COMPOSITES

PBX systems in the Brazilian Test

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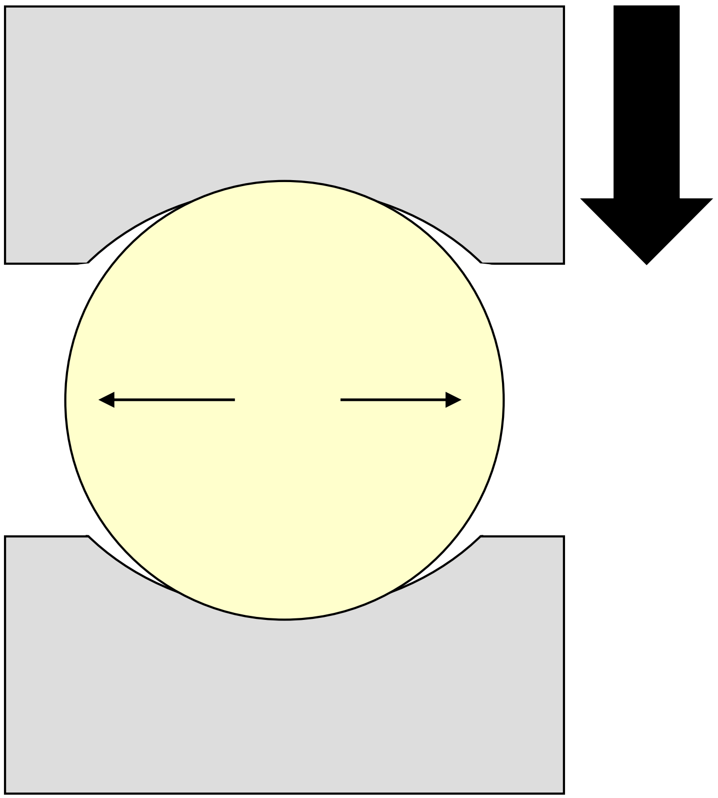
Thanks to:

Dr DM.Williamson, SCCM 2009

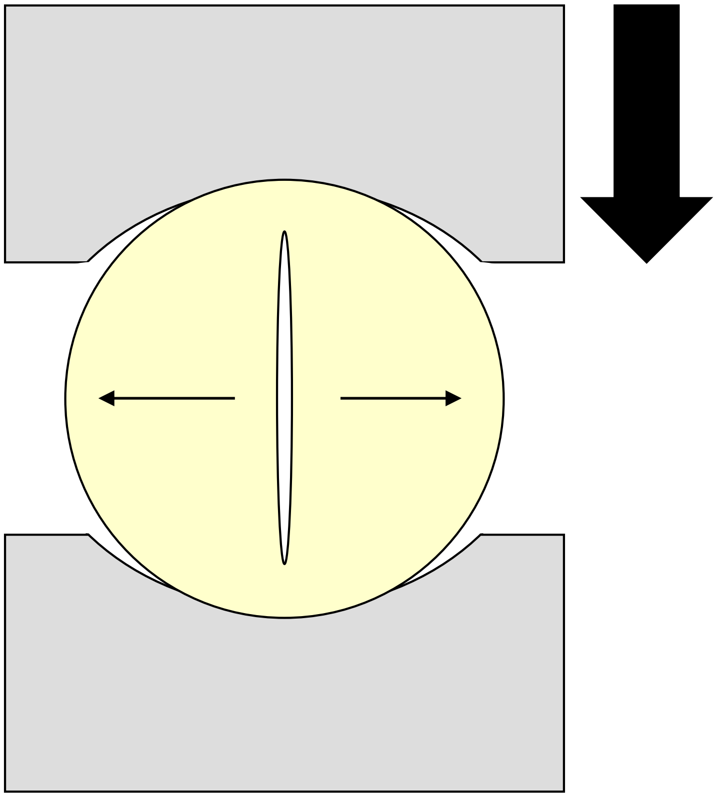
Brazilian test



Tensile failure through compression, in a predictable location.

Brazilian test

Brazilian test



Tensile failure through compression, in a predictable location.

$$\sigma_F = \frac{2P}{\pi DT}\left(1 - \left(\frac{b}{R}\right)^2\right)$$

Brazilian test

Brazilian test

What should full-field strain maps look like?

$$\sigma_r = -\frac{2p}{\pi}\left\{a + \sum_{n=1}^{n=\infty}\left[1-\left(1-\frac{1}{n}\right)\left(\frac{r}{R}\right)^2\right]\left(\frac{r}{R}\right)^{2n-2}\sin 2na\cos 2n\theta\right\},$$

$$\sigma_\theta = -\frac{2p}{\pi}\left\{a - \sum_{n=1}^{n=\infty}\left[1-\left(1+\frac{1}{n}\right)\left(\frac{r}{R}\right)^2\right]\left(\frac{r}{R}\right)^{2n-2}\sin 2na\cos 2n\theta\right\},$$

$$\tau_{r\theta} = \frac{2p}{\pi}\left\{\sum_{n=1}^{n=\infty}\left[1-\left(\frac{r}{R}\right)^2\right]\left(\frac{r}{R}\right)^{2n-2}\sin 2na\sin 2n\theta\right\},$$

where p, a, r, R, and θ are load, contact width (2b in some notation), radial position, disk Radius and angular position respectively. These expressions can be transformed into Cartesian variables σ_x, σ_y and σ_{xy}, with the use of Mohr's circle:

$$\sigma_x = \frac{\sigma_r + \sigma_\theta}{2} + \frac{\sigma_r - \sigma_\theta}{2}\cos 2\theta - \sigma_{r\theta}\sin 2\theta,$$

$$\sigma_x = \frac{\sigma_r + \sigma_\theta}{2} - \frac{\sigma_r - \sigma_\theta}{2}\cos 2\theta + \sigma_{r\theta}\sin 2\theta,$$

$$\sigma_{xy} = \frac{\sigma_r - \sigma_\theta}{2}\sin 2\theta +_{r\theta}\cos 2\theta.$$

Assuming plane stress ($\sigma_z = 0$), and a value of Poisson's ratio v and elastic modulus E, strain values can then be calculated:

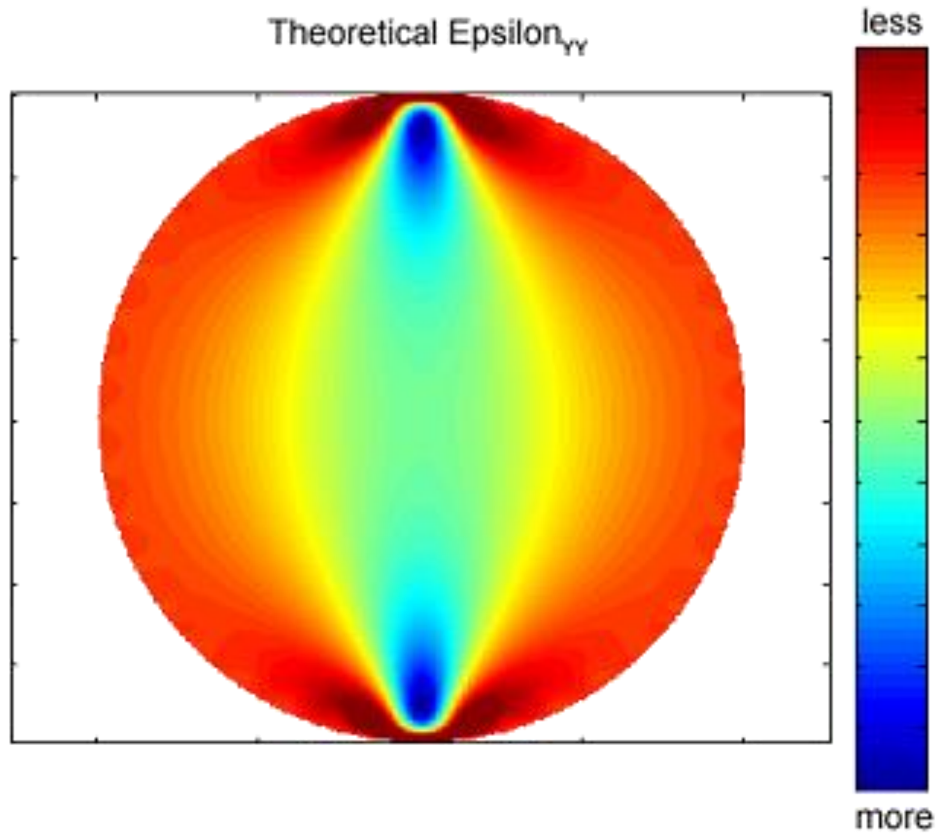
$$\varepsilon_{xx} = \frac{1}{E}(\sigma_x - v\sigma_y),$$

$$\varepsilon_{yy} = \frac{1}{E}(\sigma y - v\sigma_x).$$

Hondros G. 1959 The evaluation of Poisson's ratio and the modulus of materials of a low tensile resistance by the Brazilian (indirect tensile) test with particular reference to concrete. *J. Aust. appl. Sci*. **10** 243-267.

Brazilian test

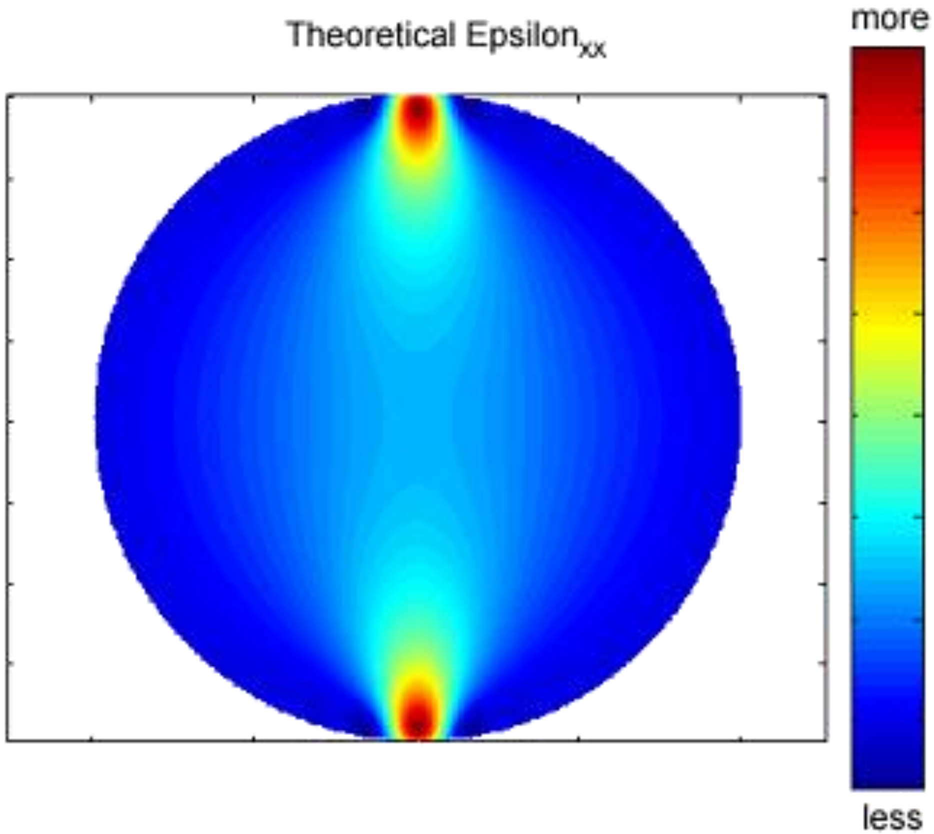
Full field strain distributions



compressive

Brazilian test

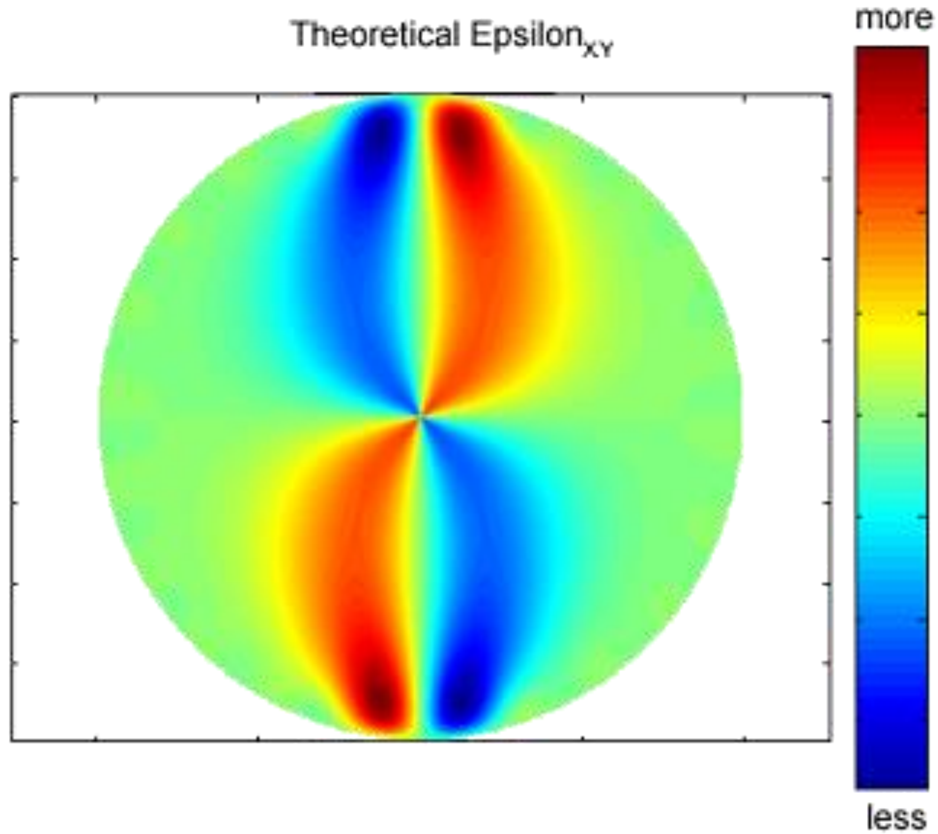
Full field strain distributions



tension

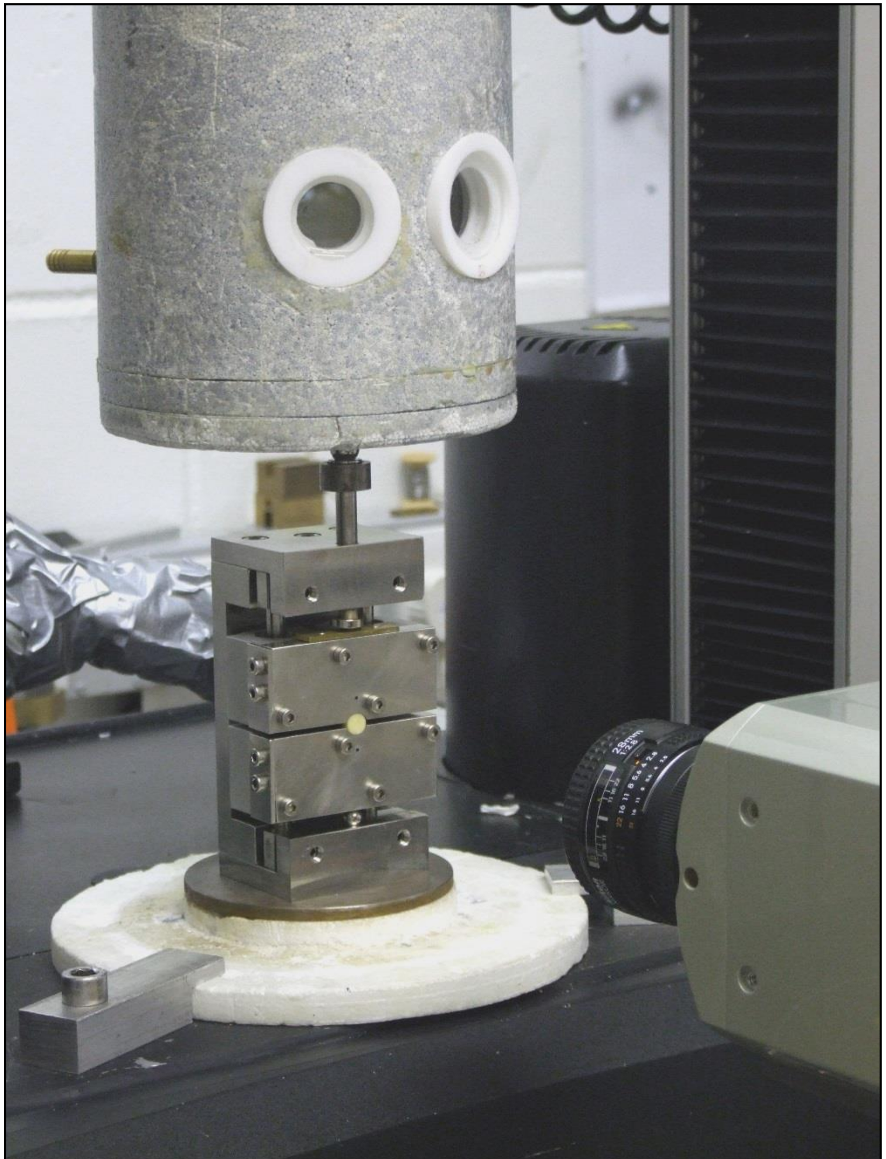
Brazilian test

Full field strain distributions



shear

Experiment



Rig has:

- Full stainless steel construction.
- PTFE based linear bearings.
- Magnetic couplings.

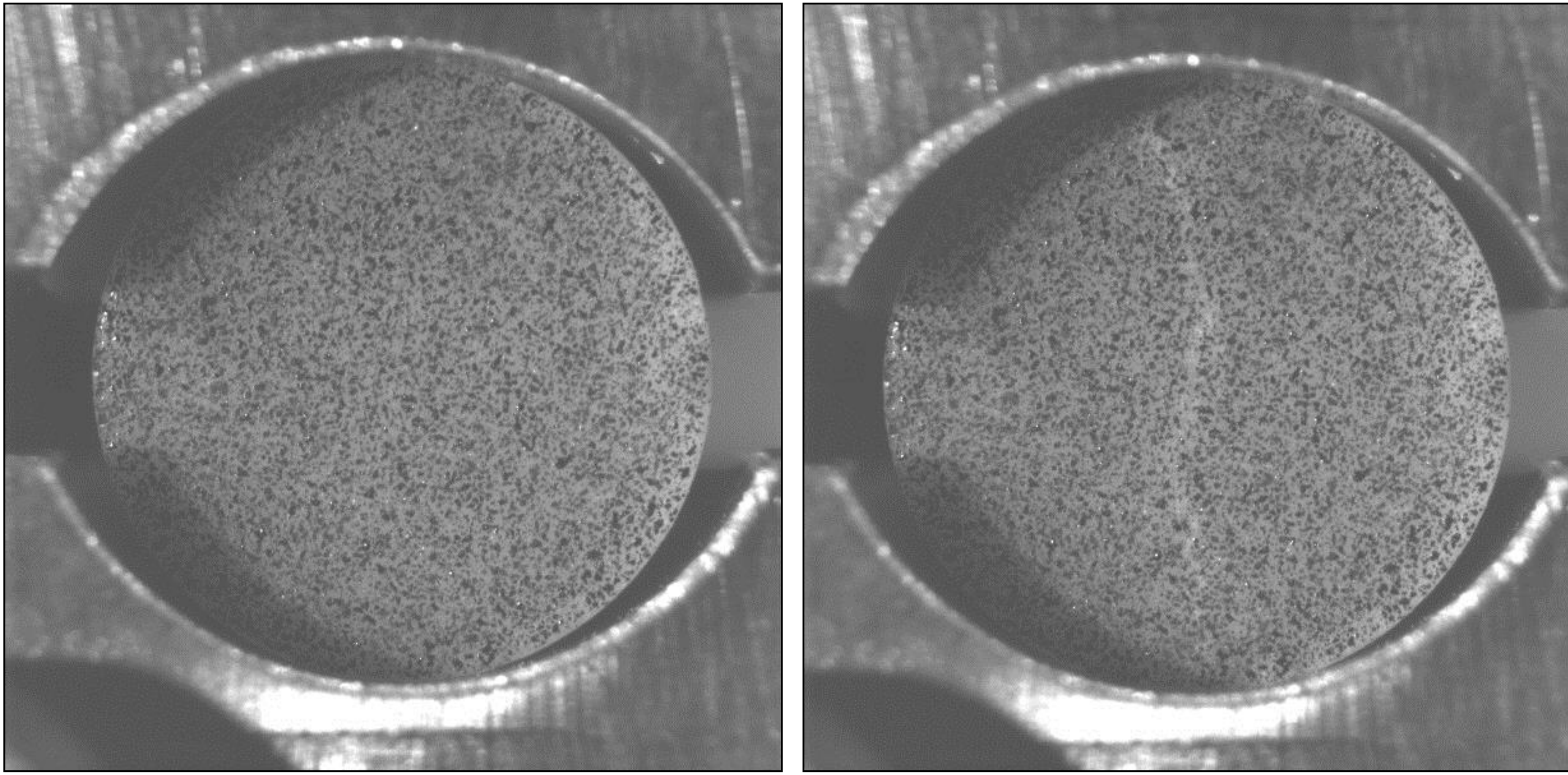
Shroud has:

- Liquid nitrogen cooling.
- Shroud has double glazed viewing & illumination ports.

Camera is:

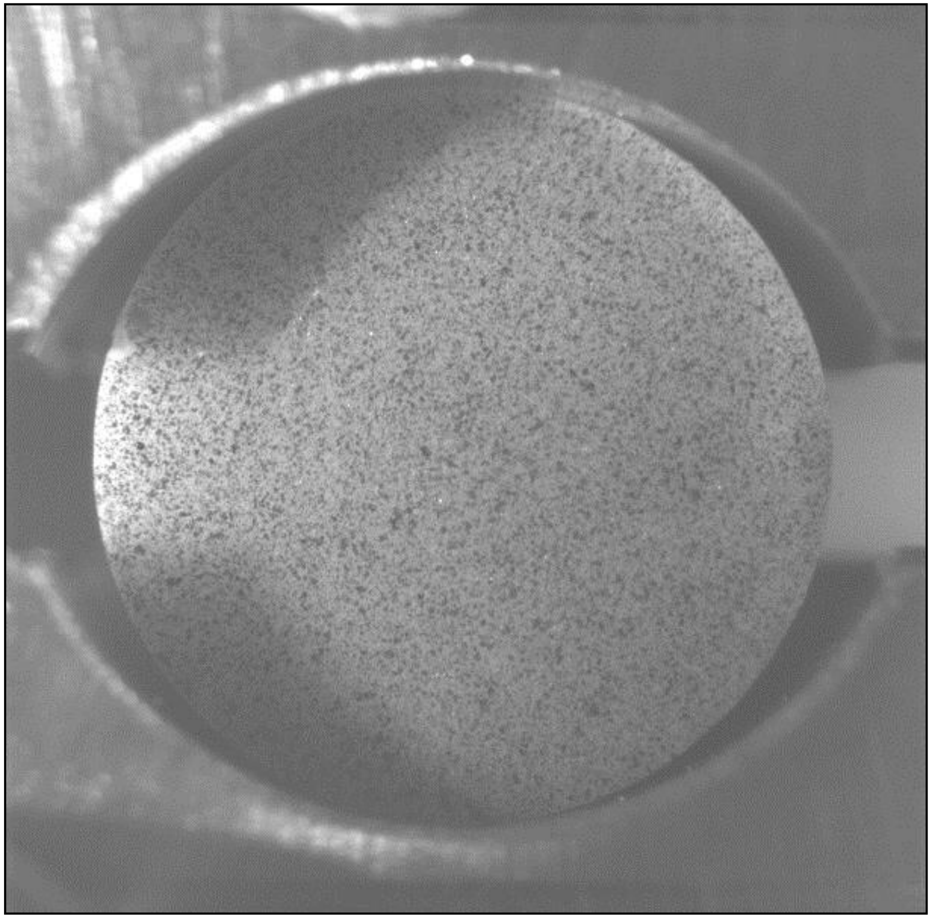
- Phantom v4.3 high speed digital
- Synchronised sampling rate of Instron

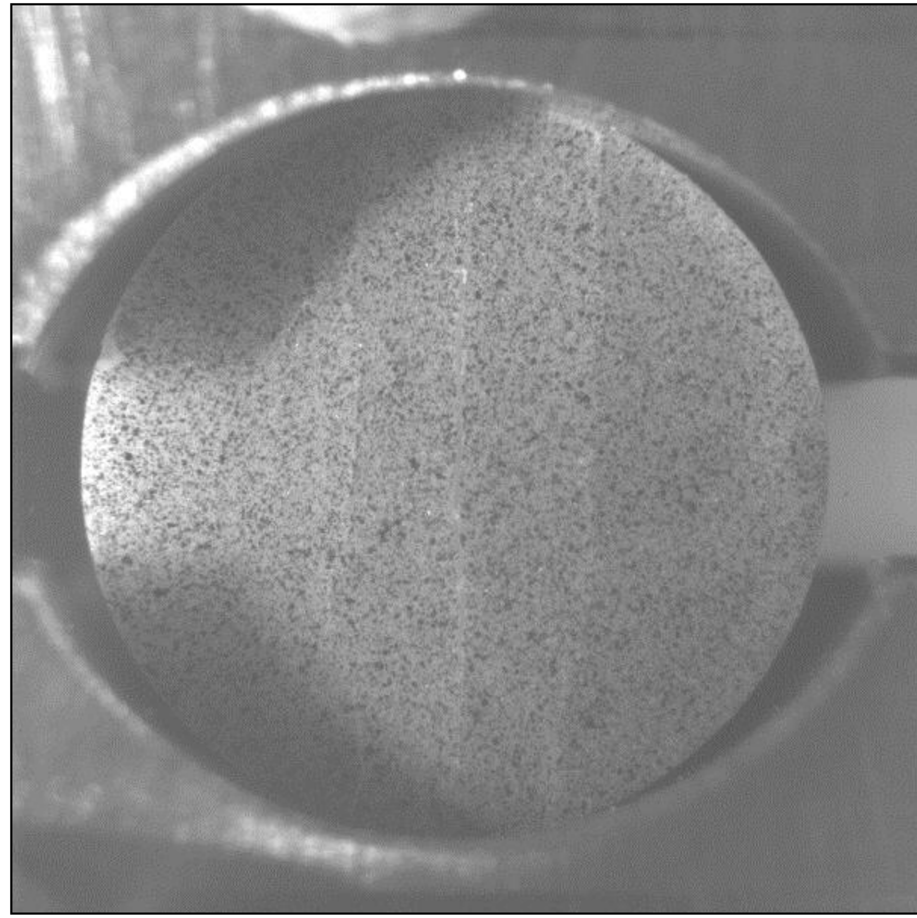
Results: room temperature



Progressive failure at 107 N

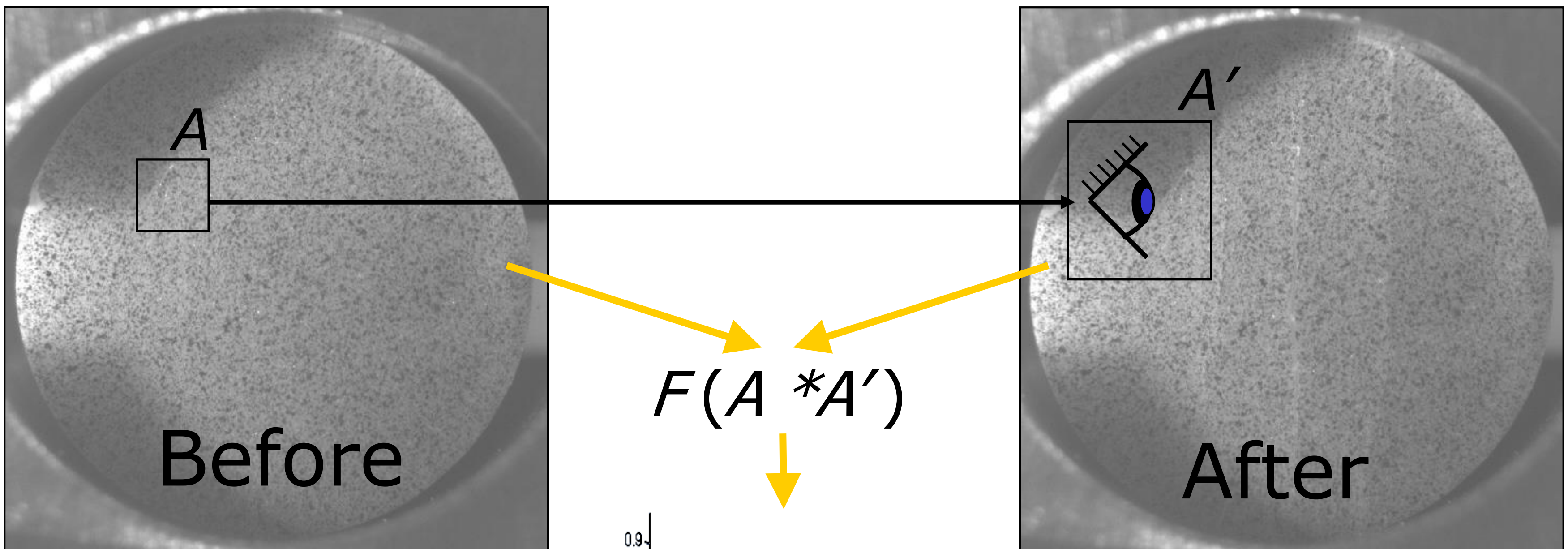
Results: -94˚C

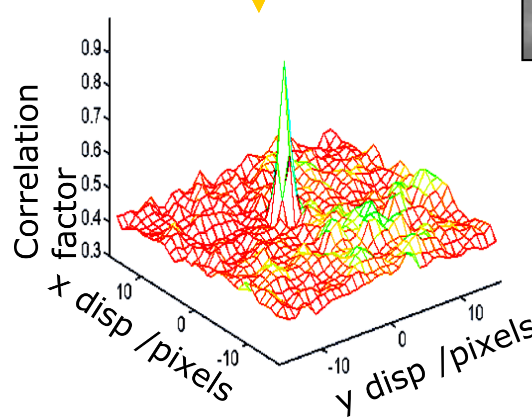




Catastrophic failure at 589 N

DICC analysis

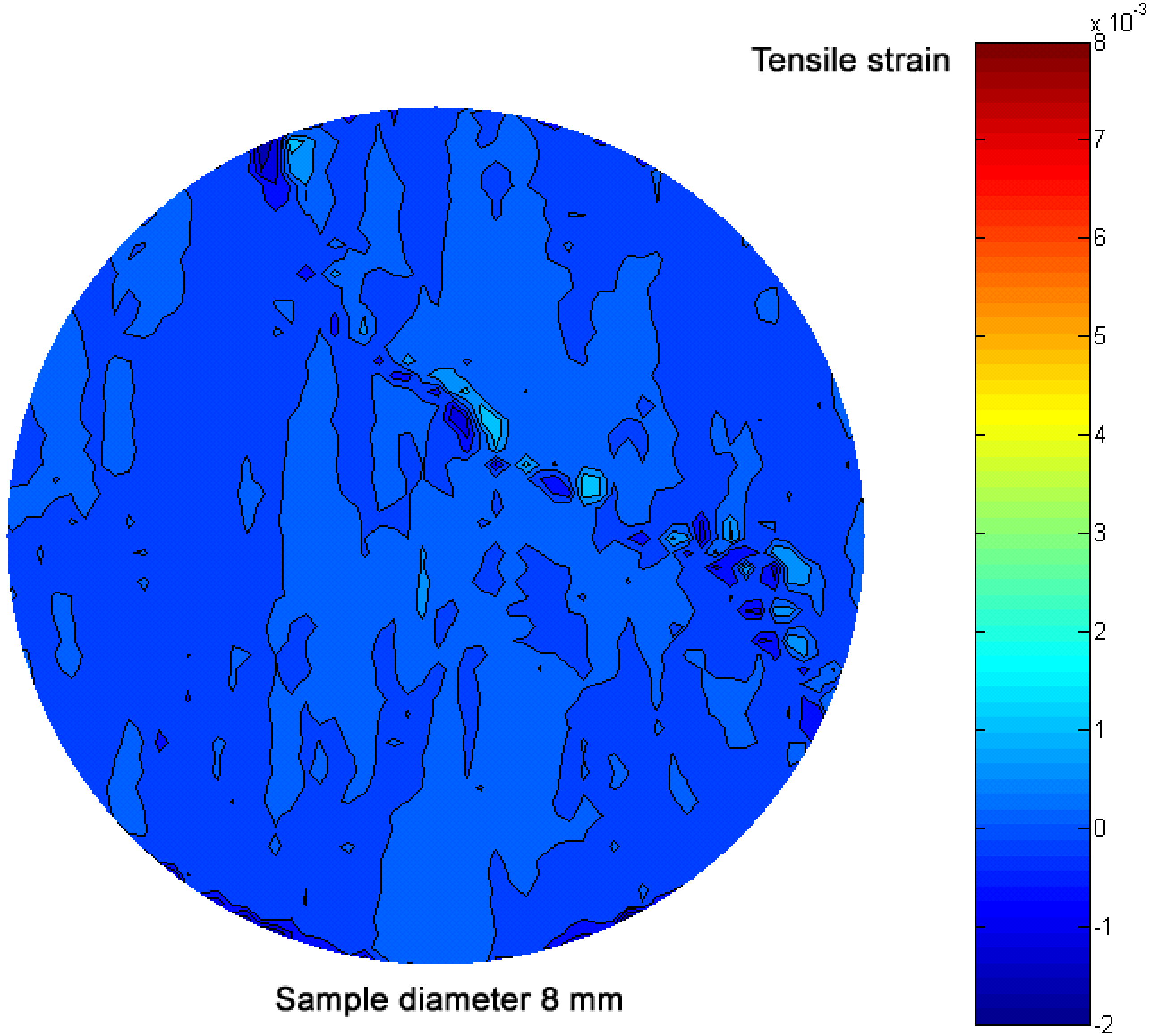




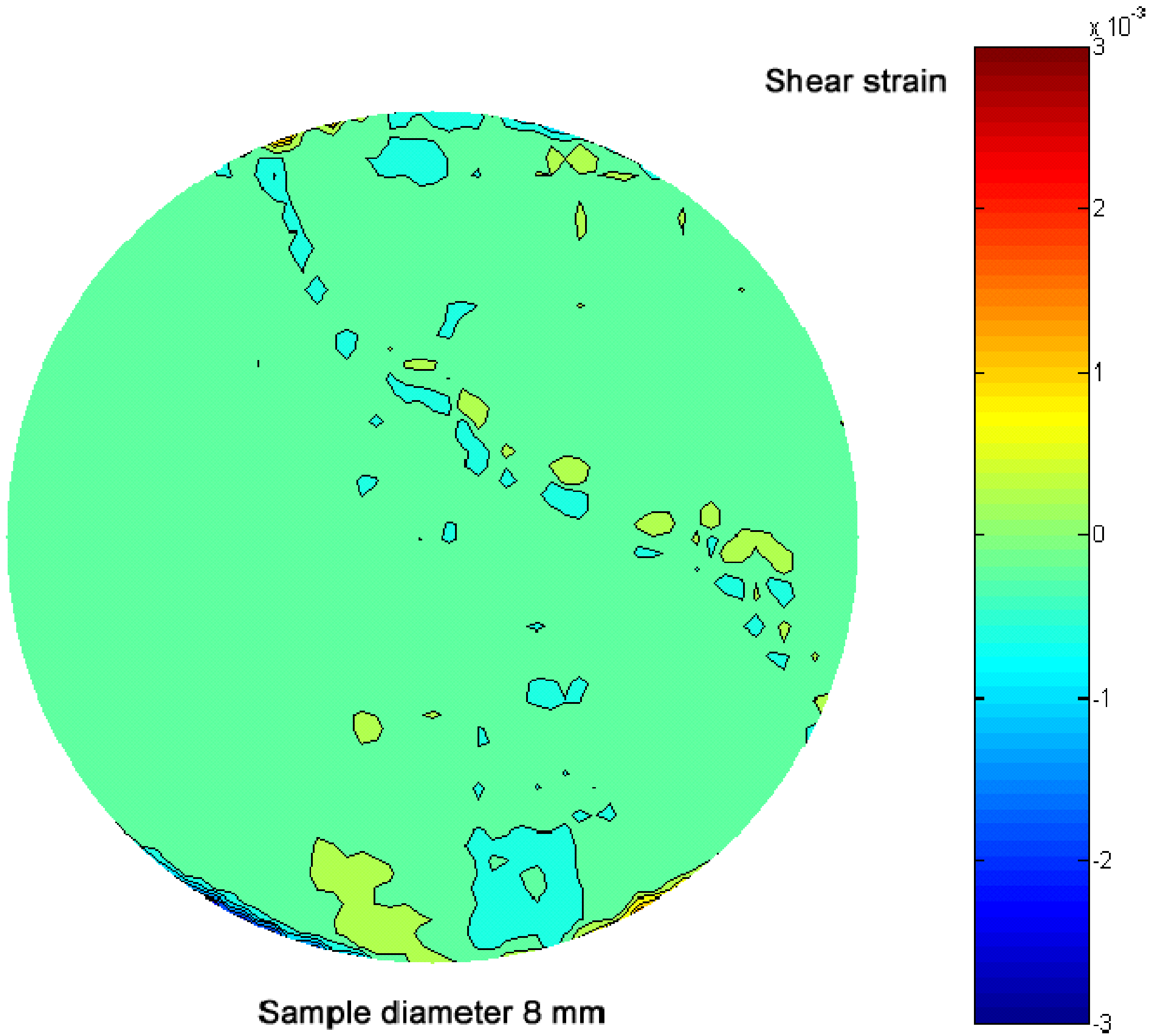
Find location of maximum correlation using Fourier transforms of *A* and *A′*.

Raster and repeat across whole image to build up displacement field.

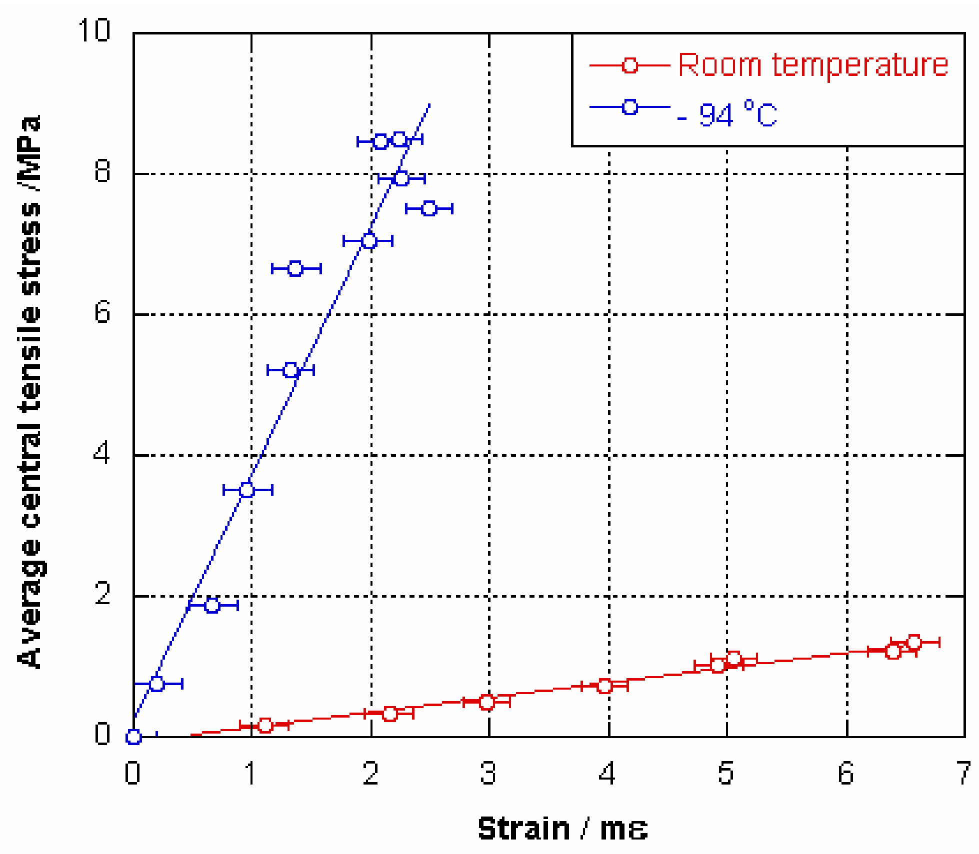
Room temperature tensile



Room temperature shear



Room temperature DICC

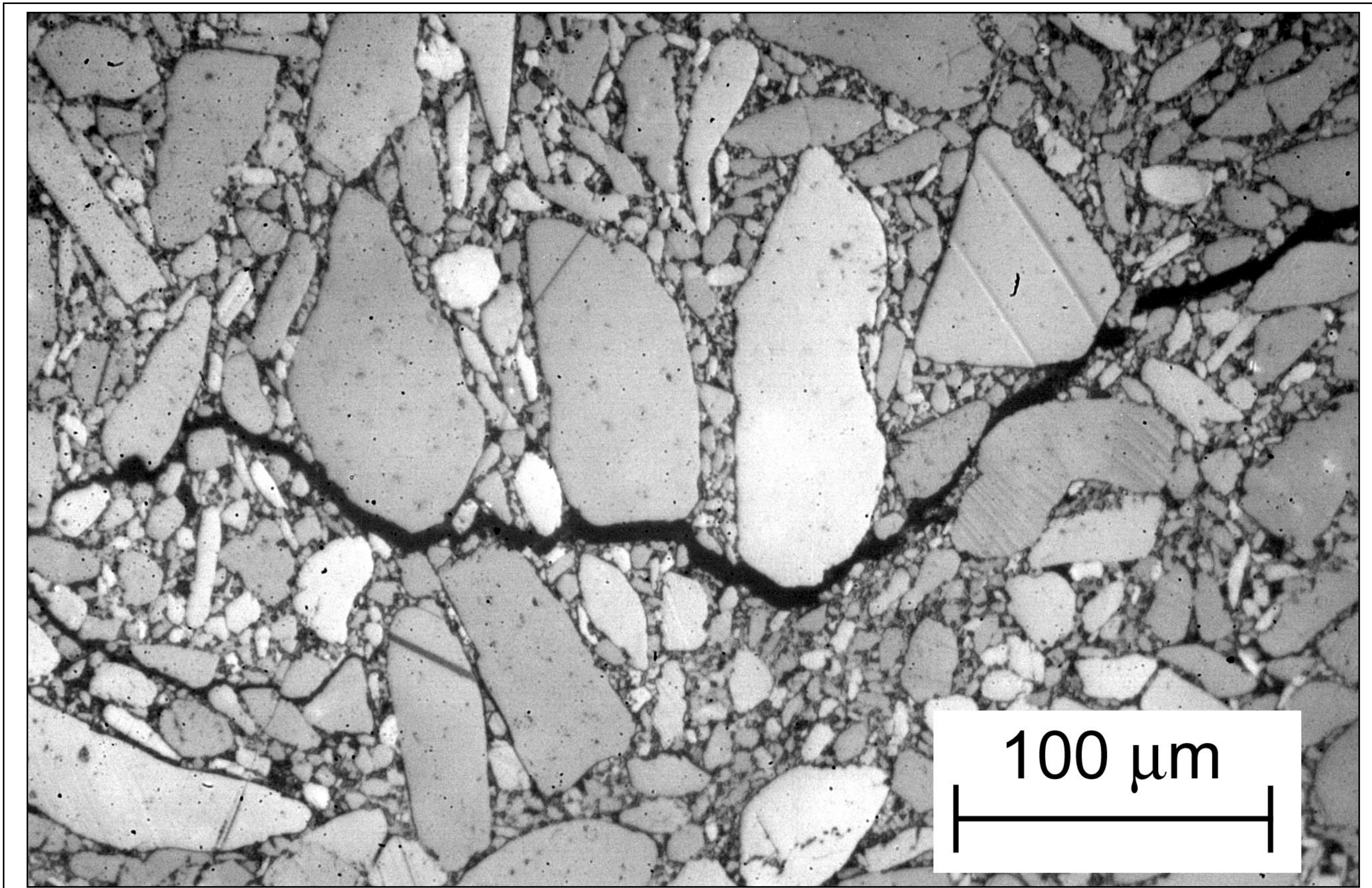


Sample	Temp / °C	Failure	
		σ / MPa	ε / 10^{-3}
#1	+28 ± 1	1.48 ± 0.06	6.5 ± 0.2
#2	+28 ± 1	1.49 ± 0.06	7.7 ± 0.2
#3	+28 ± 1	1.59 ± 0.06	7.8 ± 0.2
#4*	+28 ± 1	1.75 ± 0.06	6.7 ± 0.2
mean	**+28 ± 1**	**1.59 ± 0.07**	**7.2 ± 0.3**
#5*	-94 ± 3	6.68 ± 0.06	3.8 ± 0.2
#6	-94 ± 3	8.19 ± 0.06	2.3 ± 0.2
#7	-94 ± 3	6.30 ± 0.06	2.6 ± 0.2
#8	-94 ± 3	7.08 ± 0.06	3.4 ± 0.2
mean	**-94 ± 3**	**7.1 ± 0.4**	**3.0 ± 0.3**

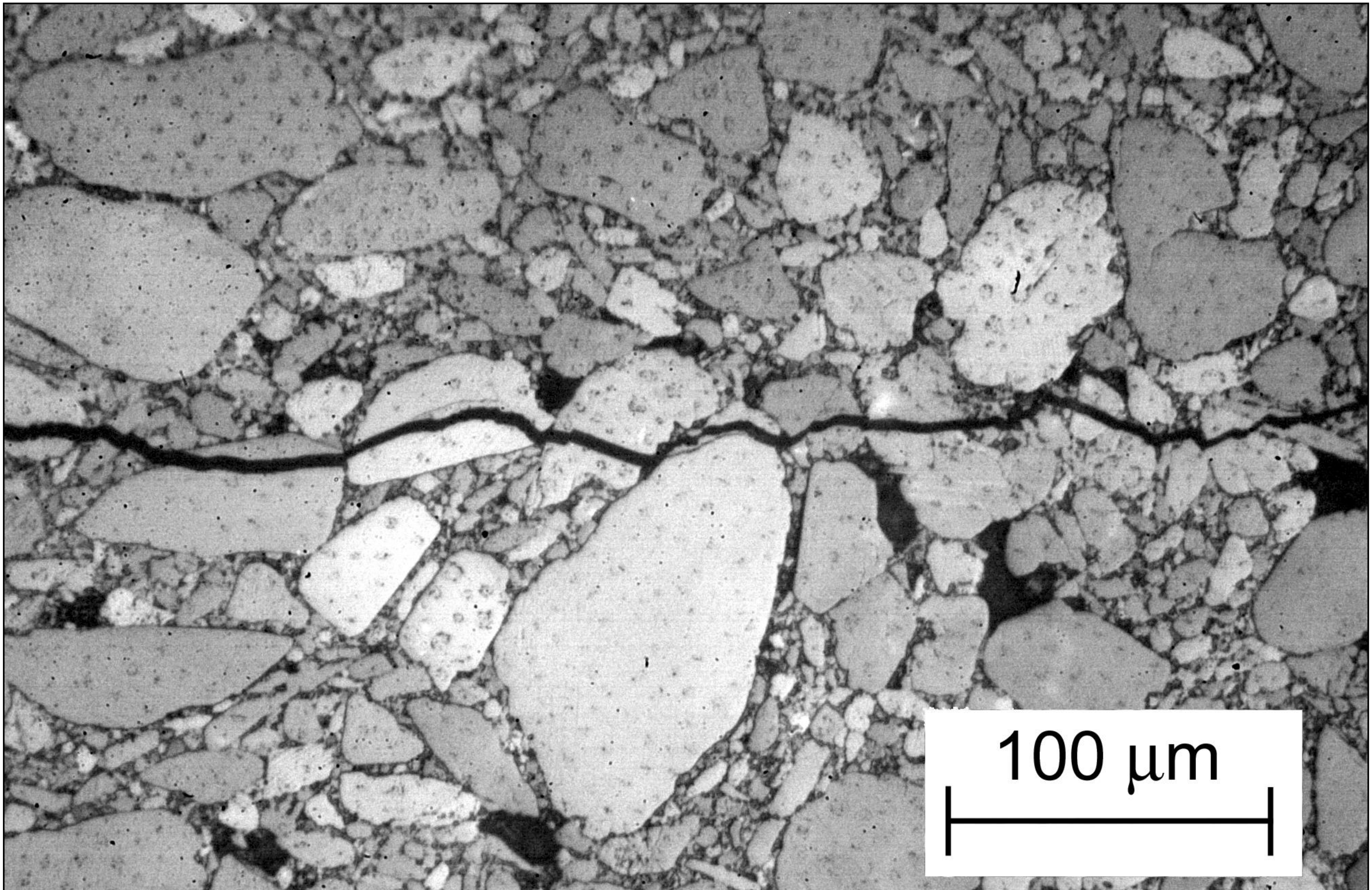
* denotes polished sample

Increase in failure stress and reduction in failure strain.

Room temperature microscopy



-94 °C microscopy



Conclusions

- Upon testing below $T_{G:}$
  - Strength is increased and strain to failure is reduced.
  - Fracture mode changes intergranular → transgranular.
  - Fracture faces nominally HMX-on-binder → HMX-HMX.
- By invoking concept of time-temperature superposition we expect same behaviour at room temperatures and high strain rates.
- Bulk response and local response:
  - Before failure
  - Localisation of failure
  - Compare 'ideal homogeneous response' to real composite response
  - Damage model – needs development