Reinforcement effectiveness in composites evaluated by low load acoustic emission

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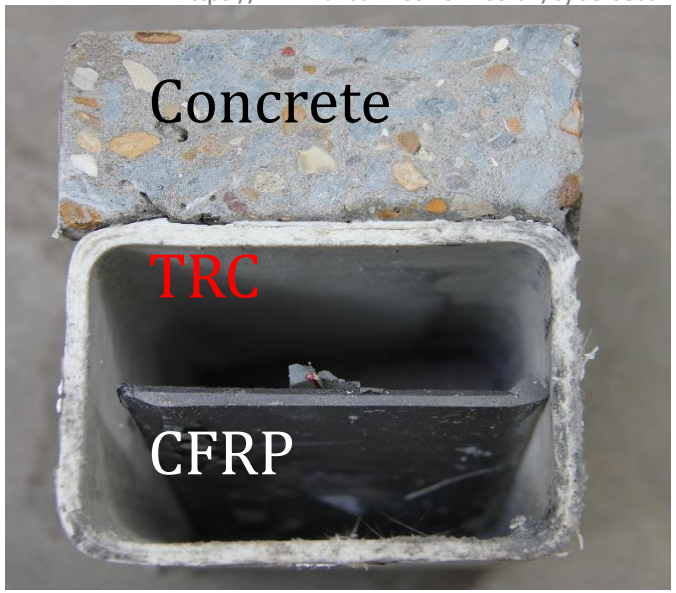
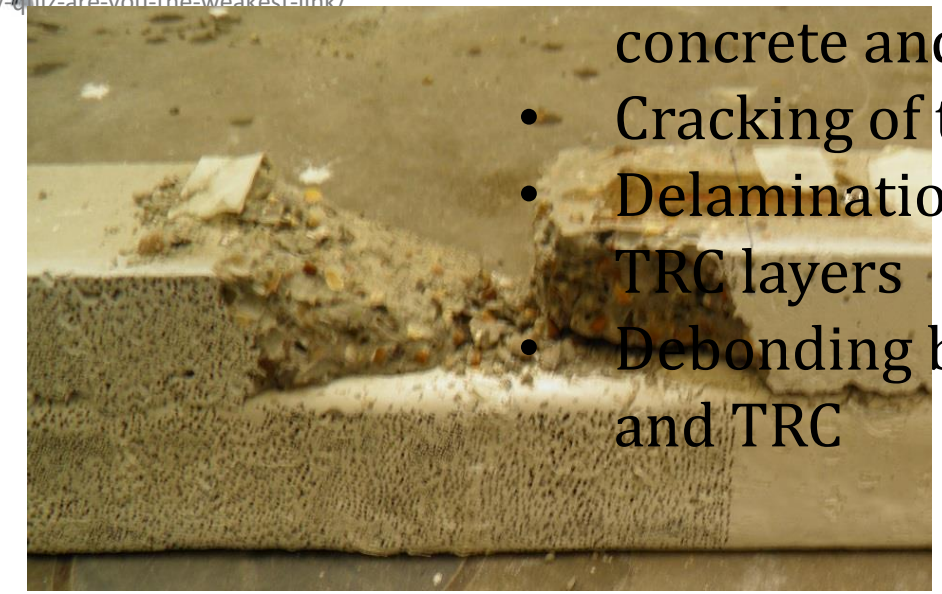
Fracture mode determination=**What is the weakest link of our system?**

https://www.urbannetwork.co.uk/cybersecurity-quiz-are-you-the-weakest-link/



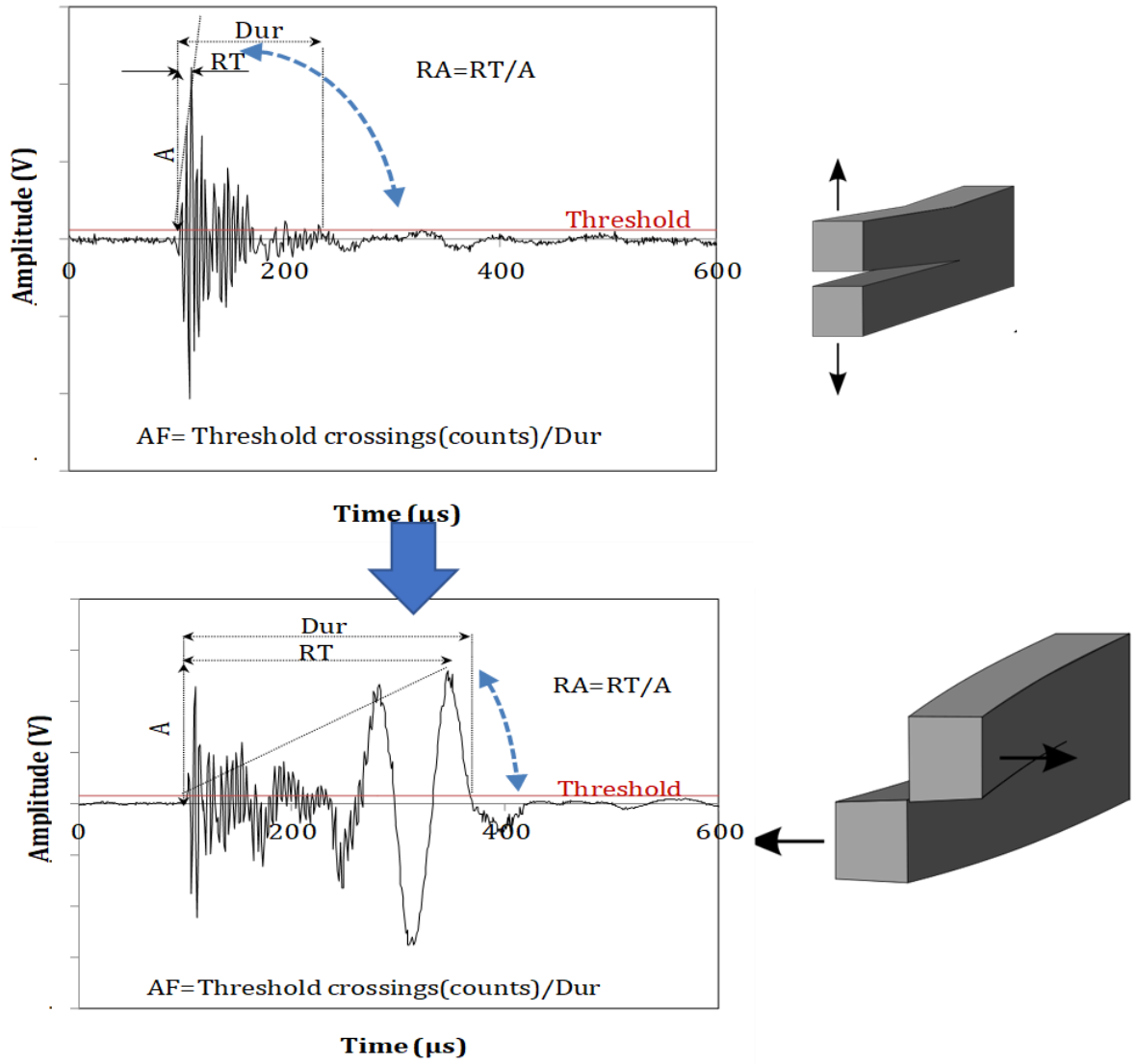


Possible fracture mechanisms:

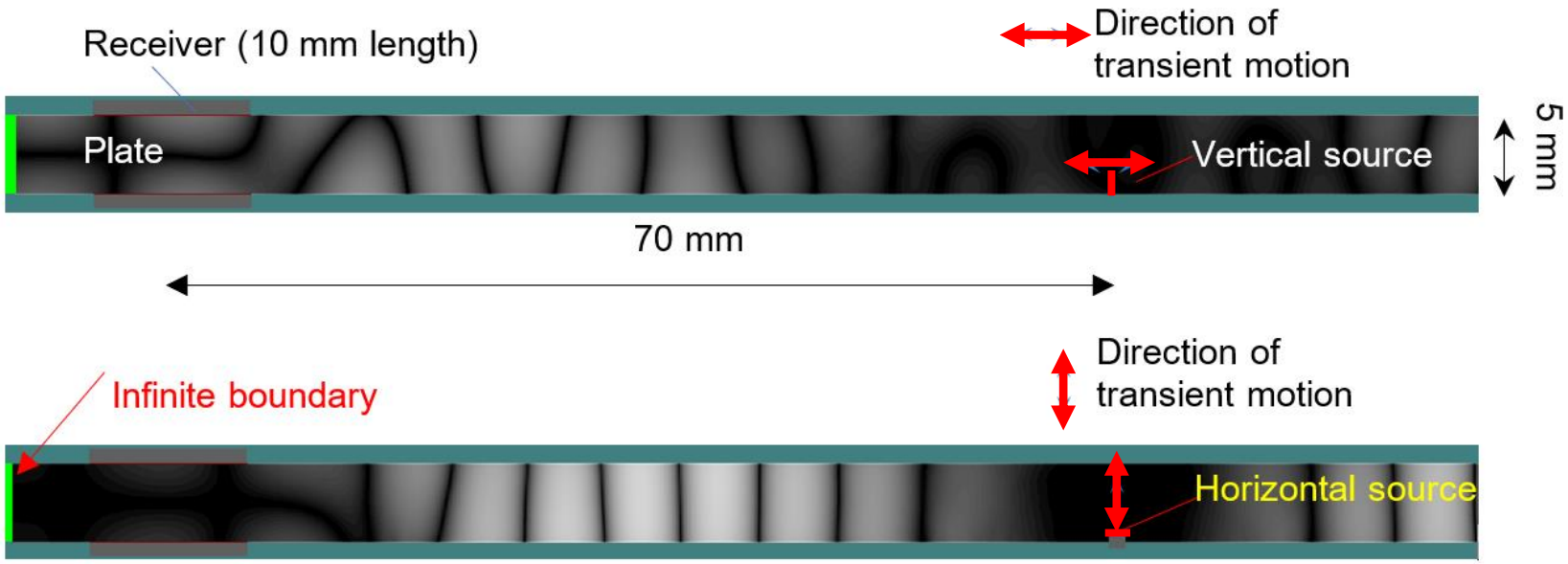
- Crushing of concrete
- Debonding between concrete and TRC box
- Cracking of the TRC matrix
- Delaminations within the TRC layers
- Debonding between CFRP and TRC

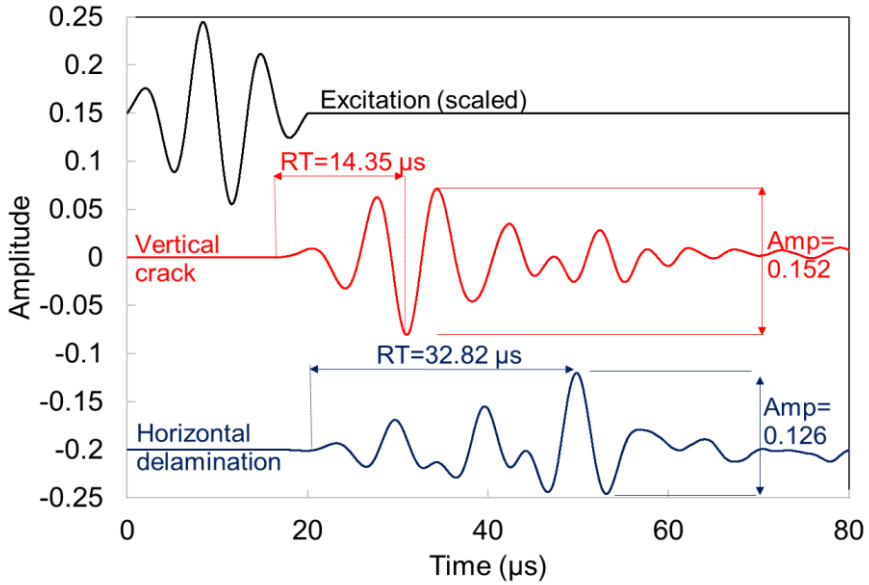
Helps to characterize the type of damage in heterogeneous components and **improve** the **design** and final properties **(strength)**

In other words… Can AE of early loading stages indicate the effectiveness of reinforcement (goodness of bonding)?



Numerical simulations confirm relation between AE wave and source



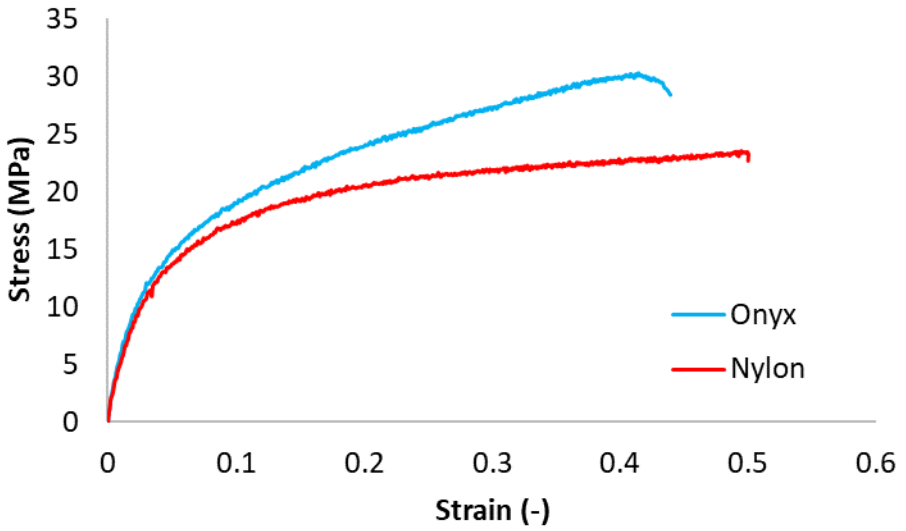


A change in crack orientation results in different waveform shape and AE parameters.
Longitudinal defects in plates (usually delaminations) result in longer waveforms of lower frequency than matrix cracks

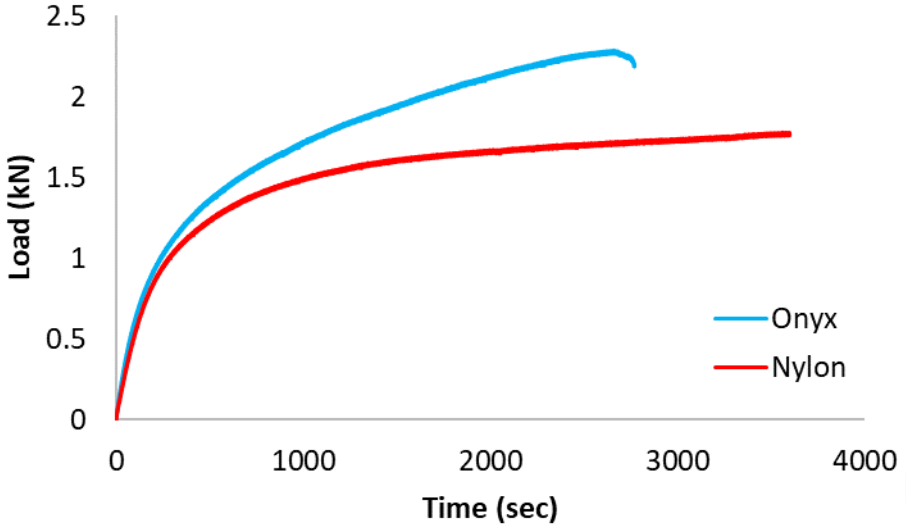
- Tsangouri, E., Aggelis D.G., A review of acoustic emission as indicator of reinforcement effectiveness in concrete and cementitious composites, Construction and Building Materials, 224, 10 2019, Pages 198-205

Tensile tests on 3D printed Onyx and Nylon specimens

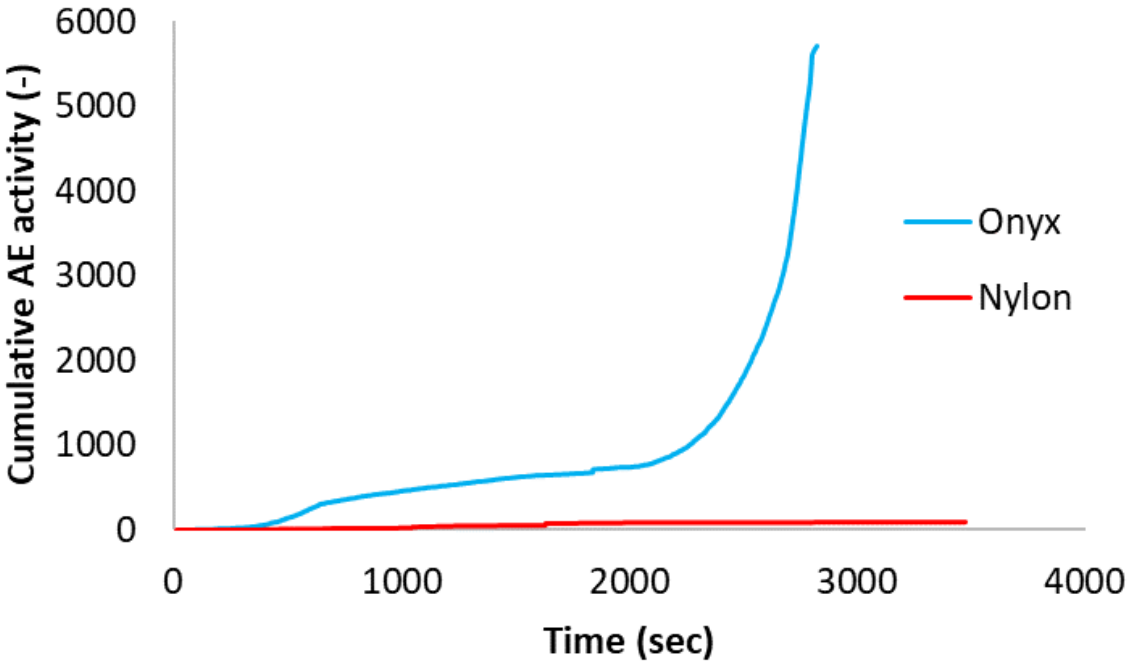
- Quasi-static tests
- 1 mm/min displacement rate
- Test until a displacement of 60 mm or final failure
- 30 dB AE amplitude threshold
- 50 mm distance between sensors



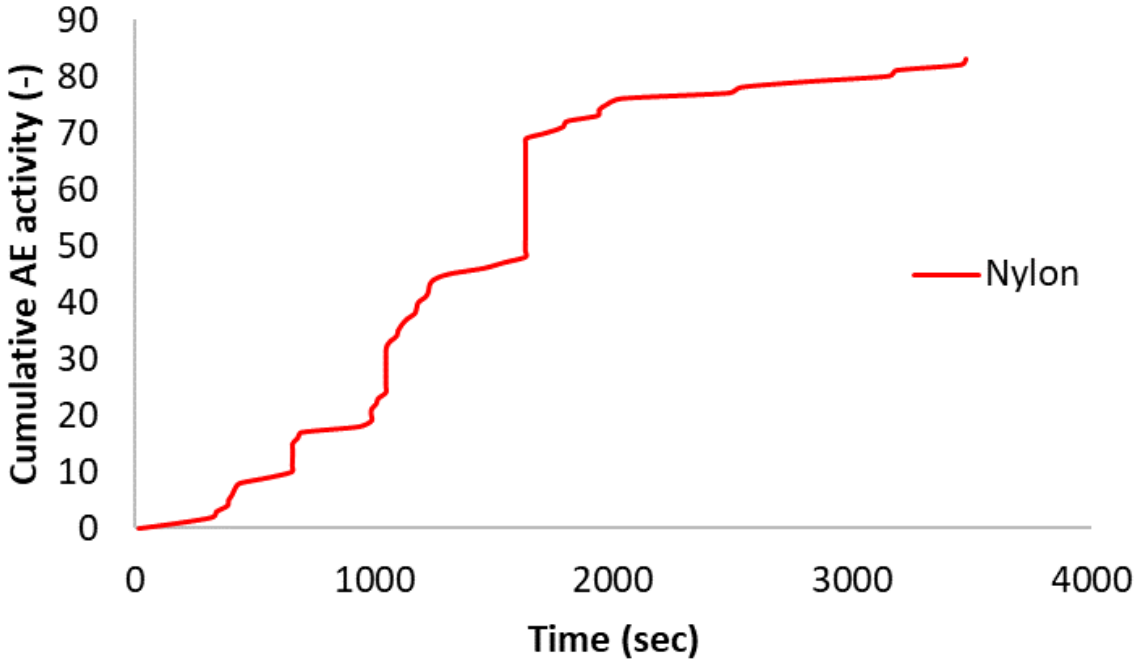
A clear impact of the fiber reinforcement on the mechanical properties



Tensile tests on Onyx and Nylon specimens

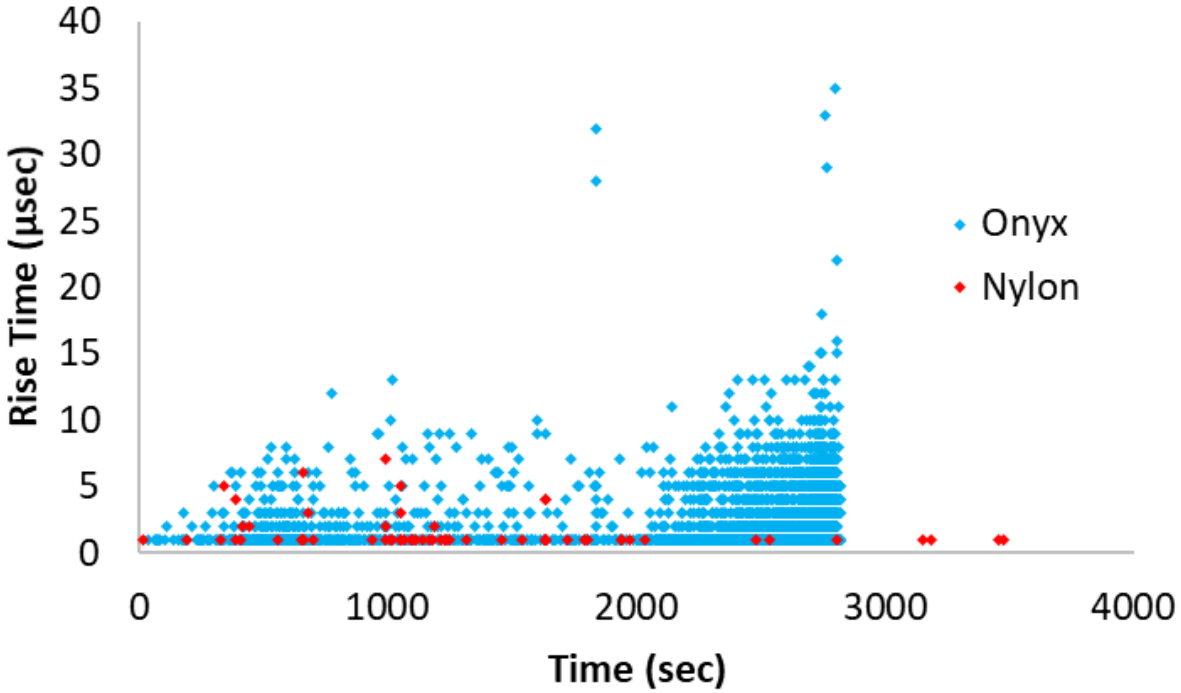


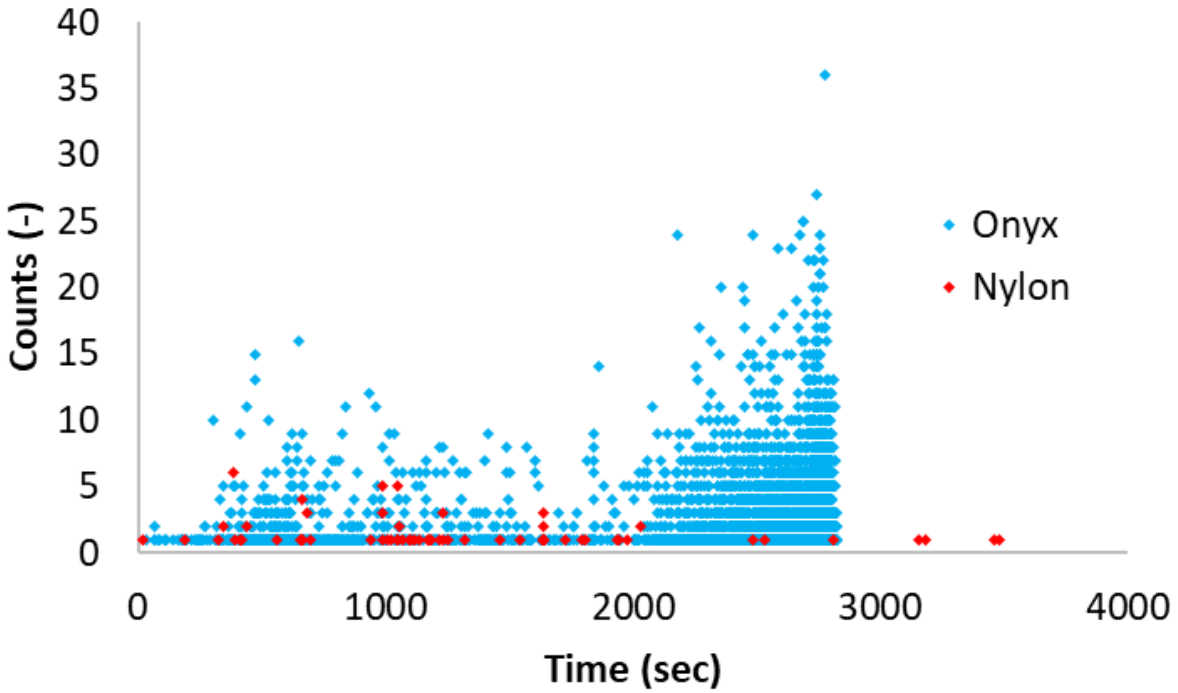
Zoom-in for Nylon specimens



A great difference in the cumulative AE activity

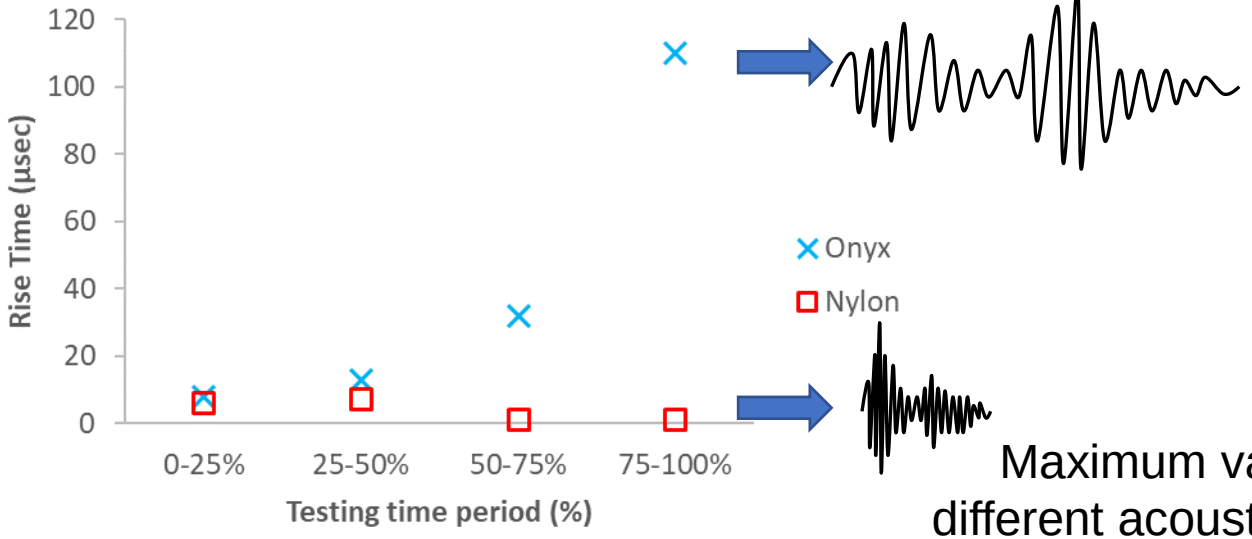
Tensile tests on Onyx and Nylon specimens



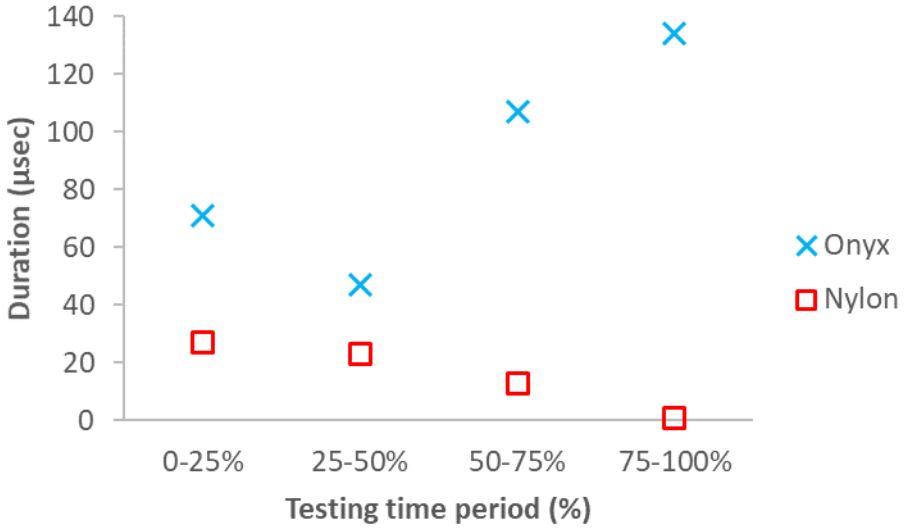


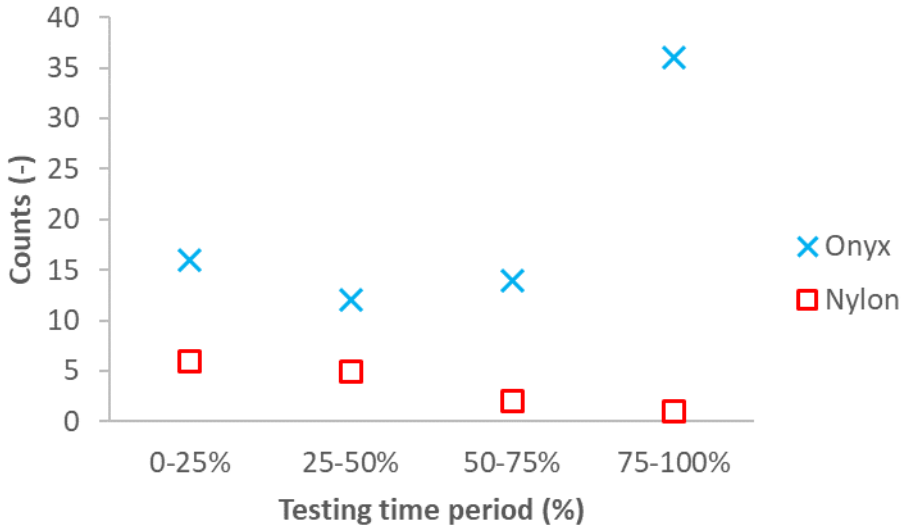
The presence of fibers leads to higher values of the rise time and the number of counts from early loads

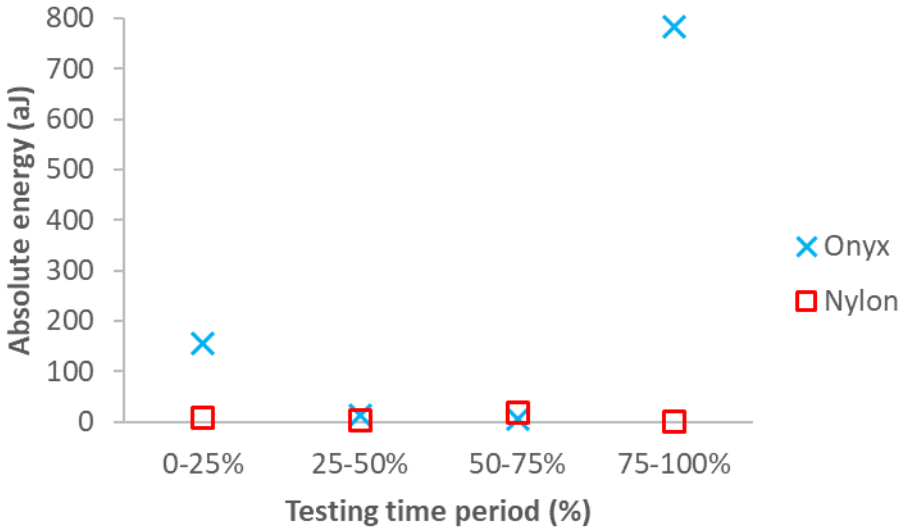
Tensile tests on Onyx and Nylon specimens



Maximum values of different acoustic features for distinct time periods during the test







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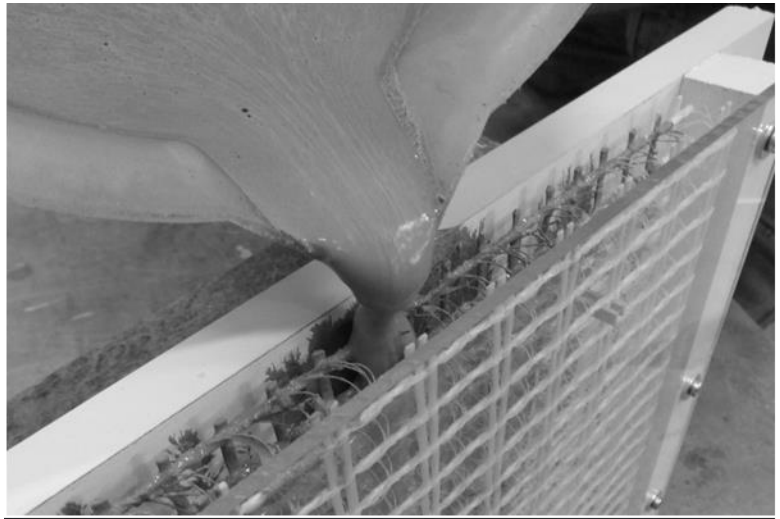
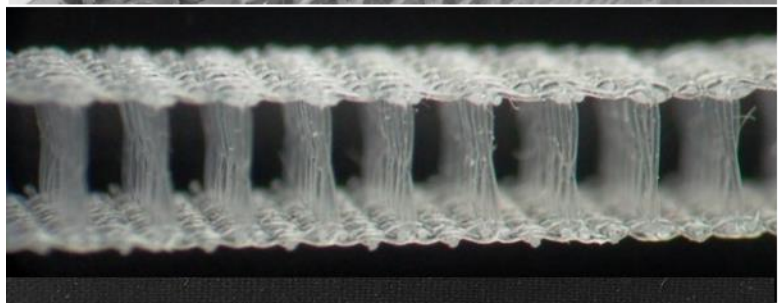
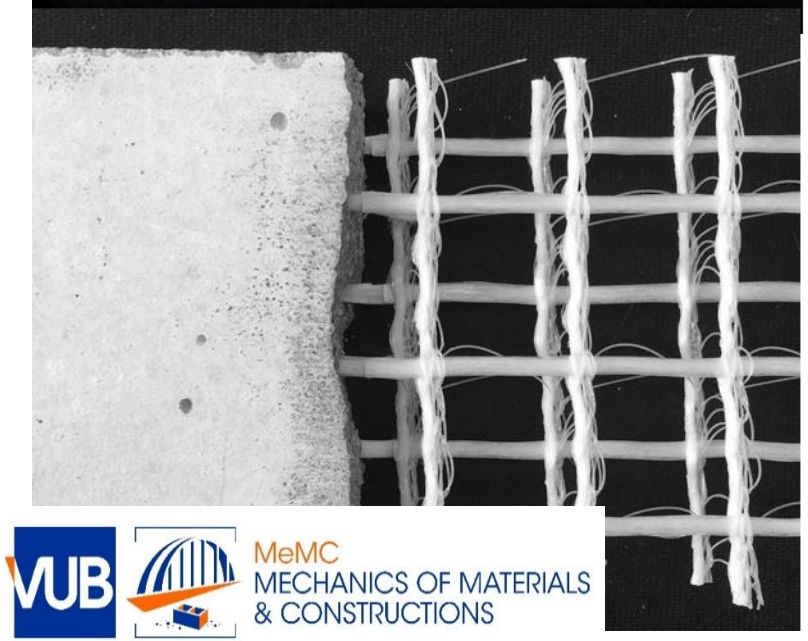




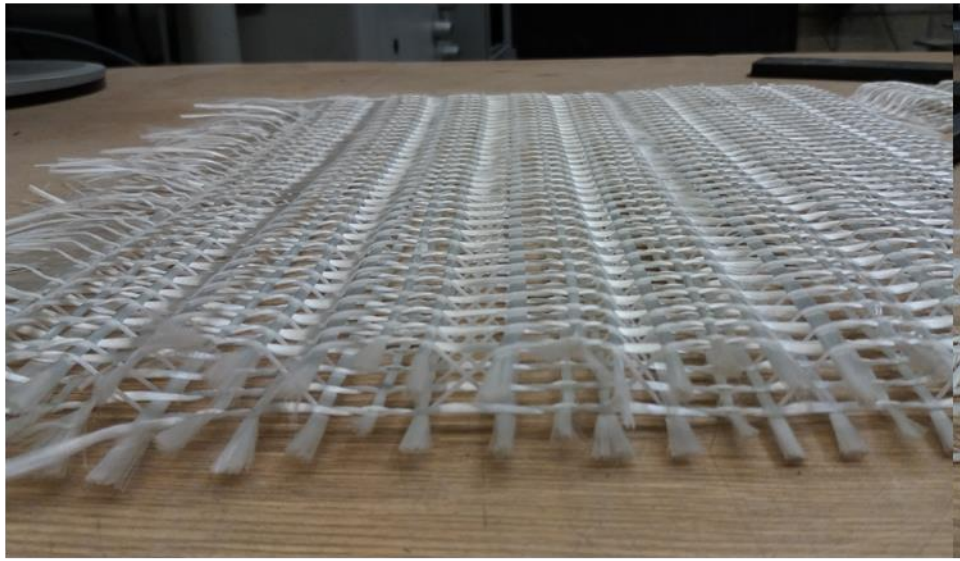


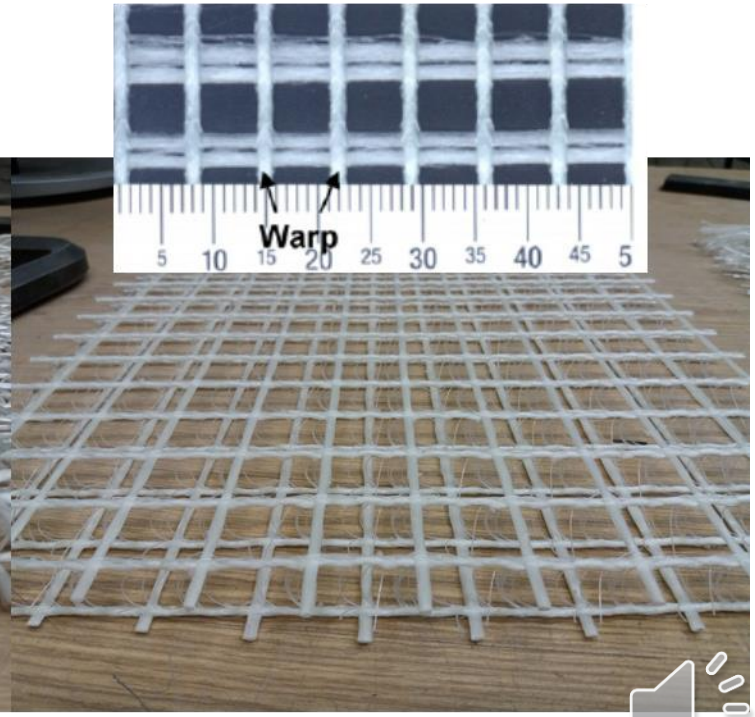
Fracture of 3D TRC under bending

Composite = Matrix + Reinforcement

Fine grained (in)organic cementitious matrix
Fibers cover
Design of thin elements
Easily pourable through fibers

AR glass textile mat (3%v.f.)
Orthogonal or randomly distributed fibers
2D or 3D structure
Optimized waving design





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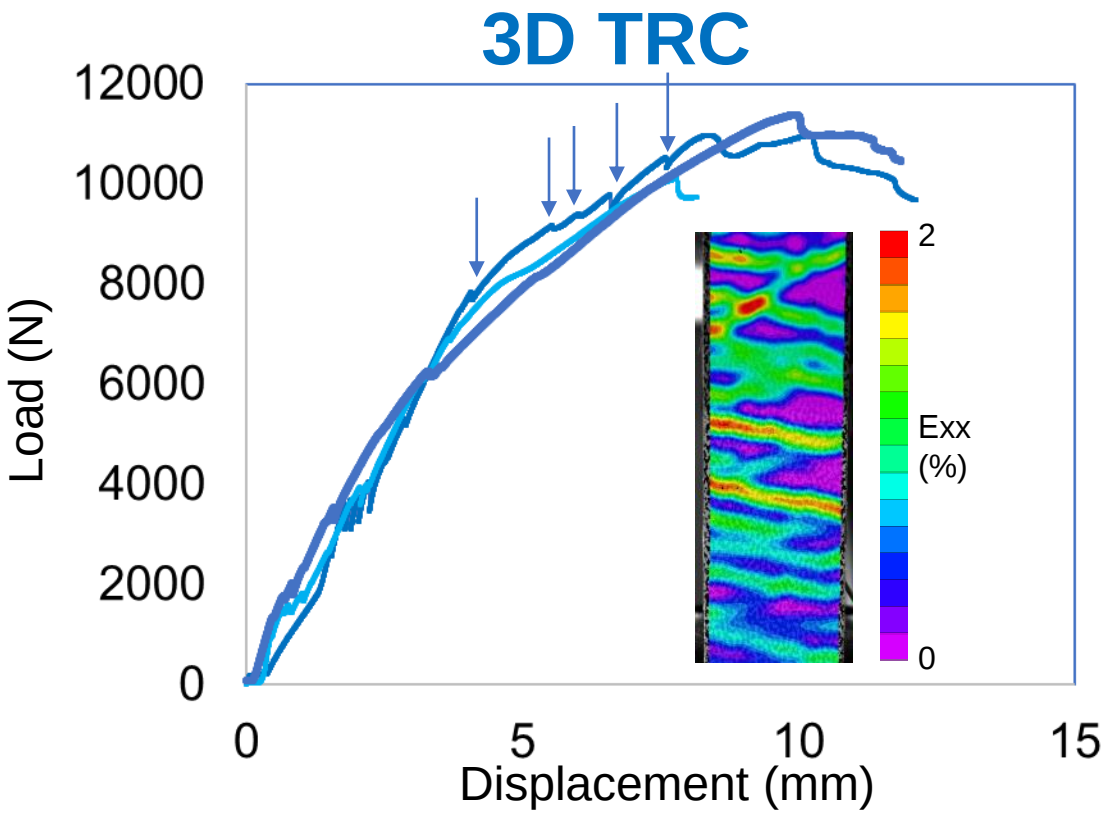
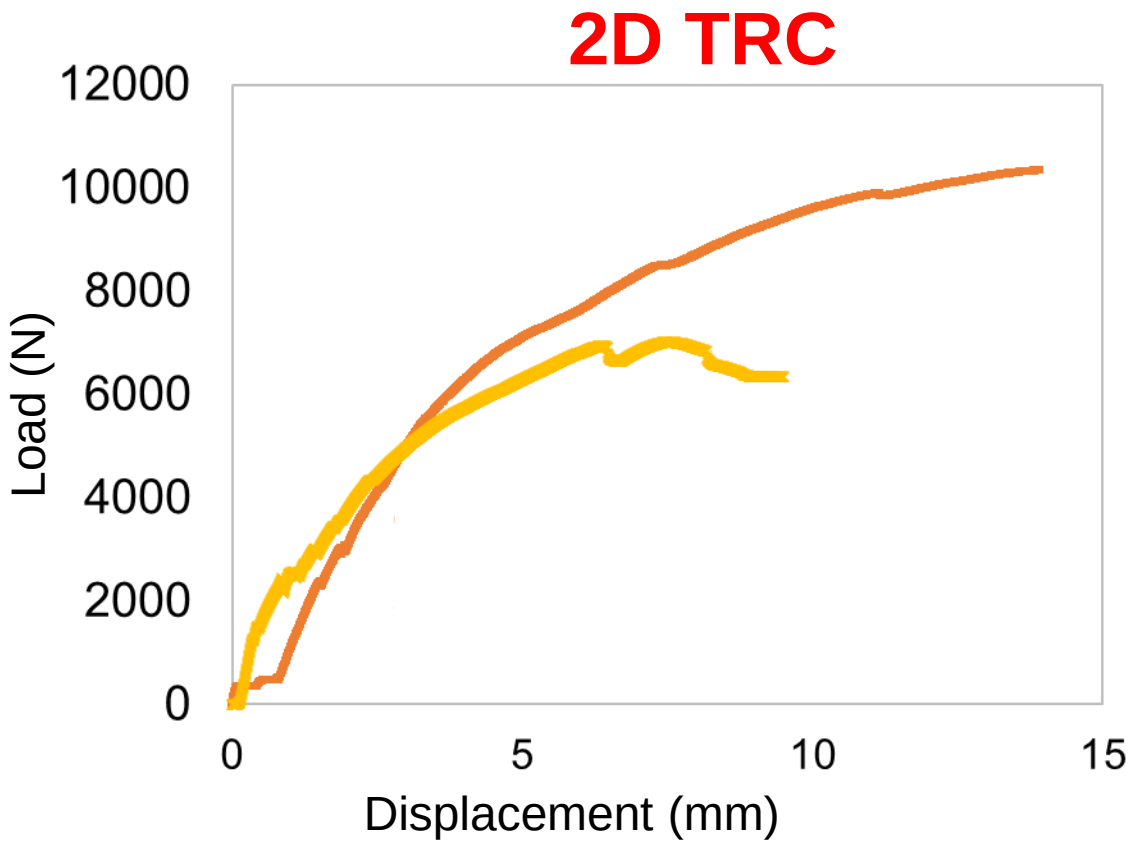
Influence of fiber pattern (3D/2D) on mechanical behavior





3D has more consistent behavior resulting in more cracking and some higher capacity

- Tsangouri, E., Michels, L., El Kadi, M., Tysmans, T., Aggelis, D.G., A fundamental investigation of textile reinforced cementitious composites tensile response by Acoustic Emission (2019) Cement and Concrete Research, 123, art. no. 105776, DOI: 10.1016/j.cemconres.2019.105776

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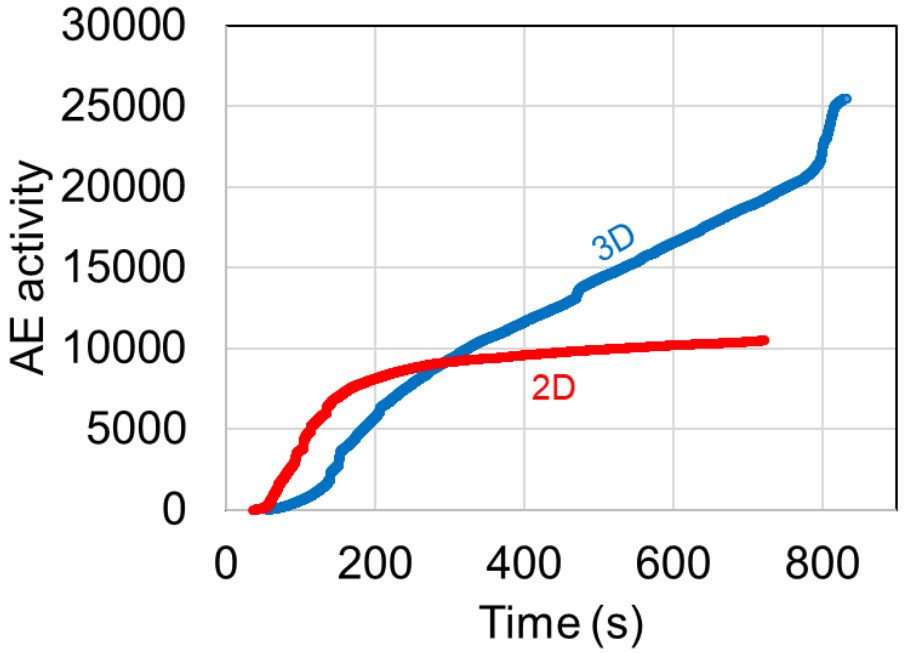
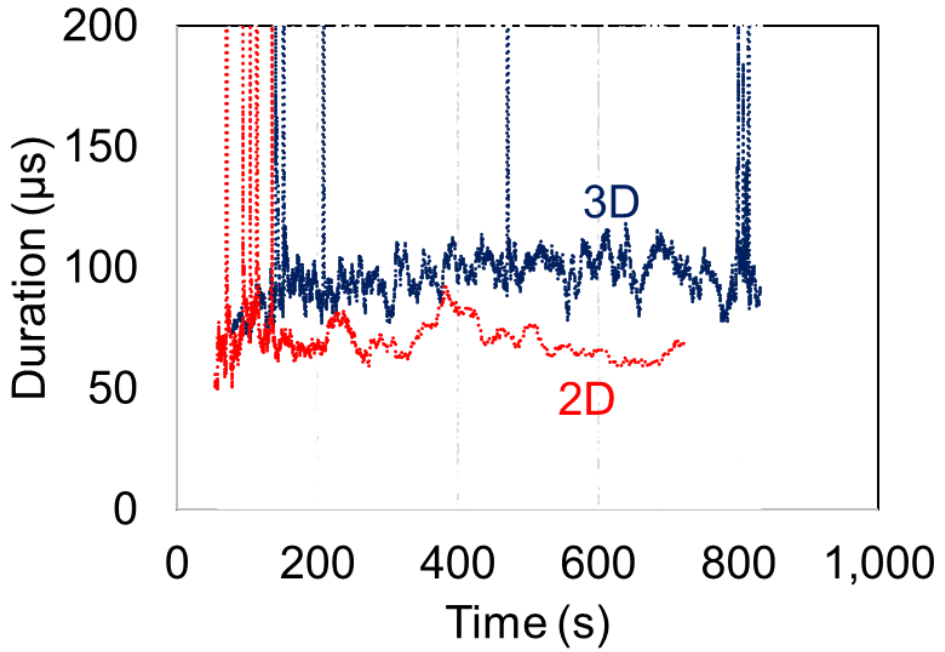
Influence of fiber pattern (3D/2D) on AE





AE parameters clearly shows the shearing of the reinforcement, even from the start (from 200 initial hits)

Averages	DUR (µs)	AF (kHz)
3D	80.5	165.4
2D	65.7	184.1

- Michels, L., Tsangouri, E., El Kadi, M., Tysmans, T., Aggelis, D.G. (2018), 3D Textile Reinforced Cements: AE inspection of the fracture of this innovative construction material, in Progress in Acoustic Emission XIX, Eds. T. Shiotani, Y. Mizutani, H. Yuki, pp.173-178.

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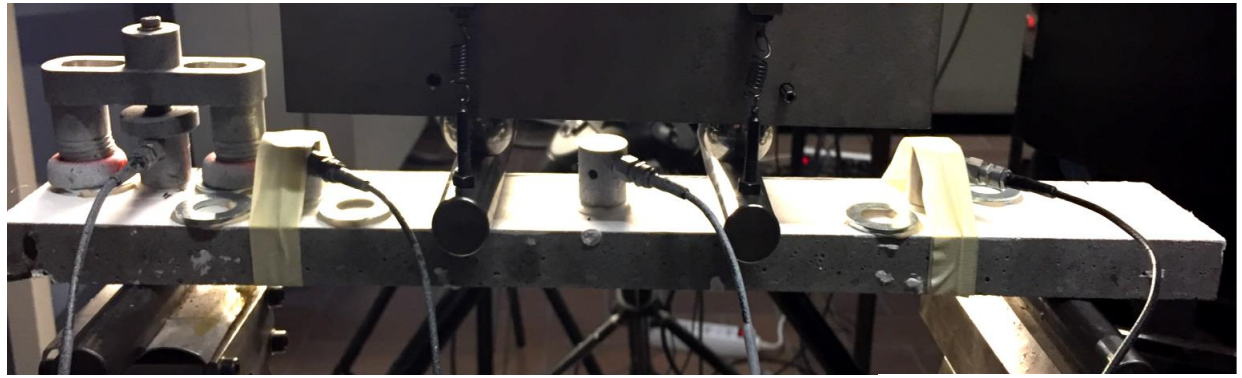
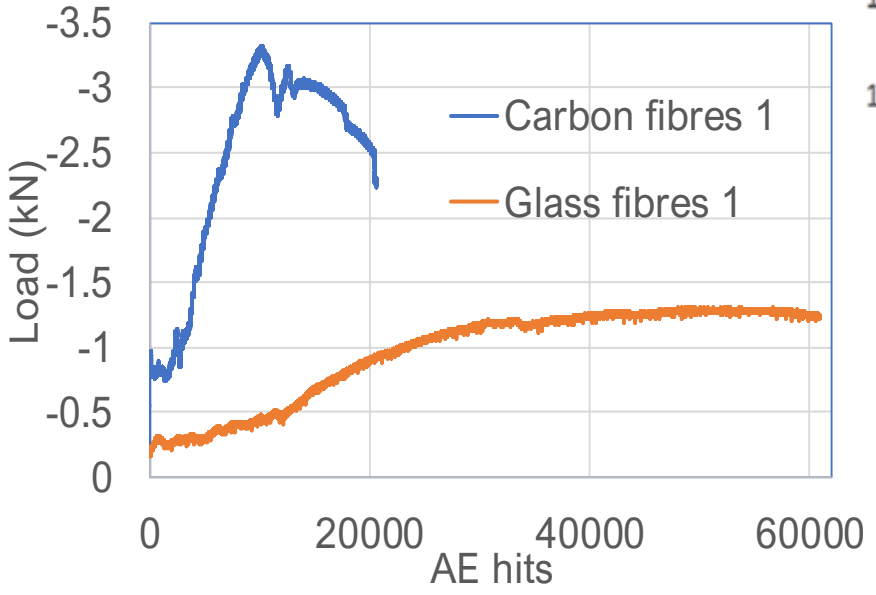
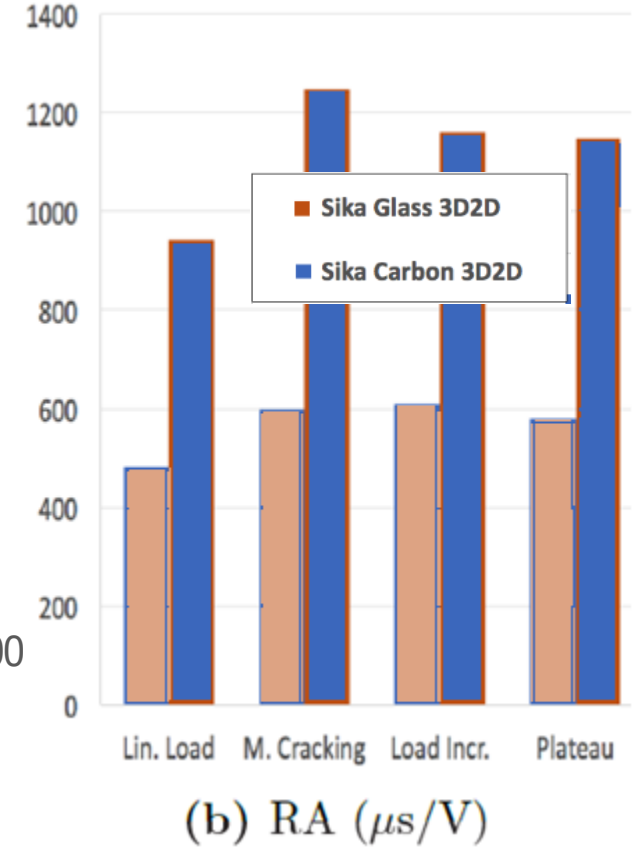
Influence of fiber type (Carbon/Glass) on AE





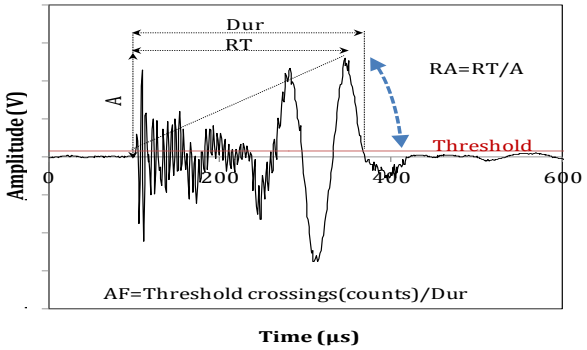


(b) RA (μs/V)

AE in bending of 3D-TRC with Carbon or Glass fibres.

Carbon fibres result in much higher ultimate load

Also in much higher RA even from the early loading, due to more effective reinforcement effect.



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Conclusions

The effect of the reinforcement is shown early in the AE behavior by more “shear” characteristics)

3D pattern in cement composites helps to distribute the cracking

In 3D printed polymer composites the effect of fibers is similar and evident from the early stages of loading.

RA value of early AE seems indicative of the effectiveness of the reinforcement

The final performance of the composite can be evaluated by the AE during a low proof loading

Flower Carpet, Grand Place, Brussels, August 2018

Thank you

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Financial support of FWO (Fonds Wetenschappelijk Onderzoek-Vlaanderen, projects number G.0C38.15, 12J7720 N, G.0090.1) is gratefully acknowledged.