Circular Ocean
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Arctic Technology Centre
Technical University of Denmark

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Engineering properties of fibres from waste fishing nets

Materials, Systems and Structures in Civil Engineering

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www.circularocean.eu

Northern Periphery and Arctic Programme
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In pursuit of innovative and sustainable solutions for marine plastic waste, the Circular Ocean project seeks to inspire enterprises and entrepreneurs to realise the hidden opportunities of discarded fishing nets and ropes in the Northern Periphery & Arctic (NPA) region.

As increasing levels of marine litter is particularly pertinent to the NPA region, the Circular Ocean project will act as a catalyst to motivate and empower remote communities to develop sustainable and green business opportunities that will enhance income generation and retention within local regions.

Through transnational collaboration and eco-innovation, Circular Ocean will develop, share and test new sustainable solutions to incentivise the collection and reprocessing of discarded fishing nets and assist the movement towards a more circular economy.

Circular Ocean is led by the Environmental Research Institute, www.eri.ac.uk (Scotland), and is funded under the European Regional Development Fund (ERDF) Interreg VB Northern Periphery and Arctic (NPA) Programme http://www.interreg-npa.eu. It has partners in Ireland (Macroom E www.macroom-e.com), England (The Centre for Sustaibale Desgin www.cfsd.org.uk), Greenland (Arctic Technology Centre www.artek.byg.dtu.dk), and Norway (Norwegian University of Science and Technology www.ntnu.edu).

Engineering properties of fibres from waste fishing nets

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Presentation outline

- The project "Circular Ocean"
- Motivation
- Introduction
- Possible applications
- Methods
- Results
- Comparison with other fibres
- Conclusion

Circular Ocean

- An international project focusing on reusing waste materials from the fishing industry in the Northern Periphery and Arctic region (NPA). Partners from Greenland, Scotland, Ireland and Norway

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Motivation

- Prevent marine plastic litter in Arctic
- Reuse of local waste materials from the fishing industry (fishing nets)
- Find a proper application for waste nets in the construction industry

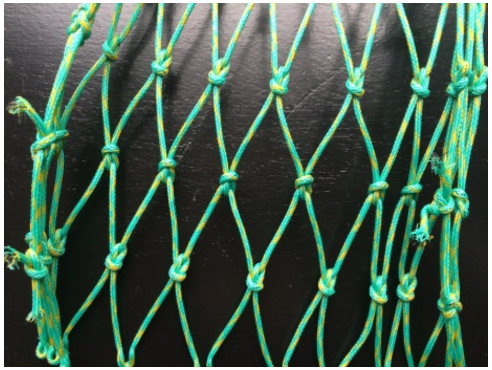
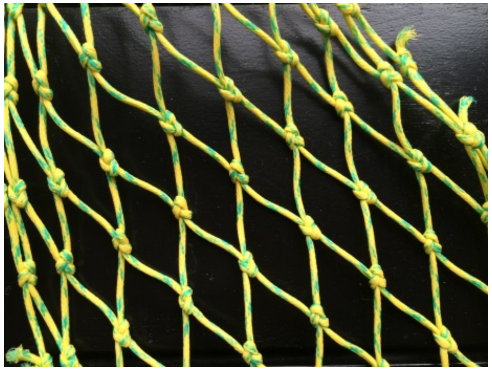
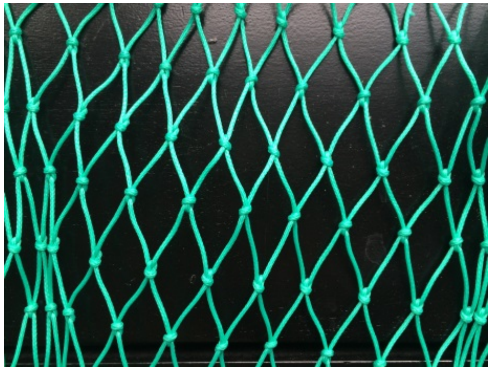
Introduction - Fishing nets

- Fishing industry in the NPA region
- Nets made of high density polyethylene (HDPE)
- Non-biodegradable material

- Nets are used for 1-2 years before disposal
- Degradation due to abrasion, mechanical load, UV-radiation
- Waste fishing nets are stored at the dumpsite

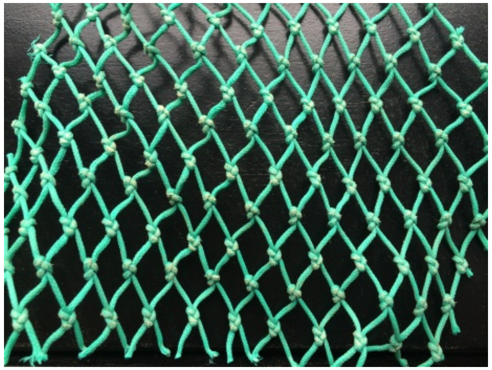
Introduction - Fishing nets

- HDPE nettings from Greenland before use and after disposal

New nets

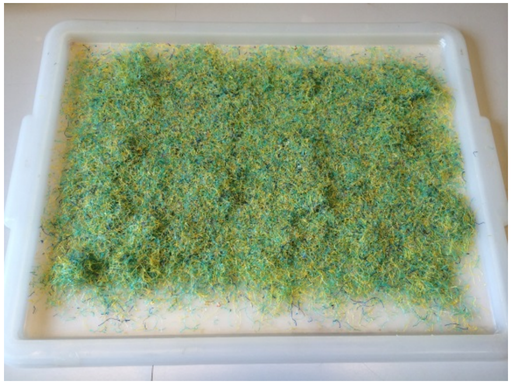




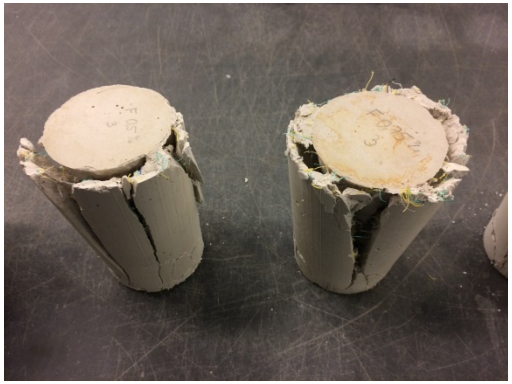
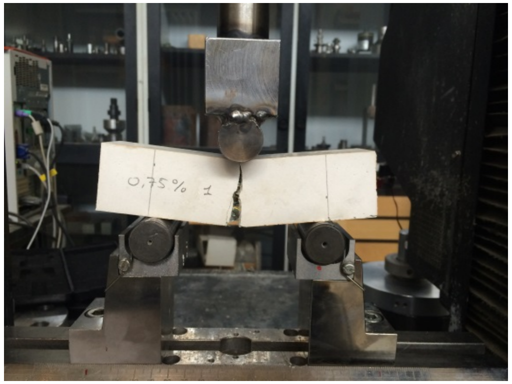
Waste nets

Possible applications – Fibre reinforcement

- Fibre reinforcement of mortar, gypsum or clay samples



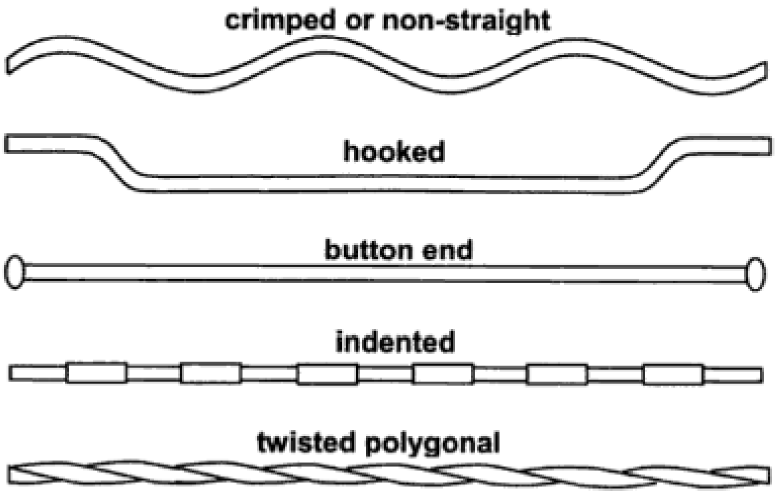


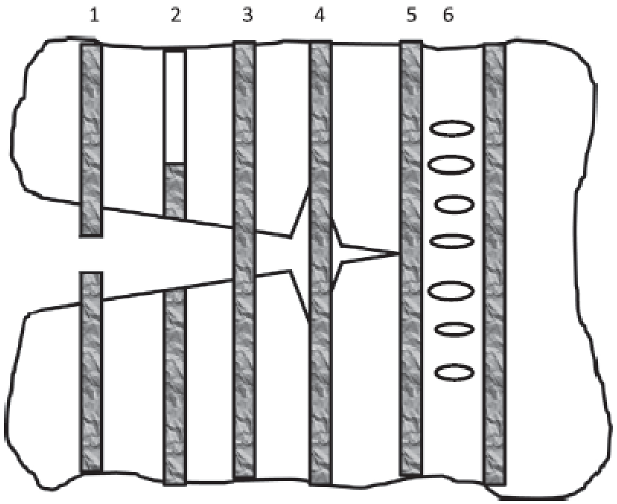



Possible applications – Fibre reinforcement

Requirements for fibres as reinforcement

- Must be easily dispersed the mixture
- Must have suitable mechanical and bonding properties
- Must be durable in the environment of the material

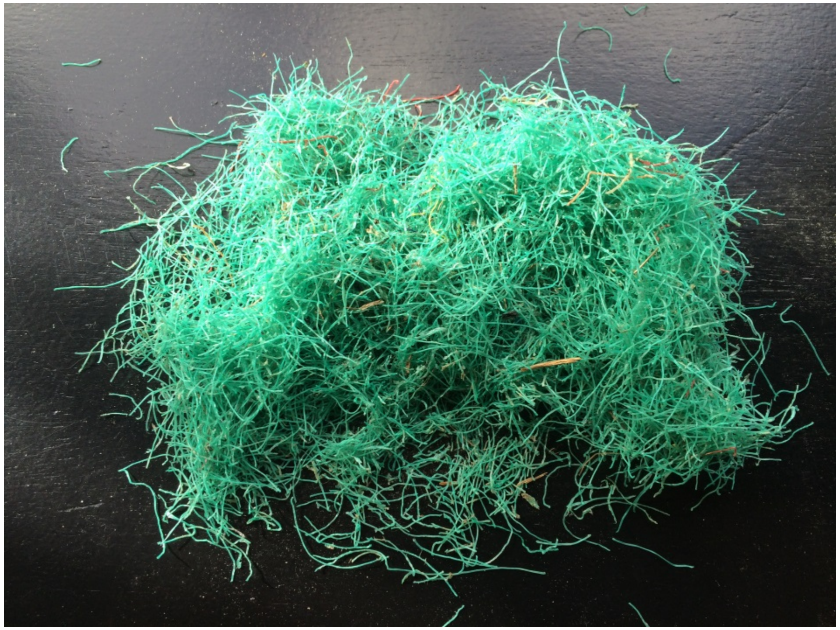




Failure mechanisms in fibre reinforced concrete. (1) Fibre rupture; (2) fibre pull-out; (3) fibre bridging; (4) fibre/matrix debonding; (5) fibre preventing crack propagation; (6) matrix cracking (Yin, 2005)

Methods – Engineering properties of fibres

- Comparison of fibres from new and waste nets
- Mechanical properties (tensile test)
- Durability properties (immersion in 1M NaOH for 28 days)
- Physical properties (SEM)
- Thermal properties



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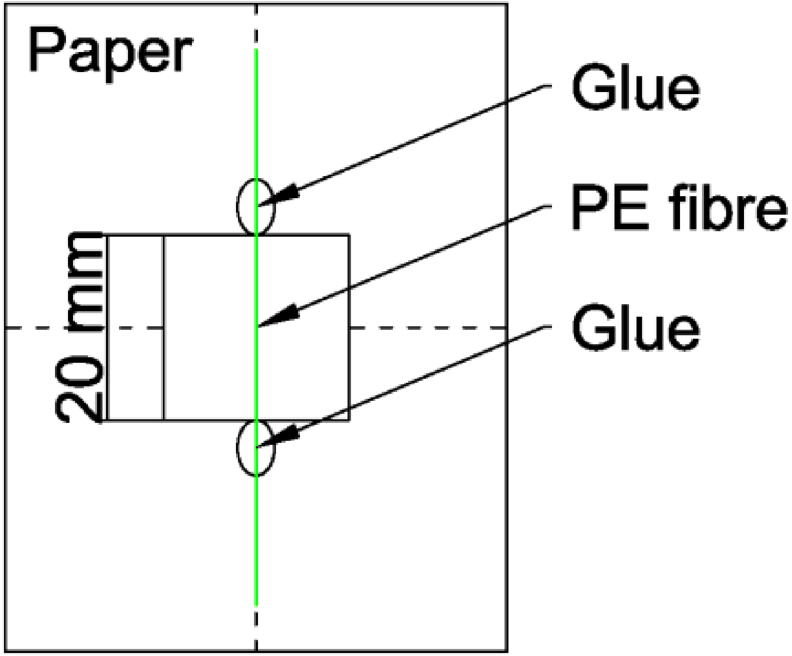
Methods – Tensile testing

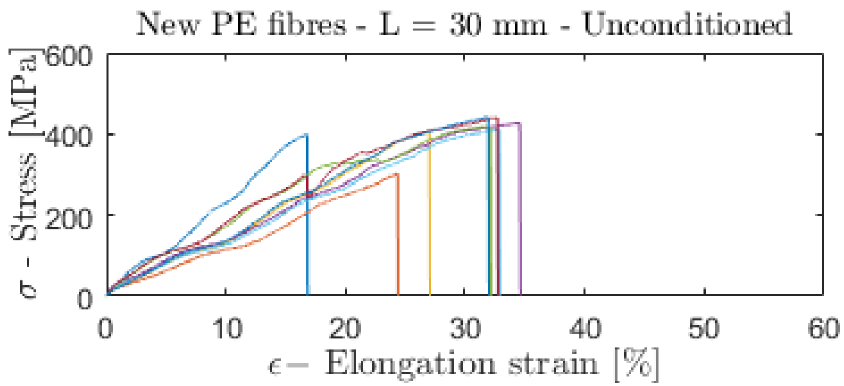
Tensile testing of single fibres on displacement-controlled Instron:

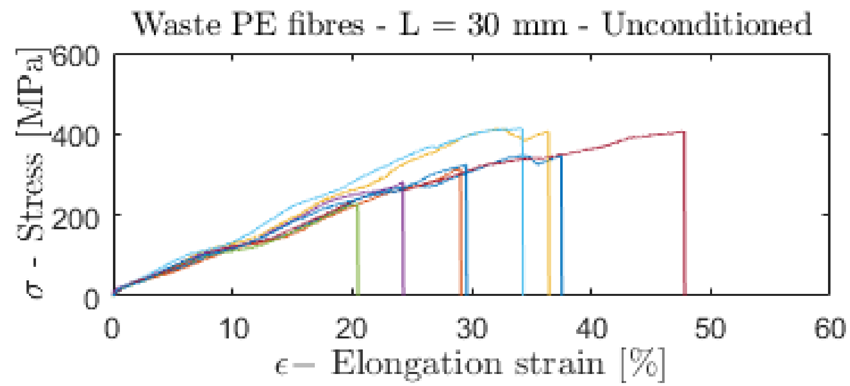
- Unconditioned new fibres
- Unconditioned waste fibres
- NaOH-conditioned new fibres
- NaOH-conditioned waste fibres



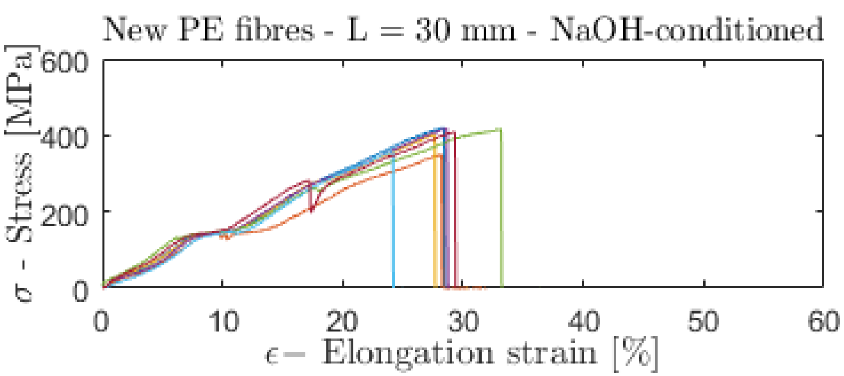
Results – Tensile test

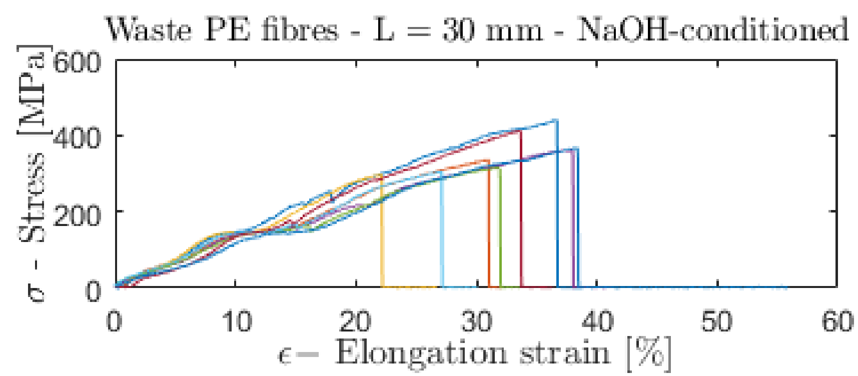
Unconditioned fibres





NaOH-conditioned fibres





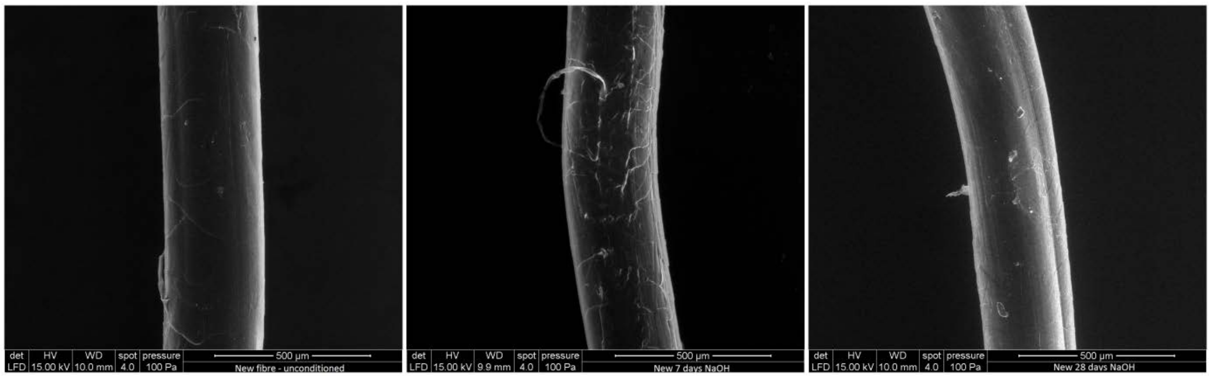
Results - Mechanical properties

- Tensile strength is ~15 % higher for new fibres compared to waste
- Tensile stress and strain unchanged after 28 days immersion in NaOH
- Larger standard deviation for waste fibres

	Tensile stress	SD	Tensile strain	SD	Young's modulus	SD
	σ [Mpa]	[-]	ε [%]	[-]	E [Mpa]	[-]
Unconditioned fibres						
New fibres	416	38.2	29.4	4.9	1454	293
Waste fibres	356	56.3	30.5	6.6	1199	218
NaOH-conditioned fibres						
New fibres	413	35.4	30.9	4.1	1351	138
Waste fibres	355	66.7	31.8	6.7	1127	125

Results - Durability properties

- Immersion of fibres in alkaline solution (1M NaOH) for 7 and 28 days



(a) New fibre - unconditioned (b) New fibre - 7 days NaOH (c) New fibre - 28 days NaOH

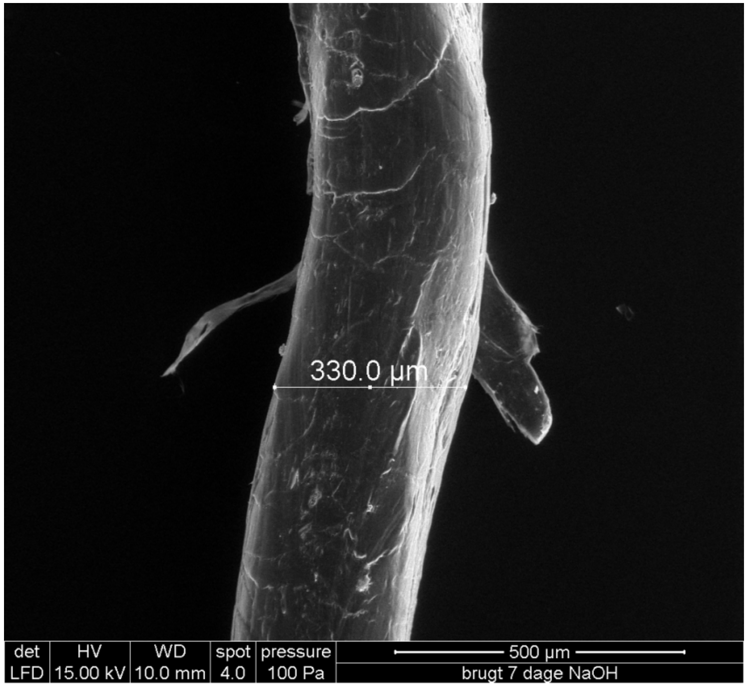
New fibres

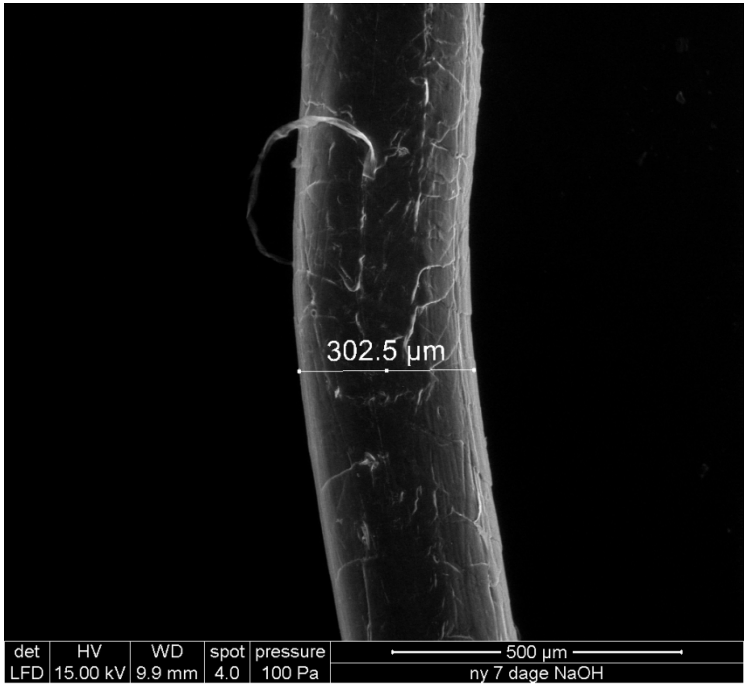
(a) Waste fibres - unconditioned (b) Waste fibres - 7 days NaOH (c) Waste fibres - 28 days NaOH

Waste fibres

Physical properties

- Fiber diameter: d=270-330 µm
- Very smooth fibre surface





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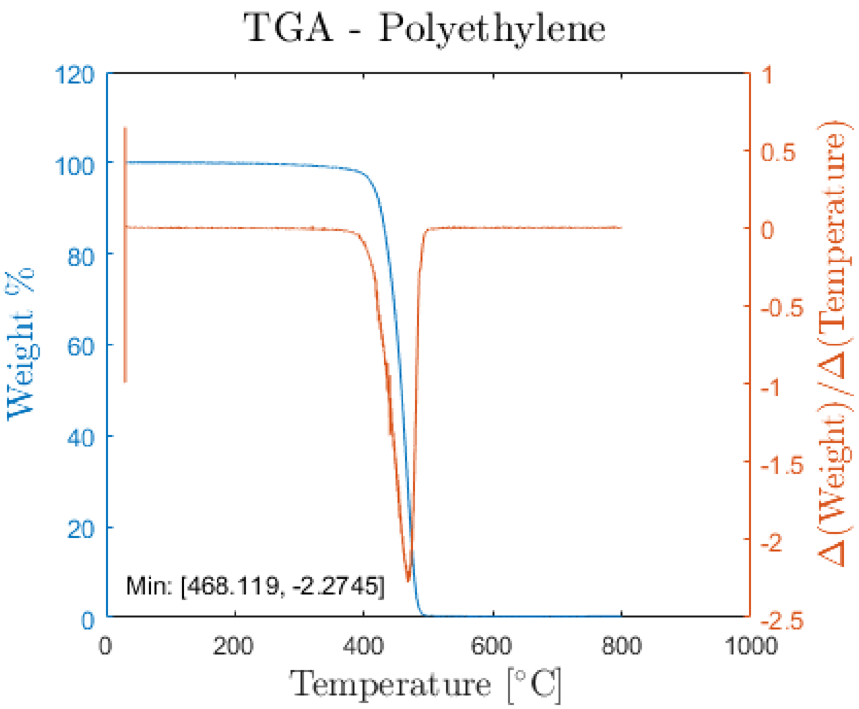
Results - Thermal properties

- Mass loss as function of temperature. Decomposition at 400-490 °C
- Melting point at 130 °C



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Comparison with other fibres

- Comparison with PE and PP fibres from other studies

Reference	Fibre Diameter [μm]	Specific Density [g/cm³]	Tensile Strength [MPa]	Young's Modulus [MPa]	Ultimate Strain [%]
PE fishing net	270 - 330*	0.95*	310 - 445*	1100-1450*	26 – 34*
Polyethylene (PE) fibres used as reinforcement of cementitious materials					
ACI [11]	25 - 1000	0.92 - 0.96	75 - 590	5000	3.0 - 80
Banthia [16]	40	No data	400	2000 - 4000	100 - 400
Kobayashi [23]	900	0.96	200	5000	No data
Polypropylene (PP) fibres used as reinforcement of cementitious materials					
ACI [11]	No data	0.90 - 0.91	135 - 700	3500 - 4800	15
Banthia [16]	10 – 150	No data	200 - 700	500 - 9800	10 - 15
Sun [14]	100	0.91	560-770	3500	16-22

Comparison with other fibres

Primary fibre reinforcement commonly improves:

- Flexural toughness
- Post-crack performance

Secondary fibre reinforcement commonly improves:

- Crack resistance
- Plastic shrinkage cracking
- Durability

Comparison with other polymeric fibres

Studies of plastic waste materials used as reinforcement of construction materials

- PET bottles in cementitious materials
- Textile carpet waste
- Nylon fishing nets

Conclusion

- Suitable tensile strength
- Low stiffness
- Insignificant change in tensile strength after alkali-conditioning
- Durable in an alkaline environment
- Smooth surface – poor bonding properties?

- Next step:
- Mix fibres into a dry mixture such as mortar, gypsum or clay
- Testing of bonding properties in different materials

Acknowledgement

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