TRUSS ITN

Workshop

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TRUSS
Training in Reducing Uncertainty in Structural Safety

A comparative study on different BFRP rebar design methodologies

Sofia Antonopoulou, Ciaran McNally and Greg Byrne

UCD DUBLIN University College Dublin

Burgmann Packings Composites

Outline

- Background and Motivation
- General Research Idea
- Experimental part
- Results
- Conclusions

Background and Motivation

Deterioration of global infrastructure

Degradation of reinforced concrete structures due to corrosion of steel

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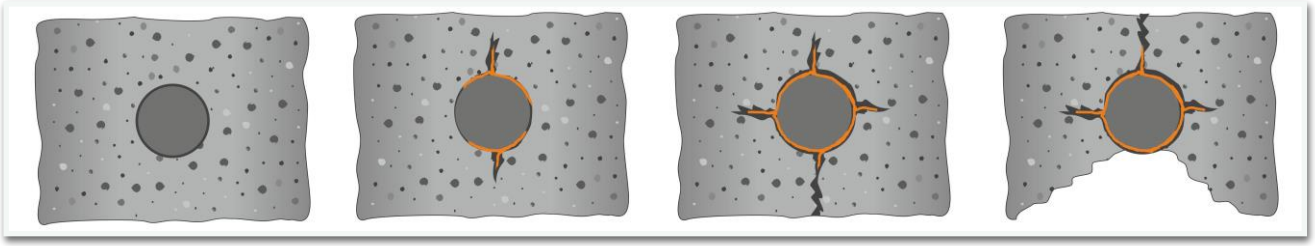
affects long-term durability, total service life, structural safety of RC elements



Estimated global **cost of corrosion** ⟶ ~ $ 2.5 trillion

Background and Motivation

Replacement of steel as internal concrete reinforcement by FRP composites

FRP properties strongly dependent on

- Type of fibre & matrix
- Fibre & void content
- Fibre-matrix interface
- Orientation of fibres

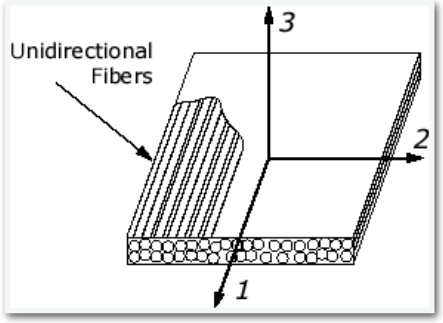
Advantages of FRP → **Corrosion resistant** & Lightweight

Main disadvantage of FRP → **Brittle failure** without warning

Background and Motivation

Manufacture methods of FRP:

- **Pultrusion** ⟶ low cost & continuous process
- **Braiding** ⟶ additional ductility & increased bond with concrete



Design guidelines for the efficient use of FRPs in construction:

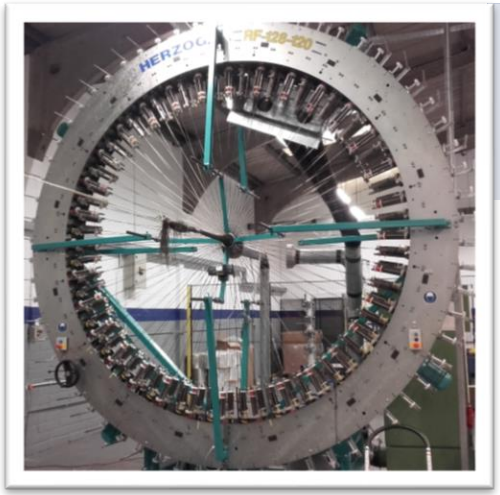
- **ACI-440.1R**
- **CSA-S806-02**

Background and Motivation

Basic principle of braiding:

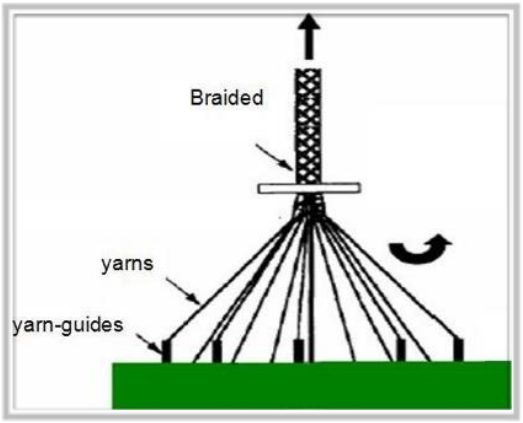
Interlacing of yarns in a diagonal direction -

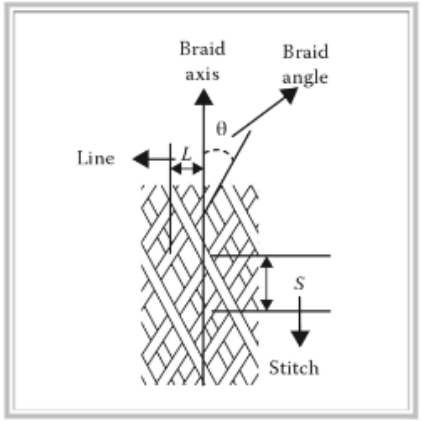
Multiaxial Orientation



Braiding Angle:

Affects mechanical properties of braids





General Research Idea

Aim of the project:

Design, Development & Characterisation of **B**asalt **F**ibre **R**einforced **P**olymer composites, for internal concrete reinforcement, using **braiding** technique & **unidirectional fibre** approach

Main goal:

Explore the potential of braided & hybrid BFRP reinforcement in infrastructure applications

Experimental Part

Manufacturing design & process of BFRP preforms

Materials

- Basalt fibres
- PET fibres
- Epoxy resin

2 different rebar **designs**:

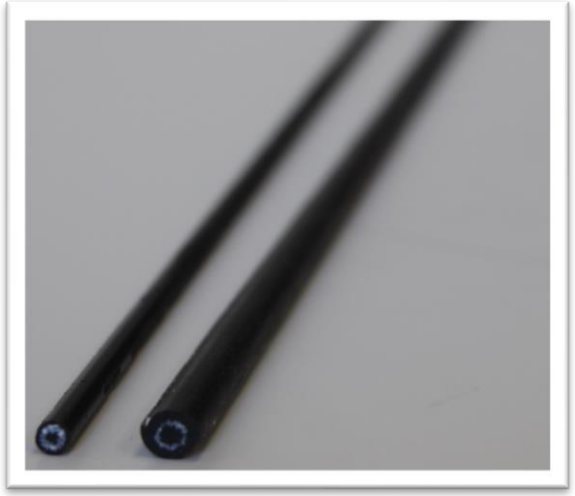
- Fully braided
- Hybrid

Product name	*Uses*	*Tensile strength (MPa)*	*Elastic modulus (GPa)*
BASALTEX® - Basalt assembled roving – 300, 600, 2400 tex 13, 17, 19 µm	**Fibre reinforcement**	2800 – 4800	87 - 89
M183 semi-dull round - PET Monofilament	**Impregnation aid**	57 – 60	10
Easy Composites - IN2 Epoxy infusion resin/ Slow cure	**Resin**	65.5 – 73.5	2.95

Experimental Part

BFRP 1 - 8 mm				
Layer	*Material*	*Yarns*	*OD*	*Angle*
1	300	8	1.6	12
2	300	16	2.7	16
3	600	16	4.0	17
4	PET	32	4.9	12
5	PET	32	5.6	14
6	300	16	6.5	16
7	600	16	7.2	45
8	600	24	7.9	40

BFRP 2 - 8 mm				
Layer	Material	Yarns	OD	Angle
Core	2400	10	4.4	0
1	PET	24	5.3	30
2	600	8	5.8	45
3	600	8	6.5	45
4	600	12	7.2	45
5	600	12	7.8	45

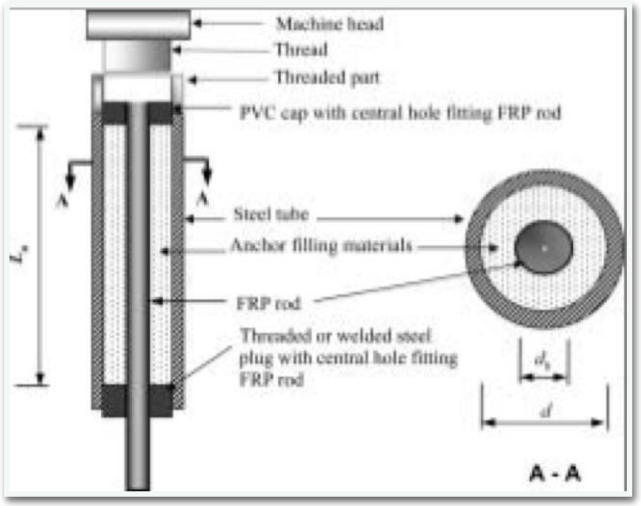


Experimental Part

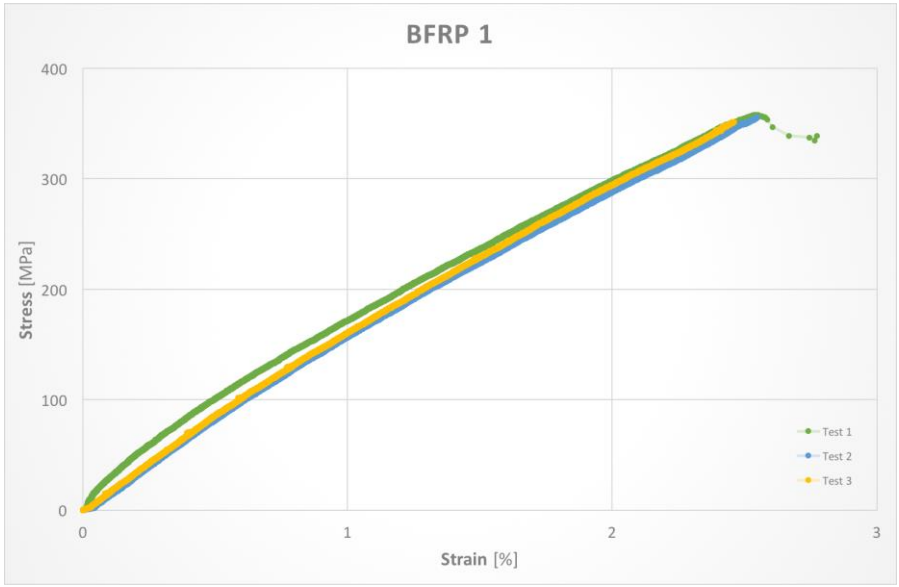
Numerical analysis – Mechanical characterisation

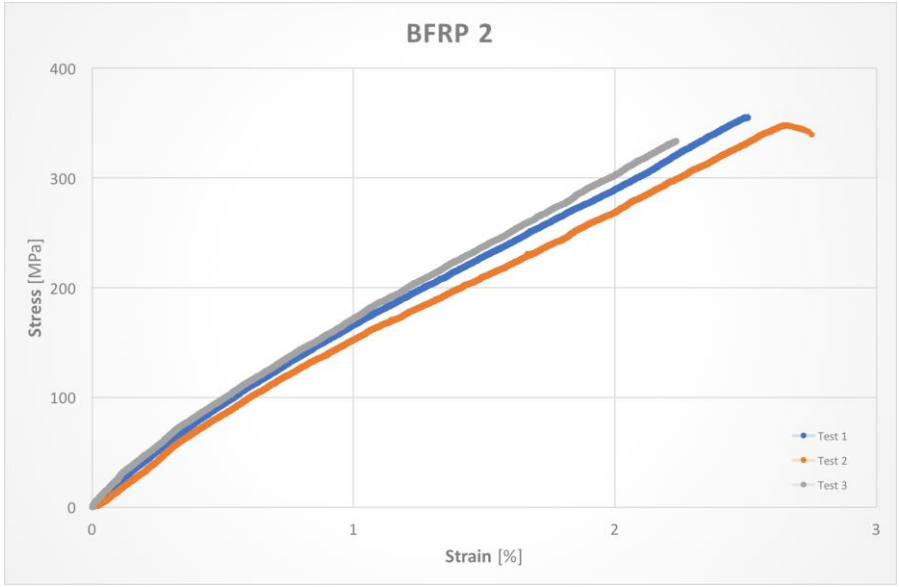
Classical **L**amination **T**heory (CLT) numerical approach

→ Evaluation of elastic properties of braided composites



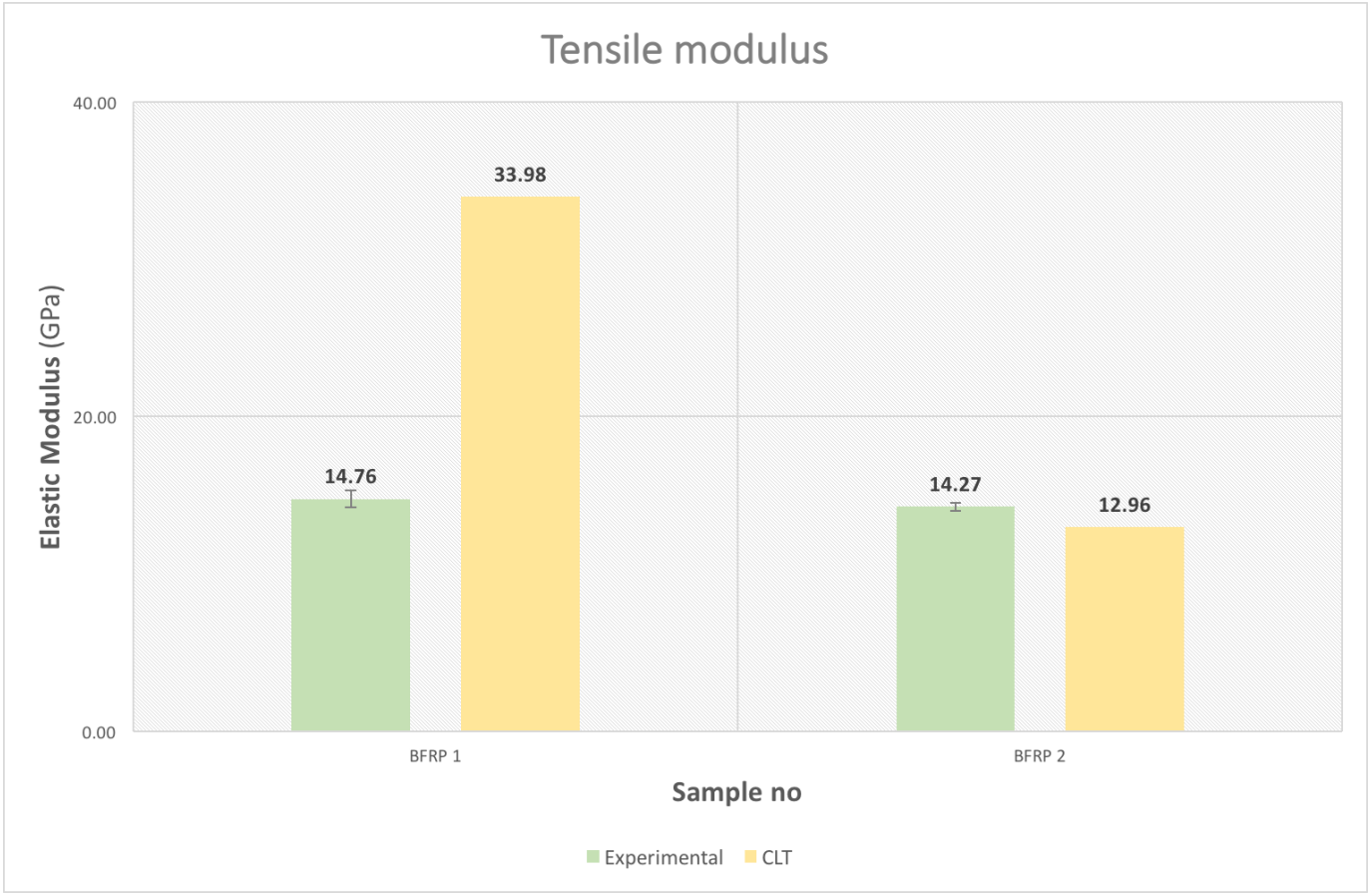
Results





Sample no	BFRP 1	BFRP 2
OD (mm)	8	
Fibre Volume Fraction (%)*	51.63	48.96
	Aver./ CoV	
Maximum Load (kN)	17.84/ 0.01	17.38/ 0.03
Ultimate Tensile Strength (MPa)	354.99/ 0.01	345.73/ 0.03
Maximum Displacement (mm)	10.09/ 0.05	10.50/ 0.06
Ultimate Strain (%)	2.59/ 0.06	2.50/ 0.10
Elastic Modulus (GPa)	14.76/ 0.02	14.27/ 0.06

Results


Tensile modulus
40.00
20.00
0.00
Elastic Modulus (GPa)
33.98
14.76
14.27
12.96
BFRP 1
BFRP 2
Sample no
Experimental
CLT

Conclusions

- This paper focuses on development and characterisation of BFRP composites for internal concrete reinforcement, using both braiding and hybrid designs.

- By combining aspects of pultrusion and braiding into a single manufacturing process, a high initial tensile strength is obtained, contributed mostly by the high modulus UD core followed by a gradual failure process associated with the outer braided sleeve.

- The maximum tensile strength is comparable to the one of steel and both design approaches exhibited similar mechanical behaviour, although hybrid types can reach higher values with improved fibre volume fractions.

Conclusions

- There are also significant discrepancies between theoretical and experimental values for tensile properties on the fully braided type, mainly due to the anisotropic nature & out-of-plane properties of braided composites. The CLT method was instead able to predict the elastic modulus of the hybrid type to a satisfactory degree.

- This research contributes to a further understanding on the various available design approaches for FRP composite rebars, although additional work towards an optimal design is needed, focusing on both the design flexibility and the wide availability of manufacturing processes.

Thanks for your attention

sofia.antonopoulou@ucd.ie

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