# Challenging the Norm: Sustainable Innovation in Construction Industry

Theme: Change that Challenges

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Innovate UK | Knowledge Transfer Partnerships | SDG | Queen's University Belfast

## CONTEXT AND NEED

### ABSTRACT

Change in construction industry requires challenging long-standing reliance on unsustainable, import-dependent products. Through a Knowledge Transfer Partnership between SDG Construction Ltd and Queen's University Belfast, this project confronts that challenge. From raw ideation, material discovery through market research and technical validation, this project drives the complete development of a sustainable alternative product: a low-carbon, durable BFRP solution designed to replace corrosion-prone steel in concrete while competing directly with established market players. The ultimate goal is a locally manufactured, independent solution with full technical support reshaping how the construction industry thinks about materials.

### KTP PROJECT STATUS

### WHAT IS A PRECAST LIFTING SYSTEM?

Lifting inserts are anchors cast into precast concrete panels and beams, used to lift and position elements during construction. Currently steel anchors are used universally yet they corrode, increasing safety risk and long-term maintenance costs.

### INDUSTRY CONTEXT & EMISSIONS IMPACT

| 8% | 40% | ~60% |
|---|---|---|
| of global $CO_2$ emissions from cement & concrete production | less embodied carbon FRP vs steel in lifting applications | weight reduction FRP anchor vs equivalent steel insert |

### WHY REPLACE STEEL?

**Corrosion Failure**
Steel anchors corrode when exposed to moisture and chlorides, creating critical safety risks in lifting operations and reducing the service life of precast elements.

**Carbon-Intensive Production**
Steel manufacturing is among the most energy-intensive industrial processes globally, contributing significantly to embodied carbon in construction projects.

**Import Dependency**
Current steel lifting systems are largely imported, creating supply chain vulnerability and missed opportunities for local economic development in Northern Ireland.

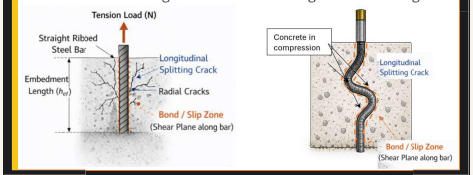
**Sustainability Mandate**
Construction must decarbonise to meet net zero targets. Replacing steel with BFRP in high-volume precast applications delivers measurable, scalable carbon reduction.

## ENGINEERING APPROACH

### DESIGN

**1. Material Selection**
Steel currently dominates anchor applications in precast construction, with a UTS of 400–500 MPa, whereas BFRP offers 900–1,200 MPa nearly double. FRP's density of 2,100 kg/m³ is approximately 3.7 times lighter than steel's 7,850 kg/m³ yet delivers superior tensile capacity. This study examines FRP's feasibility in anchorage applications.

**2. Geometry Optimisation**
Failure resistance higher in bent bar is higher than straight bar




**3. Design to Manufacture**
Product geometry developed to balance composite manufacturability with mechanical performance. The chosen profile maximises contact length to enhance bond strength.

**4. Design Calculations**
Analytical calculation was conducted to ensure the safety guidelines is in place to determine concrete failure load.

**Design Concrete Breakout Resistance**

$$N_{Rd,c} = (\pi \times \phi \times l_{bd} \times f_{bd}) (3.1)$$

$$f_{bd} = 2.25 \times f_{ctd} \ (3.2)$$

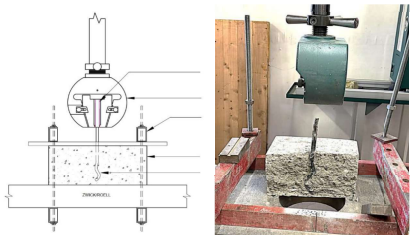
$$f_{ctd} = \alpha_{ct} \times f_{ctk,0.05} \ (3.3)$$

$$f_{ctk,0.05} = 0.7 \times [0.3 \times f_{ck}{}^{0.66}]$$

$\sigma = F/A$ ; Where: $\sigma$ = Stress, F = Loading Force and $A$= Bonding Area

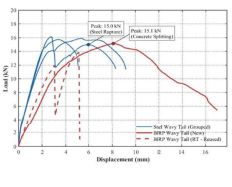
### TEST

**1. Pullout Strength Testing**

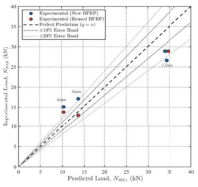


**Test setup**
Anchor of steel and bfrp material were tested on UTM with concrete clamped on the machine and anchor were pulled out at uniform rate to compare failure load capacity.

**2. Test results**




BFRP vs Steel Wavy Tail Pullout Performance

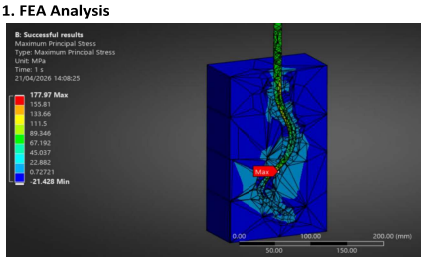



Experimental vs Predicted Parity Plot

**Test conclusion**
The results confirm near-identical rupture values for steel and BFRP. The parity plot demonstrates that reused BFRP performance closely matches that of new BFRP.

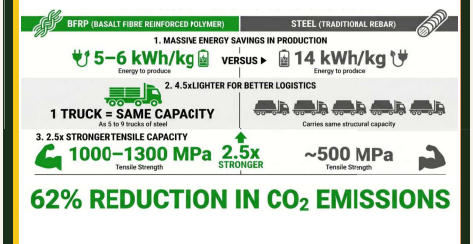
### ANALYSIS

**1. FEA Analysis**




**Comparative Benchmarking**
Concrete embedment restricted direct observation of failure mechanisms and stress concentrations, FEA was conducted to identify maximum stress locations and local failure modes.

**2. Life Cycle Assessment overview**




**LCA conclusion**
LCA results confirm BFRP as a sustainable alternative to steel, performing at greater capacity and presenting strong potential for product range expansion replacing steel.

## CONCLUSION

This KTP project demonstrates that a commercially viable BFRP lifting system for precast concrete is achievable and necessary. By replacing steel with BFRP anchorage, the construction industry can simultaneously address corrosion-induced safety failures, reduce embodied carbon, and build local manufacturing capability.
Early-stage design and analysis confirms that BFRP materials can meet and exceed the mechanical performance of steel lifting anchors when geometry is optimised for composite behaviour. The project bridges a critical gap of tackling the technical challenges in the construction Industry reliance on steel as a material.
The change is challenging it demands rethinking established design assumptions but the engineering evidence, sustainability imperative and commercial opportunity make this change both necessary and timely.

### REFERENCES

[1] PD CEN/TR 15728:2016 – Lifting inserts and accessories — Principles for design and verification and validation in structures made of precast concrete.
[2] Eligehausen, Rolf., Mallée, Rainer., Silva, J. F., & Sons., J. W. &. (2012). Anchorage in concrete construction
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[4] Pavlović, A., Donchev, T., Petkova, D., & Staletović, N. (2022). Sustainability of alternative reinforcement for concrete structures: Life cycle assessment of basalt FRP bars.

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