Introduction to FRP in Construction

Presented by

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What is an FRP Composite?

- FRP (Fibre Reinforced Polymer) Composite usually refers to fibrous reinforcements embedded in a matrix material which is a polymer. A structural fibre in a tough polymer matrix - the matrix enables form

  Terminology can include -
  - GRP
  - CFRP
  - Fibreglass
  - Carbon fibre
  - Pultrusion

What is **not** an FRP Composite?

- Composite action between concrete deck and steel structure through shear connectors
- Metal-polymer-metal sandwich panel
- Wood Board-foam-board SIPs type panel
Fibre Based Composites Ancient History

Definition –
2+ discrete materials combined, giving properties that none of the constituent materials could exhibit alone.

Adobe Bricks / Cobb: mud + straw
FRP Composites Recent History

Post 1970’s growth

- Leisure: skis, dinghies,
- Marine: boats, yachts, kayaks
- Aerospace: 60% FRP content in current airliners
- Sports: Tennis racquets, golf clubs
- Construction: Septic tanks, water tanks
- Water: Launders, diffusers, flumes
- Medical: Prosthetics, implants
- Military: Armour, missiles and launchers, landing craft
- Renewable energy: Turbine blades, marine turbine blades
FRP Composites Comprise

Matrix

Polymer Resin
(epoxy, vinylester, polyester, urethane, phenolic, nylon, PP etc)

FRP Composite

Fibre

Carbon
Glass
Aramid (Kevlar)
Polyethylene
Basalt
Flax
Cellulose

Resinous Matrix ➔ PART ➔ Fibre – woven or stitched mat

Fibres processed into bundles (rovings or tows) that can be used directly in automated processes or more commonly processed into mats such as wovens or non-crimps that create PLIES – hence we talk about laminates
How Composites Work

The Matrix:
- Protects, bonds
- Transfers applied loads
- Toughness

The Fibres:
- Stiffness & strength

Composite:

Properties $\alpha$ fibre content
“VOLUME FRACTION”
Materials Comparison

Stiffness
- Metal: Uniform $E_1 = E_2 = E_3$
- Timber: $E_1 = E_2 \neq E_3$
- FRP Composite: Directional $E_1 \neq E_2 \neq E_3$

Geometry
- Metal: Constant cross section
- Timber: Constant cross section
- FRP Composite: Variable thickness – additive plies

Thermal
- Steel $k = 50 \text{ W/m K}$
- FRP (E glass UPR) $k = 0.3 \text{ W/m K}$

Loads
- Metal: Uniformly distributed through section
- FRP Composite: follow fibres

Structure
- Metal: Optimised shape/frame – linear 2D
- FRP Composite: Optimised local and global material & 3D shape & thickness together
FRP Composite Advantages

- Environmental and corrosion resistance – “waterproof”
- High specific stiffness & strength (lightweight)
- Optimisation “friendly”
- Low k
- Non-conductive (not for CFRP)
- Good damping
- Excellent fatigue resistance
- Complex 3D shapes are easily manufactured
- Multifunctional – insulation provides structure

FRP:
- $E \sim 10-60\text{GPa}$, $\rho \sim 1.5\text{Te/m}^3$

Steel:
- $E \sim 200\text{GPa}$, $\rho \sim 7.9\text{Te/m}^3$

Steel:
- $k = 50\text{ W/mK}$

FRP (E glass UPR):
- $k = 0.3\text{ W/mK}$
Fire

- Adoption in rail interiors
- Use for oil and gas
- High performance fire protection
- Polymer matrix is organic chemistry – so ultimately combustible
- BSEN13501 Class B/C
- BS476..Class 0
- Evolving technology
Composite Manufacture

- Material defined by manufacturing process
- Proportions of matrix:fibre determine properties
  - Volume Fraction
- Fibre type and orientation determines properties

WE LIKE ACRONYMS!
RTM HPRTM PREPREG HAND-LAY CHOP-SPRAY VI INFUSION RTM-LITE VRTM HPM PULTRUSION INJECTION RIM PULLWIND FILAMENT WIND HOOP WIND BLADDER MOULDING SMC DMC ADVANCED SMC SELF-REINFORCED NON CRIMP NCF WOVEN UNIDIRECTIONAL UD ATL AFP BRAIDING NFC BIOCOMPOSITES THERMOFORM VACFORM
Construction 2025

Lower costs
33%
reduction in the initial cost of construction and the whole life cost of built assets

Faster delivery
50%
reduction in the overall time, from inception to completion, for newbuild and refurbished assets

Lower emissions
50%
reduction in greenhouse gas emissions in the built environment

 Improvement in exports
50%
reduction in the trade gap between total exports and total imports for construction products and materials

30% on timeline – 30% on targets?
CURRENT INDUSTRY
£100bn
£20bn avoidable errors*
95% SME delivery
Flatlining efficiency

TRANSFORMATION

FUTURE INDUSTRY
Collaborative JVs
Digitally integrated
Offsite automated mfg
Site “assembly”
Outcomes driven – WLC
Rich innovation

Issues
Ageing workforce
Skilled trade shortage
Rework/quality
Maintenance cost
Climate change
Why FRP Composites?

**WEIGHT**
- Site handling - Speed
- Dead Load
- Structural efficiency
- Reduced foundations

**CORROSION**
- Reduced maintenance
- Reduced whole life cost
- Road salt, coastal, industrial

**FORM**
- Double complex curvature
- Aesthetics
- Structural efficient forms

**FACTORY**
- Traceability
- Digital BIM
- Quality / accuracy

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100,000+ UK bridges

**Stewarton 2009**
Hidden corrosion of primary structure caused collapse of a rail underbridge whilst trafficked by a kerosene goods train.

This led to a fire and environmental damage but thankfully no loss of life.

**Omnia Coliseum GA**
CORTEN clad structure that failed to stabilise its protective oxide layer due to the climate. Early through wall corrosion leading to rapid corrosion of primary structure that was uneconomical to maintain/repair. Demolition within 25 years of construction.
Typical Civils Applications

Diverse use-
- Haramain Station roof panels supported by steel structure
- Liverpool Sandon WWTW odour covers 25m span
- Water industry flow control structures
- Lock Gates
- Tanks
- Strengthening with high performance carbon fibre
- Lightweight non conductive railway service platforms
- Fair faced complex formwork
- Interlocking sheet piles
- Halls River Bridge FL – 100% FRP rebar
Typical Bridge Applications

Used worldwide for:
Full structures and parts of structures
Steel primary structures and FRP deck
Steel structure and FRP wind shedding enclosures
FRP structure and FRP deck
Various structural forms and material types used

- Railway footbridge at Dover
- Aberfeldy cable stayed footbridge
- Ooyport Arched footbridge
- Mapledurham road bridge
- Church Road Bridge
- Arup-Mabey Pedestra modular bridge system
Typical Building Applications

Used worldwide for:
Sub-components around housing:
Dormers, bay windows, porches, chimney pots, feature columns etc
Modular bathroom pods for hotels etc
Exterior doorsets
Exterior windows
Conservatories
Panels systems for housing and low-rise building (Tufeco-Atelio)
Sanitary Ware
Roofing
Façade systems, rainscreen and cladding systems (University of Valencia, Sheraton Malpensa, Trsepa Int Cono Rostock, various by Shapeshift pty, Ferrari Barcelona, SFMOMO)
Typical Large Building Applications

Used worldwide for:
Domes – Russian Orthodox Cathedral Paris
Apple Campus 2, CA
Apple Stores
Jeddah Tower cladding and Sickle structure
Mecca Walkway
Reprise

**WEIGHT**
- Site handling
- Dead Load
- Structural efficiency
- Reduced foundations

**CORROSION**
- Reduced maintenance / WLCs
- Cost the UK 3% of GDP
- Road salt, coastal, industrial

**FORM**
- CNC double curvature
- Aesthetics
- Structural efficient forms

**FACTORY**
- Traceability
- Digital BIM
- Quality / accuracy
The NCC: Powering the full exploitation of composites opportunities for the UK

- Current and future industry standard
- 200+ composite technologists
- Materials, processes, digital control, measurement, testing, NDE, design, process simulation, cost modelling
- Digital – i4.0
- Industry scale plant and equipment

- Pre-production prototypes, testing, development
- Prototype design
- Feasibility work
- Process set-up
- Training
- Support
- Connecting
- Signpost supply chain

REDUCE RISK