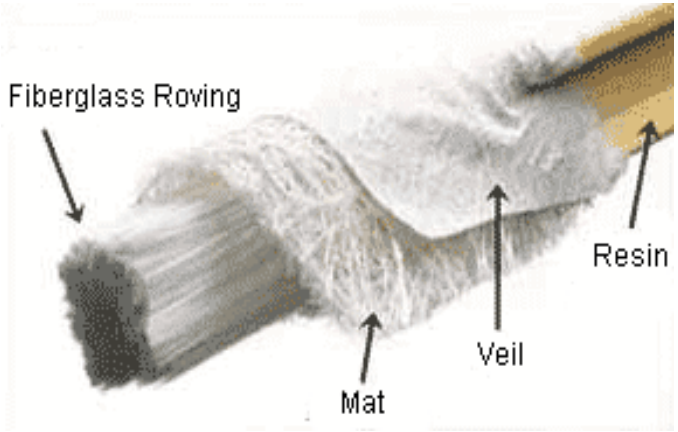
Introduction to FRP in Construction

Presented by

Neil Appleton November 2017

What is an FRP Composite?

- FRP (**F**ibre **R**einforced **P**olymer) 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

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

Fibre Based Composites Ancient History

Definition –
2+ discrete materials combined, giving properties that non of the constituent materials could exhibit alone.

Adobe Bricks / Cobb: mud + straw

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

FRP Composites Recent History

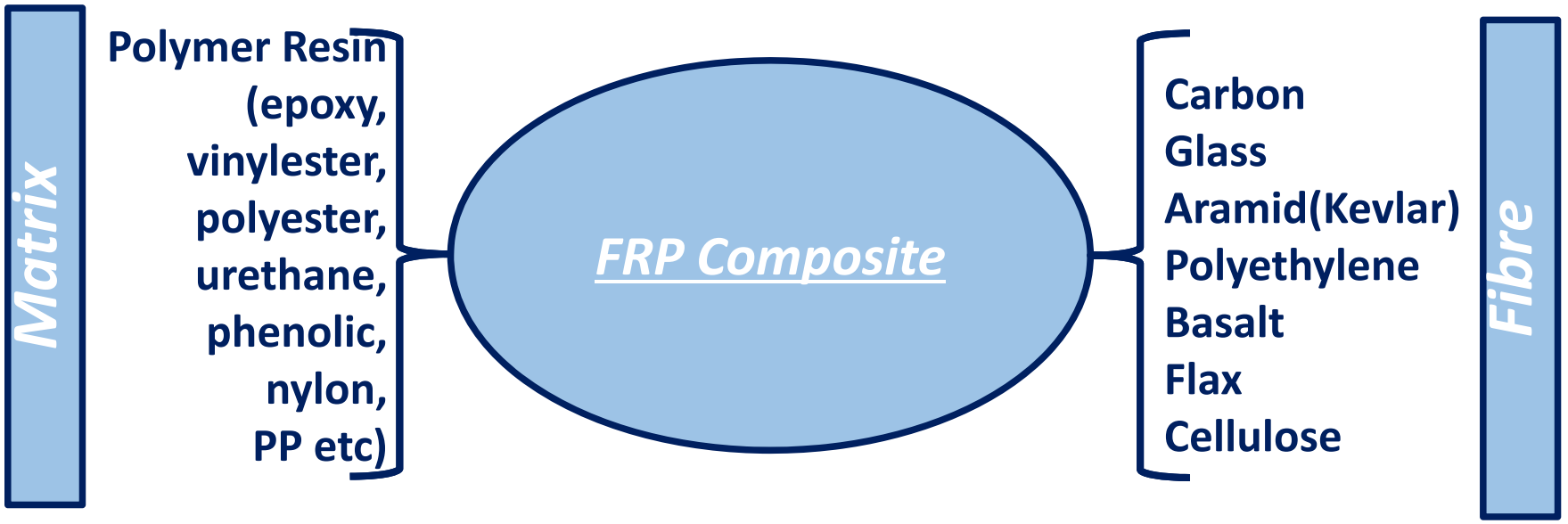
Post 1970's growth

- 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

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

FRP Composites Comprise



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

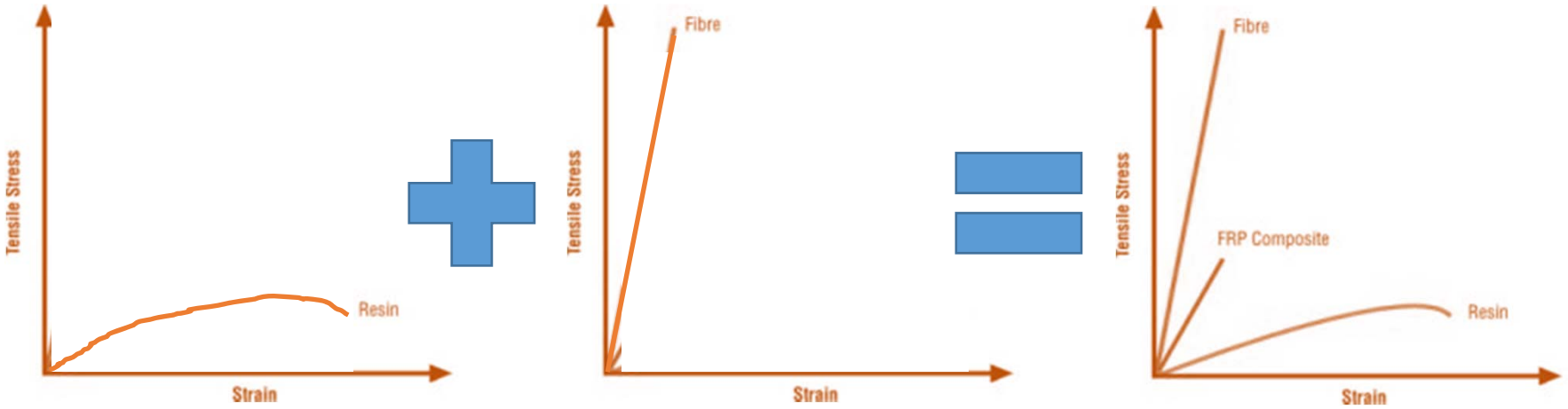
The Matrix:

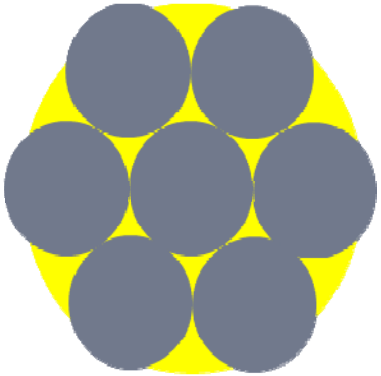
- Protects, bonds
- Transfers applied loads
- Toughness

The Fibres:

- Stiffness & strength

Composite:





Properties α fibre content
"VOLUME FRACTION"

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

Materials Comparison

Stiffness

- Metal: Uniform E1 = E2 = E3
- Timber: E1 = E2 ≠ E3
- FRP Composite: Directional E1 ≠ E2 ≠ E3

Geometry

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

Thermal

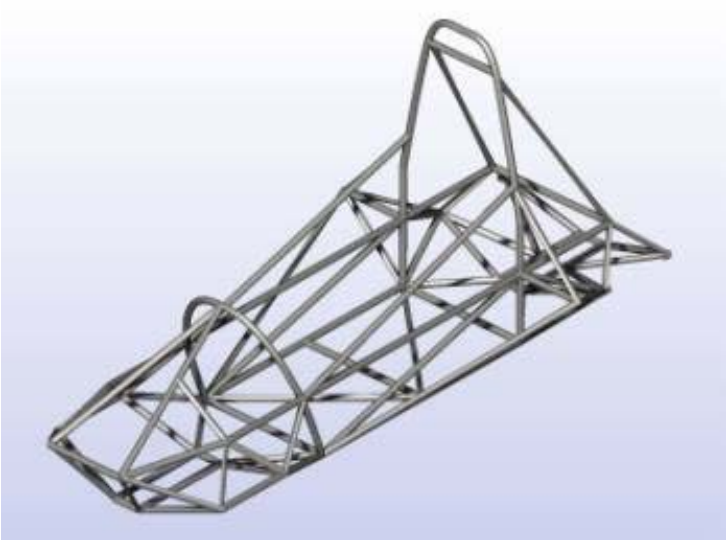
- Steel k = 50 W/m K
- FRP (E glass UPR) k = 0.3 W/m K

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



NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

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

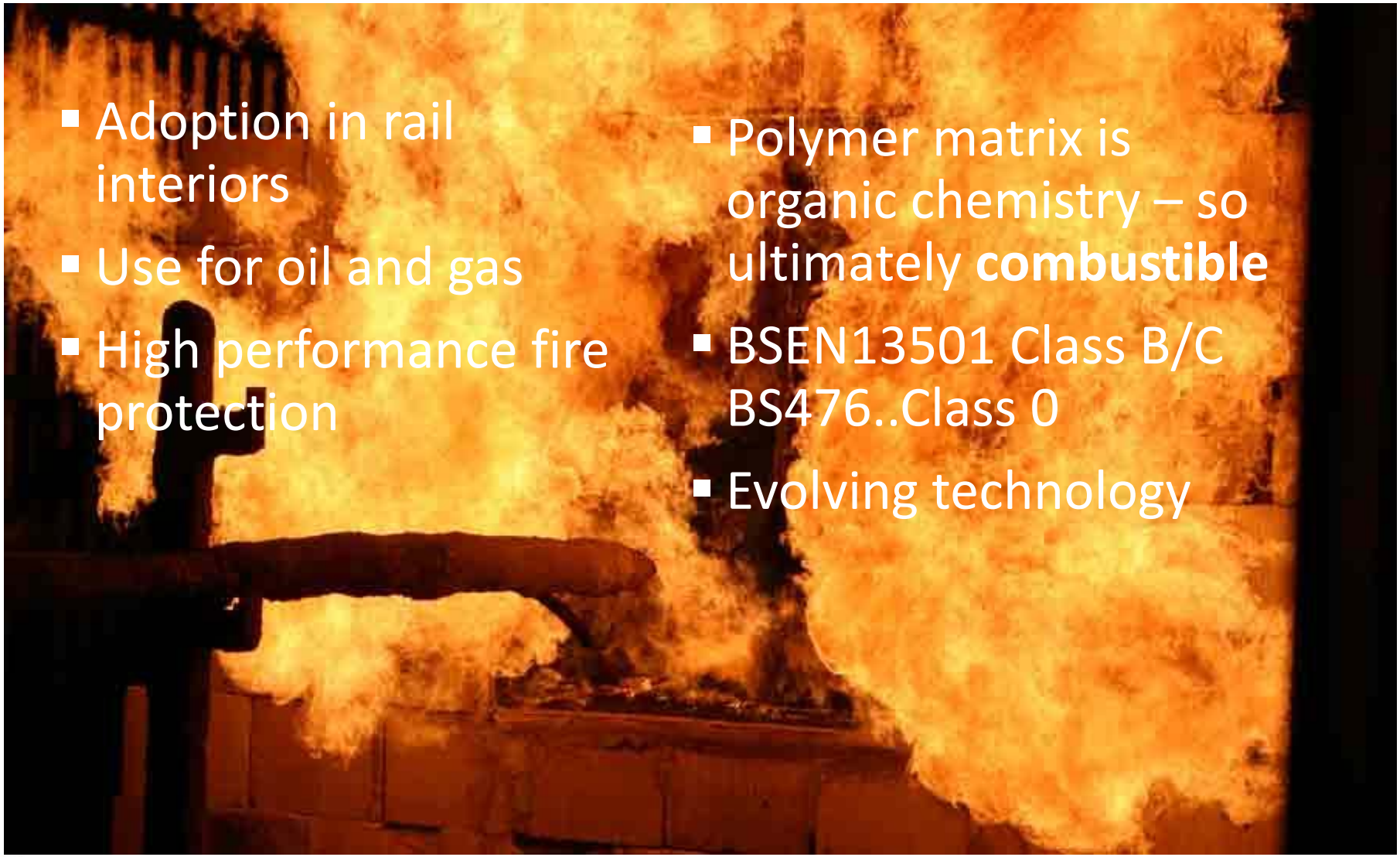
- FRP: E~10-60GPa, ρ~1.5Te/m^3
- Steel: E:~200GPa, ρ~7.9Te/m^3

Steel	k = 50 W/mK
FRP (E glass UPR)	k = 0.3 W/mK

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

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

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

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

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

HM Government

Industrial Strategy: government and industry in partnership

Construction 2025

July 2013

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?

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

CURRENT INDUSTRY

£100bn

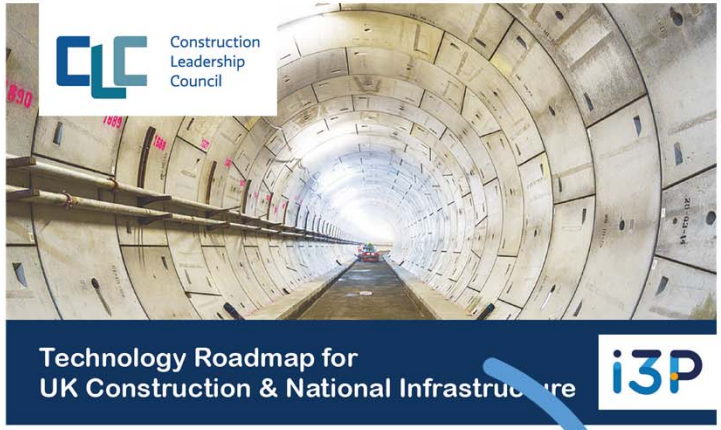
£20bn avoidable errors*

95% SME delivery

Flatlining efficiency

* GIRI 2017

TRANSFORMATION



Department for Business, Energy & Industrial Strategy · Innovate UK Knowledge Transfer Network · bre · CATAPULT High Value Manufacturing · mtc · BUILDUK · cpa · UKCRIC

Issues

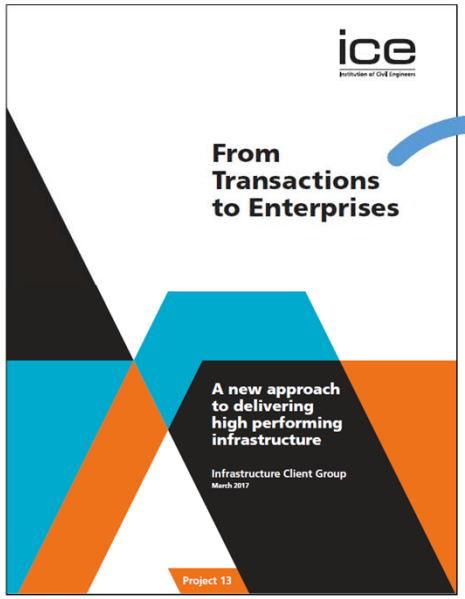
Ageing workforce

Skilled trade shortage

Rework/quality

Maintenance cost

Climate change



FUTURE INDUSTRY

Collaborative JVs

Digitally integrated

Offsite automated mfg

Site "assembly"

Outcomes driven – WLC

Rich innovation

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

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

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.

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

Typical Civils Applications

Haramain Station Roof (PCT)

Tank Covers (Armfibre)

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

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

Typicalk 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

Foryd Bridge
(Ramboll/AM Structures)

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

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

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

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

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing

Neil.Appleton@nccuk.com
Market Development Lead, Construction
Direct +44 (0) 7387 412254

www.nccuk.com
0117 3707 600
enquiries@nccuk.com
@NCCUKinfo
@NCCUKComms

AIRBUS GROUP · GKN · Rolls-Royce · LEONARDO HELICOPTERS · QinetiQ · GE

NATIONAL COMPOSITES CENTRE

CATAPULT High Value Manufacturing