UNIVERSITY OF Southampton

Modernising composite materials regulations: Structural approval procedure for rail infrastructure

AECOM

The rationale is to describe how the structural approval procedure works for composite material rail infrastructure. The flowchart of the procedure and the narrative is from a collaboration between the University of Southampton and AECOM, to publish a 'discussion document' for feedback and updates as required. Its intention is to highlight the involvement of the key stakeholders in the approval process and indicate potential blockers/ bottlenecks and possibilities to streamline the process, or reduce the timescales.This would be applicable for a new product/structure (enhancement/replacement, not repair, emergency or temporary works), including high integrity structures, and a specific case study has been considered.

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Flowchart narrative

Timescales are project specific, and hold points are indicated by . Document/ milestone outputs are indicated by . Product Acceptance (PA) is described in Ref. [1], for a new product evaluated against Rail Industry Readiness Level's (RIRL's), where Technology Readiness Level (TRL) 6 is completed and Reliability Readiness Level (RRL) is completed.

Stakeholders

EU (Define directives)

Regulator (ORR)

Industry Research Organisation (RSSB)

Manufacturer

Designer

Operator (NR)

Abbreviations

AiP	Approval in Principle
DCS	Data Communication Systems
FEA	Finite Element Analysis
gASA	graphene Acrylonitrile Styrene Acrylate
GF	Glass Fibre
NR	Network Rail
NRAP	Network Rail Assurance Panel
ORR	Office of Rail and Road
PA	Product Acceptance
PRS	Product Requirements Specification
QA	Quality Assurance
QC	Quality Control
RIRL	Rail Industry Readiness Level
RRL	Reliability Readiness Level
RSSB	Rail Safety & Standards Board
SQEP	Suitably Qualified and Experienced Personnel
TRL	Technology Readiness Level

Stages:

1. Requirement definition

Review and agree a single option for the structure and start to develop a risk and mitigation log. Define high level user requirements specification, i.e. installation time, anticipated construction sequence, cost, test and commissioning plan, maintenance cycle, and decommissioning plan.

2. Product development process

Demand is identified and technology idea is conceived and developed using desktop and laboratory research[1]. A Product Acceptance (PA) application is submitted and the generic requirements are provided to the applicant, on endorsement of the PA application by Network Rail (NR).

Technology idea is conceived and developed using desktop and laboratory research.

Experimentation and desktop modelling used to verify veracity of technology in line with anticipated usage.

Basic manufacturing implications identified.

Early ideas to satisfy an emerging or existing market need.

Sponsors instruction for development [2], .

Approval in Principle (AiP) of single option [2], .

- Design criteria
- Technical design requirements

3. Proof of concept

Proof of concept is ascertained using robust and repeatable processes. Technology validated against high level requirements in a laboratory and/or experimental environment [1]. Evidence provided by applicant/**Designer** against generic requirements and assessed by lead reviewer at NR **(Operator)**.

Manufacturing concepts and feasibility are determined and manufacturing processes identified. A manufacturing proof of concept is developed. Confirmation of buildability, material properties, design Information and route to manufacturer.

4. Validation

Evidence provided by applicant/**Designer** against user/**Operator** requirements in a representative environment. Evidence of compliance with specific technical acceptance requirements, . Confirm assumptions made in proof of concept stage with material coupon testing.

Capability to produce the technology in a laboratory or prototype production environment.

5. Prototype demonstration and qualification

Trial requirements designed to meet initial user requirements specification for the geometry, stress/strain and defection criteria for the product life cycle and application. Changes to the material specification may result following prototype demonstration from potential optimisation of the structure.

Performance of pre-production assets/system is demonstrated in an operationally representative environment (TRL 6), .

Demonstrate capability to produce prototype components in a production relevant environment.

Show performance in a representative operational environment is repeatable, verifiable and validated to required standards (RRL 7), , generating Trial certificate .

Production standard assets are qualified for use in an operational environment.

Identification of the experts possessing the required competencies for assessors and manufacturing and inspection personnel. Suitably Qualified and Experienced Personnel (SQEP) defined by engineering competency, as assessed by NR **(Operator)**. Assessment, leading to Approval certificate, .

6. Deployment

First of class asset deployed for operational usage under commercial conditions. Repeated and successful low-risk deployment of integrated system for operational usage. Low rate initial production.

Manufacturing QA/QC documentation, . Detailed QA/QC of the material production, storage and use.

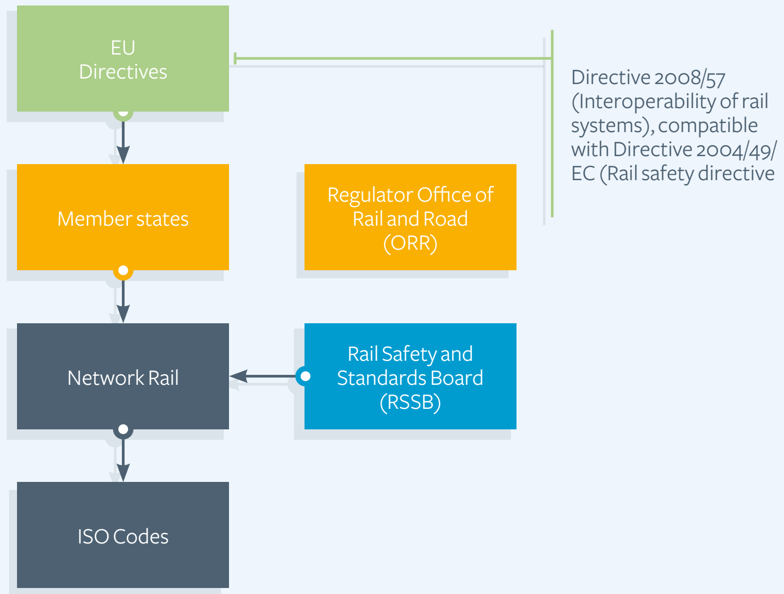
7. Production

Repeated and repeatable technology deployment in conjunction with managed asset development and evolution. Full/volume rate production capability demonstrated. Repeated and repeatable quality whole system deployment in expanding operational usage. Volume manufacturing QA/QC documentation, .

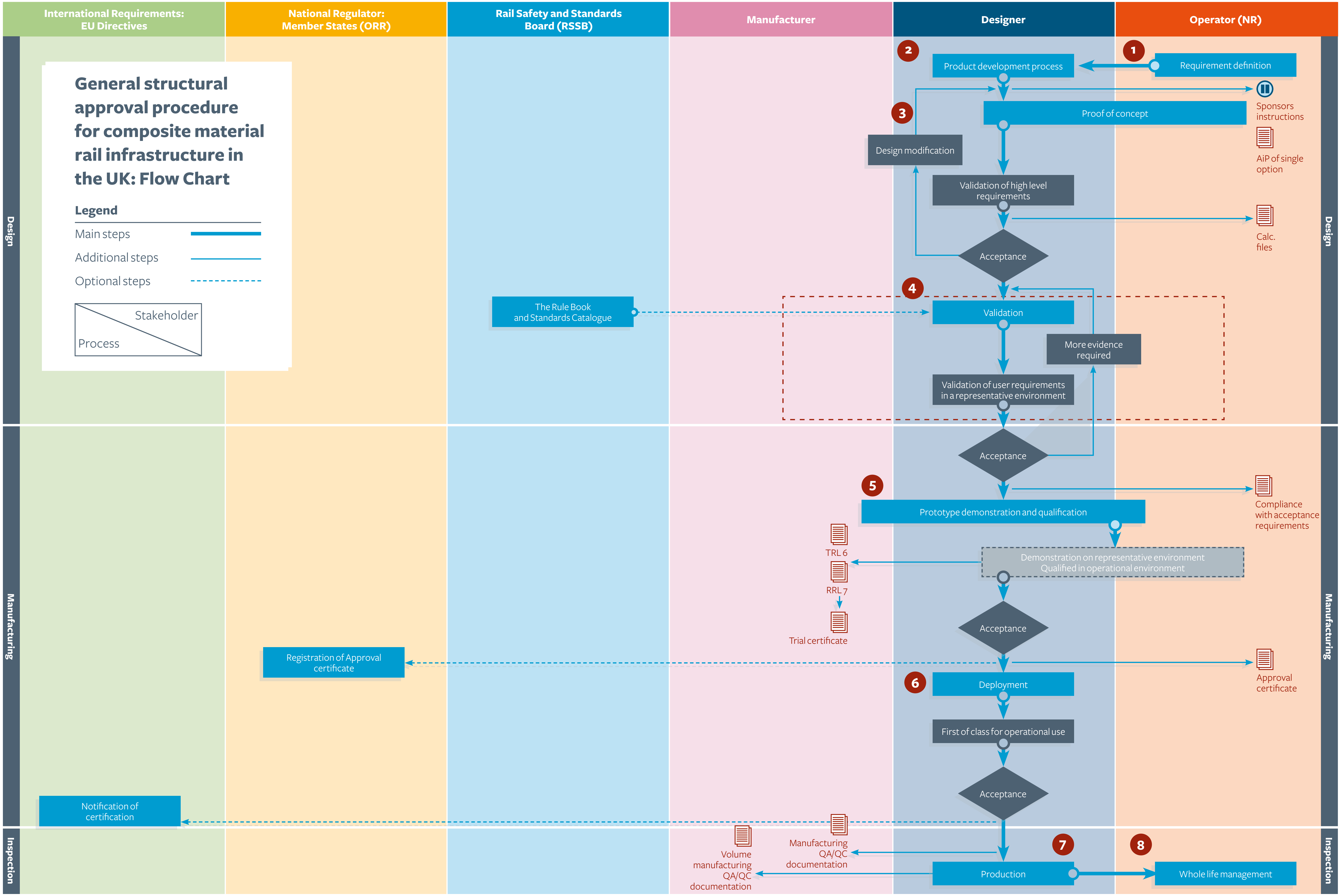
8. Whole life management

On-going continuous improvement and reliability growth. Definition of inspection, monitoring and maintenance requirements from measurements taken during the prototype phase and the product's performance in the validation phase of the product's life cycle.

Summary of regulation framework for composite material rail infrastructure structures in the UK



Key

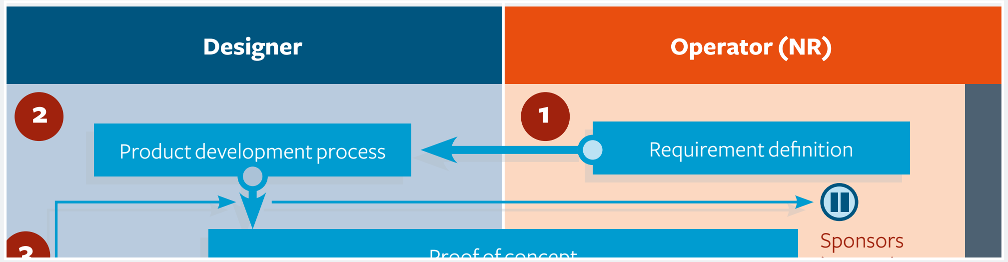

International Requirements: EU Directives
National Regulator: Member States (ORR)
Rail Safety and Standards Board (RSSB)
Manufacturer
Designer
Operator (NR)
Design
Manufacturing
Inspection
General structural approval procedure for composite material rail infrastructure in the UK: Flow Chart
Legend
Main steps
Additional steps
Optional steps
Stakeholder
Process
1
Requirement definition
2
Product development process
Sponsors instructions
Proof of concept
3
Design modification
AiP of single option
Validation of high level requirements
Calc. files
Acceptance
4
The Rule Book and Standards Catalogue
Validation
More evidence required
Validation of user requirements in a representative environment
Acceptance
5
Compliance with acceptance requirements
Prototype demonstration and qualification
TRL 6
Demonstration on representative environment Qualified in operational environment
RRL 7
Acceptance
Trial certificate
Registration of Approval certificate
Approval certificate
6
Deployment
First of class for operational use
Acceptance
Notification of certification
Manufacturing QA/QC documentation
Volume manufacturing QA/QC documentation
7
8
Production
Whole life management

Case Study 1:
Signalling arch support

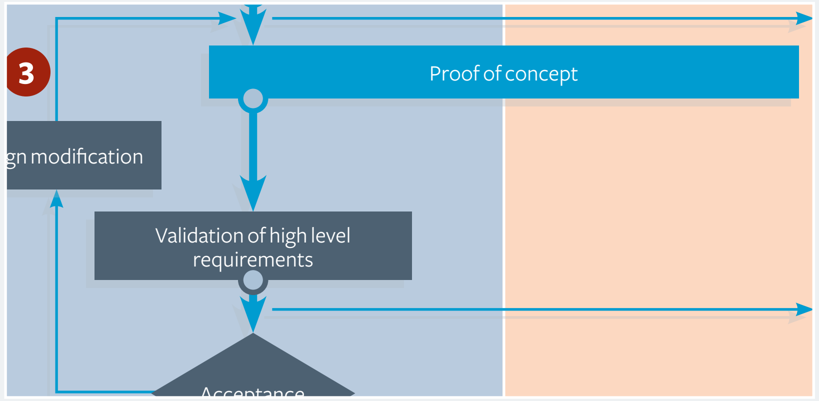
This case study presents the work to qualify the CNCT Arch, developed and designed by AECOM, for use in tunnels, see Figure 1. The CNCT (pronounced "connect") Arch and Mast are AECOM patent-pending 3D printed structures that support Data Communication Systems (DCS) units required for railway communication systems.

Figure 1: CNCT Arch (Courtesy of AECOM)

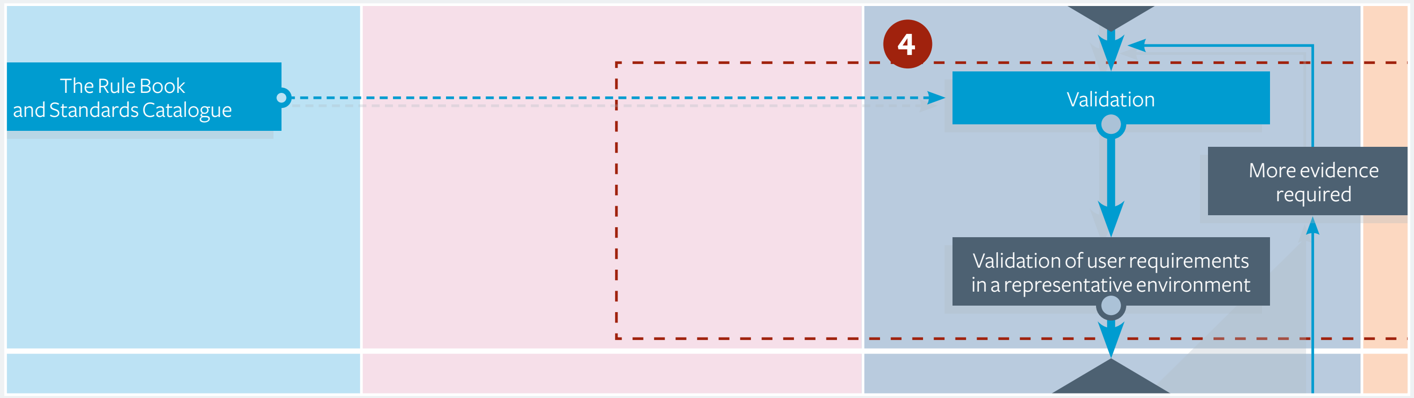
Signalling equipment is currently bolted into the brick arches of tunnels on the London Underground. There was a requirement to consider an alternative to the current approach, which is to bolt the signalling equipment into brick arches, which take multiple shifts to install. AECOM have developed a signalling arch that can be installed in a single shift, and requires no scheduled maintenance, made from reinforced printed polymer material, to meet the Requirement definition, and begin the Product development process (Stages 1 and 2 of the general process/procedure flow chart):



AECOM considered a novel reinforced printed polymer material to manufacture the product and demonstrated Proof of concept (Stage 3) through hand calculations for an arch requiring a category Ia (scale from 0 to III) design check as signalling superstructure[2]. The arch is manufactured in 1.5 m sections, with a primary cross-section that is an dumbbell shape. The overall height and width of the arch is 5 m and 5.2 m respectively.



A variety of material options for the printed polymer material, both reinforced and unreinforced, were considered in Stage 4, the Validation phase, both with regard to their mechanical properties, bolt pull-out, and manufacturability, using an extrusion process:



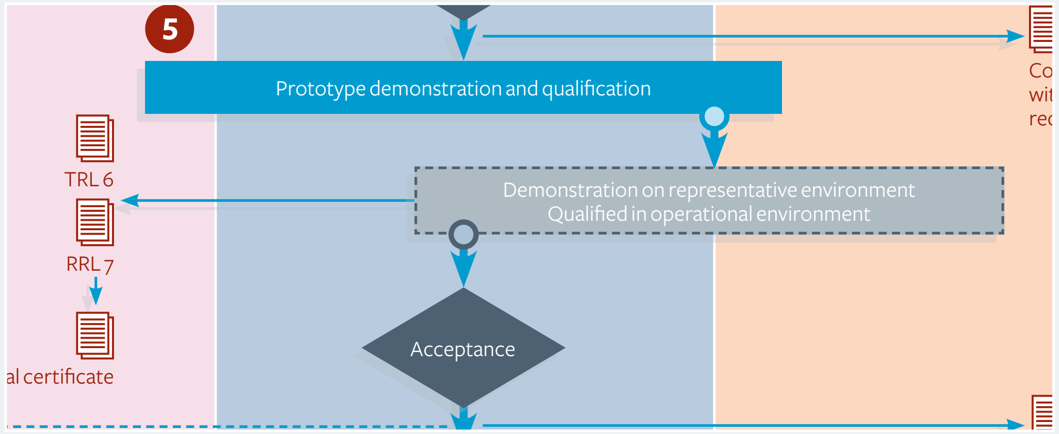
The material test plan for the candidate materials included the design codes and standards in Table 1.

Table 1: Items to be considered in the Validation phase for printed polymer material

Test type	Design Code/ Standard	Title	Reference
Tensile strength	BS EN ISO 527-1: 2012	Plastics - Determination of tensile properties - Part 1: General principles	[3]
	BS EN ISO 527-2: 2012	Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion plastics	[4]
Compressive strength	BS EN ISO 604: 2003	Plastics. Determination of compressive properties	[5]
Flexure	BS EN ISO 178: 2019	Plastics. Determination of flexural properties	[6]
Impact	BS EN ISO 180: 2000 + A2: 2013	Plastics. Determination of Izod impact strength	[7]
Creep test	BS EN ISO 899-1: 2017	Plastics. Determination of creep behaviour. Tensile creep	[8]
Adhesive peel test	BS EN 1465: 2009	Adhesives. Determination of tensile lap-shear strength of bonded assemblies	[9]
Water uptake	BS EN 62: 2008	ISO 62:2008 Plastics -- Determination of water absorption	[10]
Chemical resistance	BS EN ISO 175: 2010	Plastics. Methods of test for the determination of the effects of immersion in liquid chemicals	[11]
Flammability	UL 94	Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances	[12]

Of the six material options were tested the one selected for use was gASA (graphene Acrylonitrile Styrene Acrylate), reinforced with Glass Fibre (GF). The gASA material is extruded, from pellets, with the addition of graphene enhancing the manufacturability of the product. Details of the QA/QC process for the print/extrusion and the thermal dynamics of the print/extrusion process were also defined at this stage. The measured material properties for gASA were used in revised calculations and Finite Element Analysis (FEA), to consider the main loading cases, namely self-weight, torsion, aerodynamic loading, and fatigue, which confirmed that the maximum stresses, strains and deflections were below the allowables, with significant margin.

The next stage of the certification/verification process is Stage 5, Prototype demonstration and qualification, to demonstrate in a representative environment and qualify in an operational environment:



This is a six month trial at a signalling test site, which will validate the design work in an operational environment, measuring deflections and monitoring bolt pull-out and water absorption of the material.

References:

[1] NR/L2/RSE/100, Module 5, Product acceptance and change to Network Rail operational infrastructure, Issue 2, 03/03/18

[2] NR/L2/CIV/003, Engineering assurance of building and civil engineering works, Issue 4, 01/09/12

[3] ISO 527-1:2012, Plastics - Determination of tensile properties - Part 1: General principles, www.iso.org/standard/56045.html

[4] ISO 527-2:2012, Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion plastics, www.iso.org/standard/56046.html

[5] BS EN ISO 604:2003, Plastics. Determination of compressive properties, https://shop.bsigroup.com/ProductDetail/?pid=000000000030068343

[6] BS EN ISO 178:2019, Plastics. Determination of flexural properties, https://shop.bsigroup.com/ProductDetail/?pid=000000000030335678

[7] BS EN ISO 180:2000+A2:2013, Plastics. Determination of Izod impact strength, https://shop.bsigroup.com/ProductDetail/?pid=000000000030255169

[8] BS EN ISO 899-1:2017, Plastics. Determination of creep behaviour. Tensile creep, https://shop.bsigroup.com/ProductDetail/?pid=000000000030355115

[9] BS EN 1465:2009, Adhesives. Determination of tensile lap-shear strength of bonded assemblies, https://shop.bsigroup.com/ProductDetail/?pid=000000000030180285

[10] ISO 62:2008, Plastics - Determination of water absorption, /www.iso.org/standard/41672.html

[11] BS EN ISO 175:2010, Plastics. Methods of test for the determination of the effects of immersion in liquid chemicals, https://shop.bsigroup.com/ProductDetail/?pid=000000000030211723

[12] UL 94, Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, https://standardscatalog.ul.com/standards/en/standard_94_6

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