Review of Composites Standardisation Status and Activities

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SUMMARY

This guide reviews current standardisation of test methods, material specifications and product standards for polymeric matrix composites containing "long" fibres. Long fibre composites are defined in ISO standards "as those containing fibres with a length greater than 7.5 mm in the starting material or compound".

Several standardisation "levels", see below, of increasing complexity exist that contribute to the testing and traceability of any final composite product.

Standardisation Levels

- Constituent material specifications and test methods
- Compound specification and test methods
- Coupon level test methods and test plate manufacture
- Composite material database standards
- Structural element test methods
- Sub-component specifications
- Product approval standards
- Non-destructive evaluation standards

International standardisation for composites, at the material level, in ISO has taken a significant step forward with the transfer of the TC61/SC13 Secretariat from France to Japan, which will provide the opportunity to submit new work items. The UK industry should use this change to promote its needs for new test methods, specification standards and QA supporting infrastructure.

Composite product standards are normally developed in specialist product working groups within CEN, the standards body for Europe. It is important to review the use of materials data and design procedures across a wide range of applications standardised predominately in these standards.

Guide prepared on behalf of NCN Task Group on "Design Codes, QA and Standards".

CONTENTS

ABBREVIATIONS

AECMA	**European Aerospace Trade Federation**
AFNOR	**Association Francaise de Normalisation**
ANSI	**American National Standards Institute**
ASTM	**American Society for Testing and Materials**
BSI	**British Standards Institution**
CD	**ISO Committee Draft ballot stage**
CEN	**Comité European de Normalisation**
DIN	**Deutsches Institut fur Normung**
DIS	**Draft International Standard ballot stage**
EN	**European Standard**
EN Aerospace	**Aerospace Series of CEN standards prepared by AECMA, (n.b. EN 6000 series based on Airbus Industries Test Methods (AITMs)).**
FDIS	**Formal Draft International Standard ballot stage**
ISO	**International Standards Organisations**
JIS	**Japanese Industrial Standards**
prEN	**Preliminary enquiry vote for EN standard**
SC	**Sub-committee**
TC	**Technical Committee**
VAMAS	**Versailles Project on Advanced Materials and Standards**
WD	**ISO Working Draft (within Working Group)**
WG	**Working Group**

1. INTRODUCTION

This guide reviews progress on standardisation of test methods, material specifications and final products standards for polymer composites. The guide only considers those materials containing "long" fibres (i.e. those containing fibres with a length greater than 7.5 mm in the starting material or compound). Plastics reinforced by fibres shorter than 7.5 mm are tested in the same manner as unreinforced and particle-reinforced plastics.

Several levels of standards and specifications have been identified, as listed below. These are shown diagrammatically in Figure 1 highlighting the alternating dependence of specification and test methods standards at each level.

Standardisation levels for composite materials:

- Constituent material specifications and test methods
- Compound specification and test methods
- Coupon level test methods and test panel manufacture
- Composite material database standards
- Structural element test methods
- Sub-component specifications
- Product approval standards
- Non-destructive evaluation standards.

In Section 2, the standardisation process is briefly reviewed; followed by a review of the above standardisation levels where there is significant activity, in Section 3. Section 4 assesses standards under development and future needs.

2. STANDARDISATION INFRASTRUCTURE

The main bodies responsible for standardisation in this field are ISO, CEN (General), CEN Aerospace, ASTM, JIS and other national bodies. The activities are identified via the lead body, although most test method standards in ISO are eventually published as triple numbered BS EN ISO standards. All CEN standards are automatically published as national standards within the EU (e.g. British Standards), whereas ISO standards are subject to a re-ballot before adoption as a BSI standard.

International standardisation for composites in ISO has taken a significant step forward with the transfer of the ISO TC61/SC13 Secretariat from France to Japan. Following this change, there will be again the opportunity to submit new work items. The CEN General Series under CEN TC249, draws mainly on ISO standards for coupon and materials tests through parallel votes of ISO standards. The composite product standards in CEN are developed in specialist product working groups e.g. CEN TC210 for GRP Pressure Vessels. Development of specialist aerospace equivalent standards continues to be undertaken within the EN Aerospace series.

The new ISO Convenor for Polymer Composites is Dr Takashi Ishikawa, with Dr Kimihiro Ikezaki convening Working Group 1 covering "Fibres and fibre products (e.g. fabrics) – Test and Specifications; and Dr Graham Sims convening Working Group 2 covering "Laminates and moulding compounds" (covering Test Methods and Specifications).

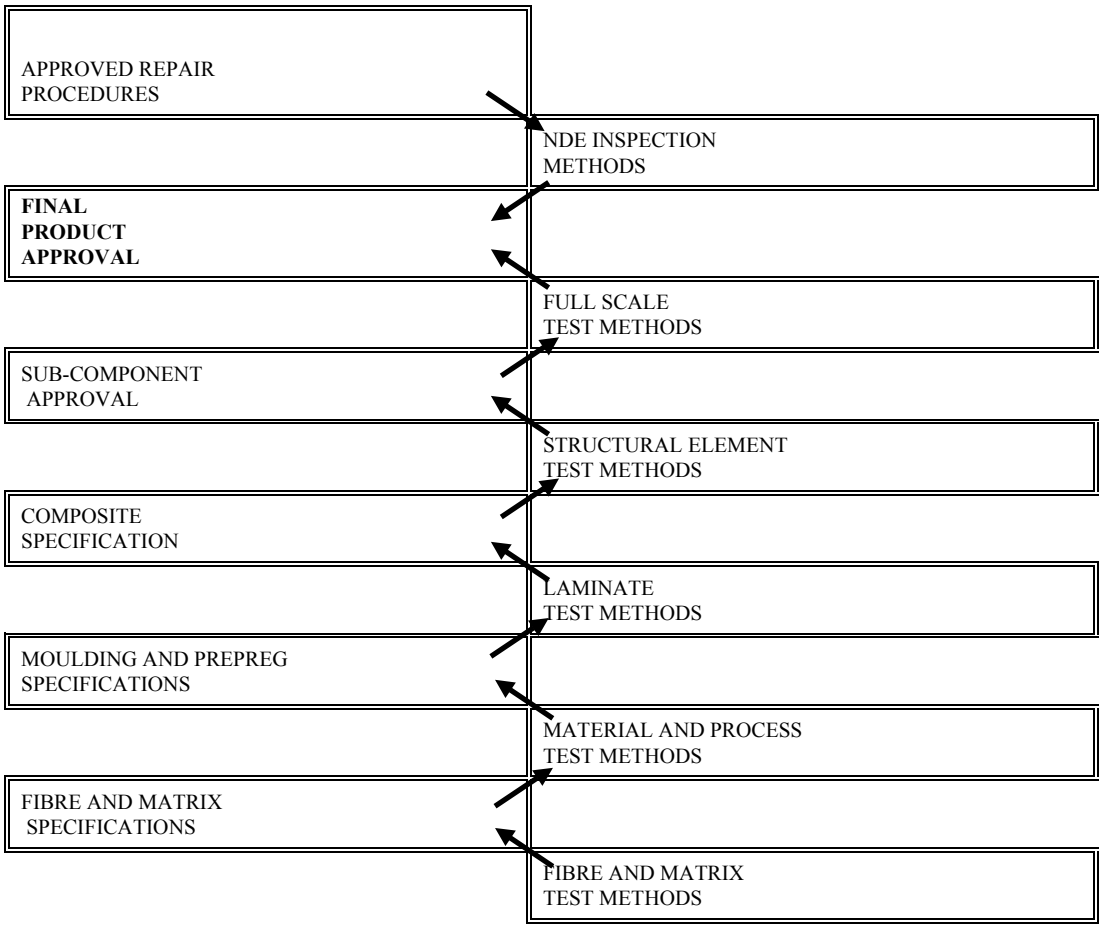


Figure 1. Chain of validation for composites products

It should also be noted that the requirements to place a new item on the official work programme as an approved work item (AWI) are quite demanding in their own right. A new work item requires 12 countries to support, 5 countries to work (i.e. read documents carefully, participate in discussions, possibly participation in round-robin test on documents with nominated experts) and a qualifying score for the need and impact of proposed documents. The score is based on assessment on the following aspects:

1 What is the potential of this project to contribute to international trade and production?

2 What is the potential of this project to contribute to economic efficiency, health, safety, or the environment?

3 How great is the need to harmonize national approaches in this subject area that may serve as barriers to international trade?

4 What is the feasibility of achieving consensus on International Standard(s) in this subject area by the proposed target dates?

5 What priority should be assigned to the development of International Standard(s) in this subject area?

3. POLYMER COMPOSITES STANDARDS

3.1 CONSTITUENT MATERIAL SPECIFICATIONS AND TEST METHODS

There is now a fairly extensive infrastructure of textile-size (e.g. can be woven into fabrics) fibre test methods, initially covering glass-fibres and similar standards for carbon-fibres. Later standardisation has been aimed at producing generic version of these test methods. For example, linear density is independent of fibre type, and a generic standard covers current fibres and importantly new fibres of this size; without the need to draft, ballot and publish a new specific standard for the new fibre. The proposed carbon fibre yarn specification standard (prEN 13002) has been withdrawn pending appointment of a new project leader. This type of specification standard is important for the supply industry as an illustration to potential end-users that fibres are available to a consistent specification, and from more than one supplier. A coding system based on mean values and defined ranges is proposed to identify the modulus and strength combinations available. However, no agreement has been obtained to date.

A CEN specification for non-crimp fabrics (NCF) published as BS EN 13473 provides timely support for this increasingly important reinforcement format. Stitched non-crimp fibre formats allow larger weights of material to be deposited with multiple fibre orientations, which is particularly suitable for resin transfer moulding (RTM) methods. The latest position on constituent fibre standards is given in Table 1

Table 1: Constituent fibre specifications and test method standards

Standard Number	Title
ISO 1887	Glass fibre – Determination of combustible matter content (size)
ISO 1888	Textile glass – Staple fibres or filaments - Determination of average diameter
ISO 1889	Reinforcement yarns – Determination of density
ISO 1890	Reinforcement yarns – Determination of twist
ISO 2078	Textile glass - Yarns -Designation
ISO 3341	Textile glass – Yarns - Determination of breaking force and breaking elongation
BS 4045	Specification for epoxide resin pre-impregnated glass fibre fabrics
ISO 9291	Textile glass reinforced plastics – rovings – preparation of unidirectional plats by winding. (being replaced by ISO 1268)
ISO 9163	Textile glass rovings – Preparation of test specimens and determination of tensile strength of impregnated rovings
ISO 10119	Carbon fibre – Determination of density
ISO 10548	Carbon fibre – Determination of size content
ISO 11566	Carbon fibre – Determination of tensile properties of single filament specimens
ISO 11567	Carbon fibre – Determination of filament diameter and cross-sectional area
ISO 10618	Carbon fibre – Determination of tensile properties of resin-impregnated yarn
ISO 13002	Carbon fibre – Designation system for filament yarns
BS ISO 10371	Fibre reinforced plastics. Braided tapes for composite materials reinforcement. Basis for a specification
BS EN 13003	Para-aramid fibre filament yarns
BS EN 13417	Specification for woven fabrics - Parts 1-3
BS EN 13473	Specification for multi-axial multi-ply fabrics (NCFs) - Parts 1-3
BS EN 14020	Specification for textile glass rovings - Parts 1-3
BS EN 14118	Specification for textile glass mats - Parts 1-3
ISO/DIS 15039	Textile glass rovings – determination of solubility of sizing
ISO/DIS 15100	Plastics – reinforcement fibres – chopped strands – determination of bulk density

Resin matrices, both thermoplastic and thermoset, are mainly covered by standards for the unreinforced plastic and are not listed here. In general, these methods and specifications are comprehensively represented in the ISO series.

3.2 COMPOUND SPECIFICATION AND TEST METHODS

Good progress has been made with two standards (i.e. EN 13677 and 13706) more recently published (see Table 2). There is a structural format difference between BS EN 13706 for pultruded profiles, which includes mandated minimum levels of performance, and the other two standards (i.e. for GMTs and SMCs specification) that rely on establishing bounds for the mean properties as agreed between supplier and moulder/user. This is to be expected in the latter cases as many "recipes" exist. The standard defines the properties to be controlled and the limits, in percentage terms, while the customer/supplier agrees the absolute level of the properties. For pultrusions, the CEN specification is already increasing the application of pultruded sections (e.g. box, tee, channel, angle).

Table 2: Compound specification and test methods

Standard Number	Title
EN 14598	Reinforced plastics composites – Specifications for thermoset moulding compounds (SMC, BMC, DMC)
EN 2833	Aerospace: Reinforced Plastics – Glass fibre pre-impregnates
EN 14447	Fibre reinforced plastics. Glass mat reinforced thermoplastics (GMT). Determination of flowability and solidification
ISO 9782	Plastics; reinforced moulding compounds and prepregs - Determination of apparent volatile matter content
ISO 10352	Fibre reinforced plastics – Moulding compounds and prepregs – Determination of mass per unit area
ISO 11667	Fibre reinforced plastics – moulding compounds and prepregs – Determination of resin, reinforced fibre and mineral filler content – Dissolution methods
BS EN ISO 12115	Fibre reinforced plastics – thermosetting moulding compounds and prepregs – determination of flowability, maturation and shelf life
ISO 12114	Fibre reinforced plastics – thermosetting moulding compounds and prepregs – determination of cure characteristics
BS EN 12575	Plastics. Thermosetting moulding compounds. Determination of the degree of fibre wet out in SMC.
EN 1342	SMC/BMC – Determination of anisotropy
EN 13677	Reinforced Plastics Composites – specifications for thermoplastic moulding compounds (GMT)
BS EN 13706	Pultruded Profiles – Specifications - Parts 1-3
EN 14447	GMT - Determination of flowability and solidification
EN 14598	SMC/DMC - Specifications - Parts 1-3
ISO 15034	Composites - Prepregs – Determination of resin flow

The first public composite road bridge designed by Mouchel (see Figure 2) has been opened on the B4508 road in Oxfordshire [3]. Interestingly, the main structural load bearing units forming the cross-beams are based on plain pultruded GRP box sections, conforming to the E23 grade defined by BS EN 13706 standard, stiffened by carbon-fibre cappings. An EU research project funded the development of the more complicated shaped pultrusions known as "Asset" units that are bonded together to form the road deck. There was considerable interest in this bridge application as shown by the 250 delegates attending a seminar on the bridge design and build held on the day previous to the official opening.

Figure 2. Military tank used for on-site testing of Mouchel designed bridge *(Courtesy of Mouchel Parkman)*

3.3 COUPON LEVEL TEST METHODS

3.3.1 Test panel preparation

The revision of ISO 1268 as a multi-part standard now covers most established process routes, as noted in Table 3. The aim of these standards is to ensure that test panels are made consistently and in a representative manner for the wide range of available manufacturing routes. As new processes outside the existing scopes are established, further parts will be added to the standard. Supporting standards at this level are those related to quality aspects, such as for measuring fibre and void content. For glass-fibre based systems ISO 1172 and ISO 7822 based on resin burn-off are used. For carbon-fibre based systems, ISO 14127 provides several methods including the principle method of chemical dissolution.

Defects from unbonded laminae, or entrapment of voids or contaminates are detected using the ultrasonic C-scan technique. Drafts for standardisation [3-5] for the use of this technique were prepared in a DTI CARAD project led by NPL in conjunction with DERA (now Qinetiq) and industry are being used initially to develop in-house documents. It is proposed to standardise this work through the EN Aerospace series.

Table 3: Parts of (EN) ISO 1268 for test plate manufacture

Part No.	Title
1	General principles
2	Contact and spray-up moulding
3	Wet compression moulding
4	Moulding of preimpregnates
5	Filament moulding
6	Pultrusion moulding
7	Resin transfer moulding
8	Moulding of SMC/BMC
9	Moulding of GMT/STC
10	Injection moulding of BMC/DMC

3.3.2 Mechanical test methods

Laminate test methods are still principally developed in the ISO work programme as noted in Table 4. One of the most recent standard published is on "Fatigue Testing of Composites – General Principles (ISO 13003)". The UK, through the author, was heavily involved in drafting and editing this French-led project through the incorporation and exploitation of experiences from the VAMAS fatigue studies [6].

Table 4: Composite material test methods

Standard Number	Title
ISO 3597 Part 1 - 4 (Revision)	Textile glass reinforced plastics – Determination of mechanical properties on rods made of roving reinforced resin. (Preparation of rods, flexure, tension and shear strengths)
ISO 13003	Fatigue - General principles
ISO14127	Carbon-fibre laminates- Determination of resin, fibre and void content
ISO 15024	Standard test method for Mode I Interlaminar fracture toughness G_{IC} of unidirectional fibre reinforced polymer matrix composites
ISO 15310:	Fibre reinforced plastic composites – determination of in-plane shear modulus by plate twist
ISO NWI N565	Glass reinforced products – Determination of fibre length
ISO DIS 18352	Test method for compression-after-impact properties of carbon fibre reinforced plastics.

The six standards, shown in Table 5, provide the basic coupon tests used for design (in-plane tension, shear and compression) and QA (i.e. interlaminar shear strength, flexure) testing. These ISO test methods were harmonised during the drafting work at NPL with CRAG and ASTM versions of the same test methods, with one standard (i.e. BS EN ISO 14129) based on the equivalent ASTM test. As a result of the work corresponding changes were made to ASTM test methods to improve harmonisation. These standards have been re-balloted under the automatic five-year review procedure for confirmation, revision or withdrawal.

The tensile test methods BS EN ISO 527-4 was agreed for confirmation. However, the Japanese requested a revision of ISO 527-5 to include tapered tabs as well as, or instead of, square ended tabs, and revised strain levels for modulus determinations (c.f. ASTM D 3039 [7]). The first aspect was considered fully when the different standards were initially harmonised by NPL ten years ago. Indeed, it was a Japanese round-robin data that was tabled at the annual ISO meeting that resulted in the choice of square ended-tabs, which was common in the UK in CRAG, EN Aerospace and the existing ISO 3268 standard for GRP. The Japanese work found that for two carbon-fibre systems tested in a round-robin exercise,

one obtained a higher strength with a tapered tab, and the other with a square ended tab. Consequently, on a balance of technical aspects, but also considering the cost and time for tabbing the specimen, the Japanese recommended square tabs, especially for non-carbon fibre based systems. ASTM subsequently, modified ASTM D 3039 - the equivalent tensile standard - to allow tab angles up to 90º to harmonise with the ISO standard, while retaining a preference for 7º tapered tabs. Tapered tabs delaminate more easily during fatigue testing.

Table 5: Harmonised BS EN ISO Test Methods

Property	International Standard	ASTM Methods	CRAG Methods
Tension - "Isotropic" (nominally)	BS EN ISO 527-4	D 3930	300
Tension - Unidirectional (anisotropic)	BS EN ISO 527-5	D 3930	300
Flexure	BS EN ISO 14125	D 695	200
Compression	BS EN ISO 14126	D 3410	400
Shear - ± 45° Tension	BS EN ISO 14129	D 3815	101
Shear - interlaminar by short beam flexure	BS EN ISO 14130	D 2344	100

The strain levels used for modulus measurement in ASTM D 3039 (i.e. 0.1% to 0.3%) gives the same strain range of 0.2% as in the ISO standard based on a strain range of 0.05% to 0.25%. Whereas, the EN aerospace standard, EN 2561 [8], is fundamentally different being based on the stress-strain data between P/10 to P/2, where P = peak load. The ISO conditions were drawn from the previous standards (e.g. ISO 3268, ISO 527, ISO 178, ISO 604) that applied across all plastics (i.e. films, engineering plastics, moulding composites and composites) and test modes (i.e. tension, compression and flexure). Following discussion and consideration of the official revision ballot results, both Part 4 and 5 of ISO 527 were re-confirmed in 2005.

Work on "compression-after-impact", has progressed under the Japanese project leader. This work area is of particular interest to the UK following studies in previous and current DTI programmes (e.g. MMS13) on "defect criticality" [9]. A further NPL project is undertaking round-robin tests in support of this standard.

A round-robin (RR) validation has been undertaken for the double-notch shear test based on ASTM D 3846 [10]. Three materials representing different classes of composites were used (i.e. unidirectional carbon-fibre/epoxy, glass-fibre/polyester pultrusion and woven glass-fibre/epoxy) [11]. The RR was undertaken by supplying participants with material to prepare specimens that were subsequently returned to NPL for testing. This approach was taken as the test is considered to be particularly sensitive to the quality of test specimen preparation. A similar approach was followed for a thick adhered test method using aluminium specimens for the RR exercise [12].

3.3.3 Thermal analysis test methods

During this last year, NPL prepared, as the project leader, the CD ballot version of ISO 6721-11 on measurement of T_g (glass transition temperature) using dynamic mechanical analysis (DMA) methods, including calibration of DMA equipment. This test method was researched and precision data obtained in an NPL/industry studio project, and comparisons made with T_g measured by differential scanning calorimetry (DSC). The two techniques are routinely used for high performance pre-impregnated composites (prepregs), and are often interchanged or used in comparison, although the relationship between these two very different tests is not clear. However, not all users can afford to have both techniques in-house. These results are reported in a Measurement Good

Practice Guide [13] on thermal analysis methods, which included a draft that formed the basis of ISO 6721-11.

A typical set of RR data for Tg measurements are shown in Figure 3. Although, repeatability (within site) and reproducibility (between sites) were good for DSC (Differential Scanning Calorimetry), and repeatability was good for DMA (Dynamic Mechanical Analysis), poor reproducibility was obtained from DMA tests. The variability of DMA data was shown to be associated with temperature calibration errors in DMA equipment. Further details of the temperature calibration work are given in [13].

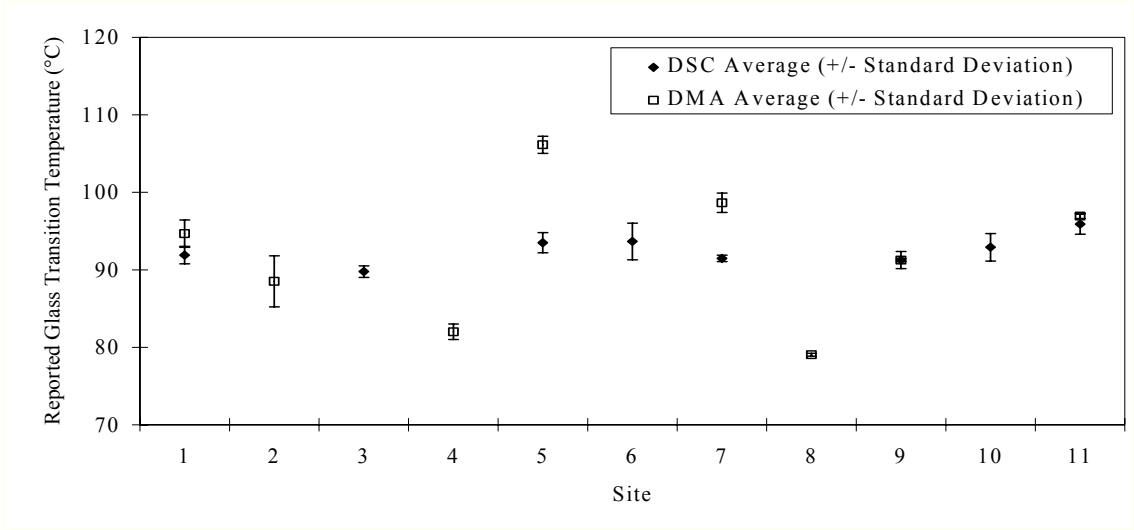


Figure 3. DSC and DMA results on unreinforced polyester [13]

ISO TC61/SC5/WG8 is planning a series of test methods for thermal conductivity measurements for all plastics as listed in Table 6. Work to be undertaken by the UK relates to use of temperature modulated DSC for thermal conductivity measurements, including a Part 1 document on General Principles. These methods were studied in the second phase of the recent thermal analysis studio project, resulting in an updated version of the Measurement Good Practice Guide [14]. It will be necessary to launch official new work item ballots and obtain sufficient support for each part, as noted in Section 2.

Table 6: Proposed new series of test methods for thermal conductivity

• **Introduction**
Introduction and presentation of the different techniques and their uses according to the plastic materials
• **Hot Wire Techniques:**:
Hot Wire (see ISO 8894)
Line Source (see ASTM D 5930)
Hot Disk
• **Wave and Pulse methods:**
Temperature Wave Analysis
Laser Flash (see ISO 18755)
• **Steady State methods:**
Guarded Hot Plate (see SO 8302)
Guarded Heat Flux (see ISO 8301/ ASTM E 1530)
• **Temperature Modulated DSC** (new separate series on DSC)

3.4 STRUCTURAL ELEMENT TEST METHODS

Round-robin validation has been completed for the pin-bearing test [14]. The pin-bearing test is used for this information for all types of composites and not only for aerospace materials. In fact, the first mandatory use of the pin-bearing test is in the specification standard for pultruded profiles (i.e. EN 13706) in recognition of the frequent use of bolting for assembly structures from these profiles (c.f. alternative of bonding). Currently, the pin-bearing test is an annex only to the CEN standard, so that, other versions can still be written for different application areas etc.

Four materials representing different classes of composites were used in the exercise. The materials were:

1. unidirectional carbon-fibre/epoxy,
2. woven glass-fibre/epoxy,
3. chopped strand mat/polyester,
4. glass-fibre/polyester pultrusion.

Abstracts from [15] are given in Figures 4-6 and Table 7. Please see reference [15] for full details. The precision data will be used to support a new work item proposal.

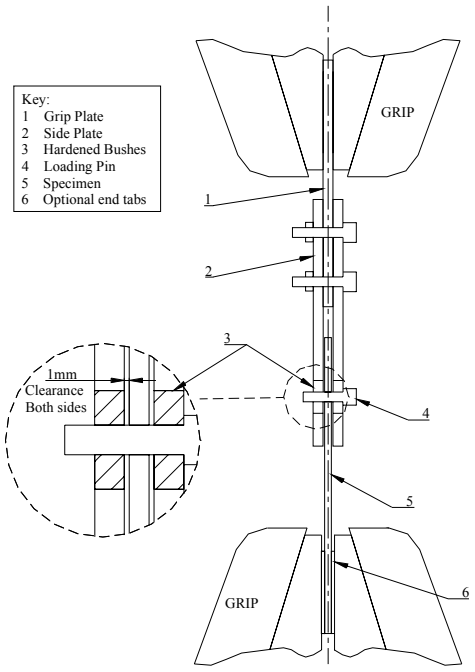
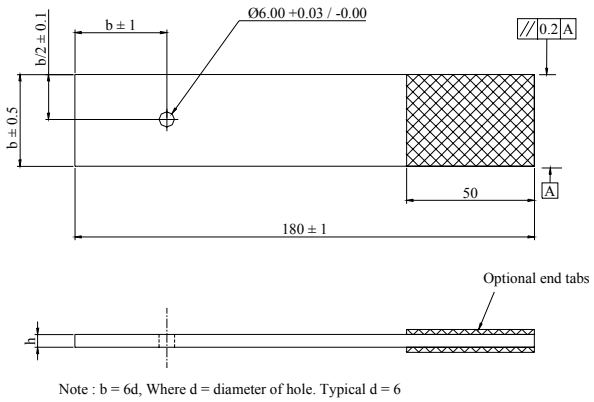


Figure 4. Pin-bearing test geometry



Note : b = 6d, Where d = diameter of hole. Typical d = 6

Figure 5. Pin-bearing specimen geometry

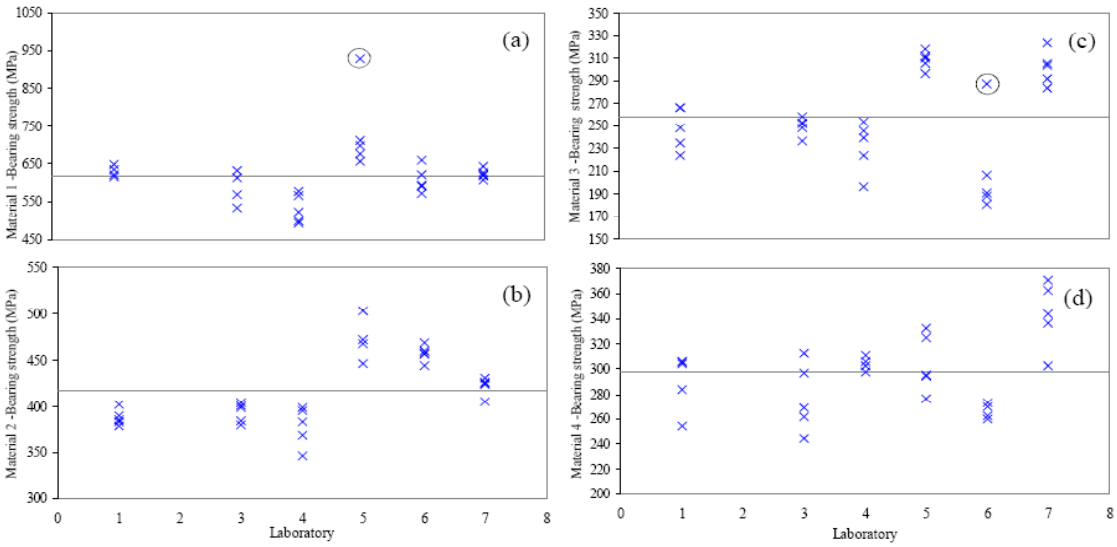


Figure 6 Data from pin bearing tests for materials (a) to (d)
(N.b. horizontal line represents overall mean, encircled points = outliers)

Table 7. Repeatability and reproducibility limits and standard deviations

Material	Repeatability Conditions		Reproducibility Conditions		Mean, σ (MPa)
	S_r	r	S_R	R	
1	30.8	86.2	57.1	160.0	606.0
2	15.1	42.2	40.0	111.9	418.0
3	15.0	42.1	44.9	125.6	257.3
4	21.2	59.3	33.1	92.7	297.7

3.5 PRODUCT APPROVAL STANDARDS

The main progress made recently was the publication of several final product standards, such as ISO 14692 covering the use of GRP pipe work in off-shore applications. This standard is likely to have a significant impact on use of composites in other applications, as the comprehensive coverage and procedures are applied more widely. The increasing use of fibre wrapped or fully composite cylinders for liquid petroleum gas (LPG) storage and rescue pack applications is well represented by the number of new linked EN and ISO standards in this area. These standards are in two application areas that are safety critical.

Equally, EN 40-7 is an important standard as it covers a routine civil construction application and contains design rules for GRP light-columns alongside other parts of the standard dealing with steel, aluminium and concrete light columns. NPL first worked on the design modifications required for anisotropic materials (i.e. composites) in lighting columns more than 15 years ago for the Department of Transport.

Table 8. Composite material product standards

Product	Standard Number
GRP pressure vessels	prEN 13121 (c.f replaces BSI 4994)
GRP piping offshore	ISO 14692
GRP Water piping	EN 1115-1 (c.f. BS 7159/6464)
GRP Water tanks	BS EN 13280 (replaces BS 7491 3 parts)
FRP Lighting Columns	EN 40-7
Wrapped Gas Cylinders	EN 12445/N12447/ISO 11119 (3 parts)

Progress continues on several other documents, which are replacing BS documents particularly in the piping and pressure vessels applications areas with publication already achieved in the case of pipe work. It should be noted that there are many cross references in these product standards to test method standards drafted in the UK as reviewed in [16]. This report covers the use of material data in the traceability and qualification of products.

4. CONCLUDING COMMENTS

4.1 FUTURE REQUIREMENTS

It is noted that there is has been an increased interest in several different applications in the compression testing of thick carbon-fibre systems (i.e. thickness > 4 mm) both for in-plane and through-thickness properties [17, 18]. Equally, other projects have identified a wide range of data and test methods needed (e.g. mechanical properties, degree of cure, water absorption, fatigue, creep, impact). Durability continues to be of major concern, with over 2000 downloads recorded of a recent review by NPL [19]. It is planned to add a 4th part to ISO 13706 on durability aspects if sufficient evidence of the relationship of laboratory tests to service performance can be obtained or modelled.

Proposals are being made in ISO TC61/SC13 for new work items on scissor shear, pin-bearing, open/filled hole tension and compression [20] and Mode II fracture energy [21].

4.2 COMPOSITE PRODUCT STANDARDISATION

It is important that the increasing number of standards related to composite products, as in table 8, use consistent design procedures where possible (e.g. bolted joint design) and both source and use material property data in a similarly consistent manner. Although some work has been undertaken at the material property level [16], the design procedures themselves have not been analysed and compared in detail. This work will be tackled by the Task Group described below.

In order to reduce the cost and increase the availability of composite data in product design it is proposed to recommend that the Standard Qualification Plan (SQP) [22] be made available as an international standard. The guide details a SQP aimed at reducing the substantial costs involved in qualifying materials on behalf of suppliers, designers and end-users of fibre-reinforced plastic composite materials. Both composites suppliers and end-users are affected by the high cost of composite materials qualification. Qualifying a product against different user specifications, introducing new materials and finding data for materials selection and preliminary design can all be prohibitively costly due to repetition of testing. For example, one qualification programme for a new product cost £2 million to repeat ten times for different customers, rather than £130,000 if one qualification could have been accepted by all. An estimate of a 40% increase in design cost was also given due to the delayed availability of design data. The SQP is aimed at satisfying the minimum common requirements necessary to allow initial material selection, quality control and preliminary design to be undertaken. Further qualification requirements, not met by the minimum SQP, are included in an Extended Qualification Plan (EQP) (e.g. compression-after-impact)

4.3 STANDARDISATION INPUTS FROM UK COMPANIES

NCN has established a NCN Task Group on "Design Codes, QA and Standards" to support future applications and are keen to hear from UK companies and research establishments on new requirements, revisions of existing standards or proposals for deleting obsolete standards. For example, inputs are requested on the standards listed in Table 5, at their 5-year review points. The Task group will be reviewing preferred design approaches and procedures, following this first publication.

Contact for further details or to send requests/proposals/information to:

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APPENDIX A. ISO and EN STANDARDS FOR FIBRE REINFORCED PLASTICS

Reinforcing fibres and fibre products - Test methods and specifications

ISO 1887: Glass fibre – Determination of combustible matter content (size)

ISO 1888: Textile glass – Staple fibres or filaments - Determination of average diameter

ISO 1889: Reinforcement yarns – Determination of density

ISO 1890: Reinforcement yarns – Determination of twist

ISO 2078: Textile glass - Yarns -Designation

ISO 3341: Textile glass – Yarns - Determination of breaking force and breaking elongation

ISO 9291. Textile glass reinforced plastics – rovings – preparation of unidirectional plats by winding. (being replaced by ISO 1268)

ISO 10119: Carbon fibre – Determination of density

ISO 10548: Carbon fibre – Determination of size content

ISO 11566: Carbon fibre – Determination of tensile properties of single filament specimens

ISO 11567: Carbon fibre – Determination of filament diameter and cross-sectional area

ISO 10618: Carbon fibre – Determination of tensile properties of resin-impregnated yarn

ISO 13002: Carbon fibre – Designation system for filament yarns.

BS 4045:1966. Specification for epoxide resin pre-impregnated glass fibre fabrics.

BS ISO 10371:1993. Fibre reinforced plastics. Braided tapes for composite materials reinforcement. Basis for a specification.

BS EN 13003:1999. Para-aramid fibre filament yarns.

ISO/DIS 15039. Textile glass rovings – determination of solubility of sizing.

ISO/DIS 15100. Plastics – reinforcement fibres – chopped strands – determination of bulk density.

Moulding compound / pre-impregnates – test methods and specifications

prEN 14598: Reinforced plastics composites – Specifications for thermoset moulding compounds (SMC, BMC, DMC)

prEN 2833. Aerospace: Reinforced Plastics – Glass fibre pre-impregnates

prEN 14447. Fibre reinforced plastics. Glass mat reinforced thermoplastics (GMT). Determination of flowability and solidification

ISO 9782. Plastics; reinforced moulding compounds and prepregs; Determination of apparent volatile matter content.

ISO 10352. Fibre reinforced plastics – Moulding compounds and prepregs – Determination of mass per unit area.

ISO 11667. Fibre reinforced plastics – moulding compounds and prepregs – Determination of resin, reinforced fibre and mineral filler content – Dissolution methods.

BS EN ISO 12115. Fibre reinforced plastics – thermosetting moulding compounds and prepregs – determination of flowability, maturation and shelf life.

ISO 12114 – Fibre reinforced plastics – thermosetting moulding compounds and prepregs – determination of cure characteristics

BS EN 12575:1998. Plastics. Thermosetting moulding compounds. Determination of the degree of fibre wet out in SMC.

prEN 13677: Reinforced Plastics Composites – specifications for thermoplastic moulding compounds (GMT)

ISO 15034: Composites - Prepregs – Determination of resin flow

ISO 15040: Composites - Prepregs – Determination of gel time

Resin systems

BS 3532:1990. Specification for unsaturated polyester resin systems for low pressure fibre reinforced plastics.

Many other standards for unreinforced thermoplastic and thermoset resins applicable (www.bsi-global.com)

Fibre reinforced plastics (or polymer matrix composites)

BS 6564-3:1990. Polytetrafluoroethylene (PTFE) materials and products. Specification for E-glass fibre filled PTFE.

Laminated materials – Mechanical property tests

BS EN ISO 75-3:1996. Plastics. Determination of temperature of deflection under load. High-strength thermosetting laminates and long-fibre-reinforced plastics

BS EN ISO 527 – Part 1: Plastics – Determination of tensile properties – General principles

BS EN ISO 527 – Part 4: Determination of tensile properties – Test conditions for isotropic and orthotropic fibre-reinforced plastic composites

BS EN ISO 527-5: Plastics. Determination of tensile properties. Test conditions for unidirectional fibre-reinforced plastic composites

ISO 1172. Textile glass reinforced plastics; Prepregs, moulding compounds and laminates – Determination of the textile-glass and mineral-filler content - Calcination methods (determination of loss on ignition)

ISO 1268: Fibre reinforced plastics – test plate manufacturing methods

ISO 2818: Plastics – Preparation of specimens by machining

ISO 3597. Textile glass reinforced plastics; Determination of mechanical properties on rods made of roving reinforced resin (Parts 1-4)

ISO 4899 Textile glass reinforced thermosetting plastics; properties and test methods.

ISO 10350-2: Plastics – acquisition and presentation *of comparable single-point data – Part 2: long fibre reinforced plastics*

ISO/FDIS 13003: Fibre reinforced plastic composites – determination of fatigue properties under cyclic loading

BS EN ISO 14125: Fibre-reinforced plastics composites – determination of flexural properties

BS EN ISO 14126: Fibre reinforced plastic composites – determination of the in-plane compression strength

ISO/DIS 14127. Composites – determination of resin, fibre and void content of composites reinforced with carbon fibre

BS EN ISO 14129: Fibre reinforced plastic composites – determination of the in-plane shear stress/shear strain, including the in-plane shear modulus and strength by the ±45° tension test method

BS EN ISO 14130: Fibre reinforced plastic composites – determination of apparent interlaminar shear strength by short-beam method

ISO 15024: standard test method for Mode I Interlaminar fracture toughness Gic of unidirectional fibre reinforced polymer matrix composites

ISO 15310: Fibre reinforced plastic composites – determination of in-plane shear modulus by plate twist

ISO DIS 18352: Test method for compression-after-impact properties of carbon fibre reinforced plastics.

Thermal analysis test methods

*I*SO 6721: Plastics – Determination of dynamic mechanical properties

ISO 11357: Plastics - Differential scanning calorimetry

Final Products –Test method and Product Standards

BS EN 40-7:2002 Lighting columns. Requirements for fibre reinforced polymer composite lighting columns.

BS EN 1013-2:1999 Light transmitting profiled plastics sheeting for single skin roofing. Specific requirements and test methods for sheets of glass fibre reinforced polyester resin (GRP).

BS EN 1115 Plastics piping systems for underground drainage and sewerage under pressure. Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP). General

BS EN 12445 Transportable gas cylinders. Fully wrapped composite cylinders

BS EN 12457 Transportable gas cylinders. Seamless, hoop-wrapped composite cylinders

BS EN 13280:2001 Specification for glass fibre reinforced cisterns of one-piece and sectional construction, for the storage, above ground, of cold water (replaces BS 7491 3 parts)

BS 4154:1985. Corrugated plastics translucent sheets from thermo-setting polyester resin (glass fibre reinforced).

BS 5480:1990. Specification for glass fibre reinforced plastics (GRP) pipes and fittings for water supply or sewerage.

ISO 7370. Glass fibre reinforced thermosetting plastics (GRP) pipes and fittings; nominal diameters, specified diameters and standard lengths.

ISO/FDIS 7432 Glass reinforced thermosetting plastics (GRP) pipes and fittings-test methods to prove the design of locked socket and spigot joints

BS 7491. Glass fibre reinforced plastics cisterns for cold water storage

ISO/DIS 7509 Plastics piping systems – glass reinforced thermosetting plastics (GRP) pipes – determination of time to failure under sustained internal pressure

ISO 7510. Plastics piping systems- glass reinforced plastics (GRP) components

ISO 7511. Plastics piping systems – glass reinforced thermosetting plastics (GRP) pipes and fittings – test methods to prove the leak tightness of the wall under short-term internal pressure.

ISO 7684. Plastics piping systems – glass reinforced thermosetting plastics (GRP) pipes – determination of the creep factor under dry conditions.

ISO 7685. Plastics piping systems - glass reinforced thermosetting plastics (GRP) pipes – determination of initial specific ring stiffness.

ISO/DIS 8483 Glass reinforced thermosetting plastics (GRP) pipes and fittings – test methods to prove the design of bolted flange joints.

ISO/DIS 8513. Plastics piping systems - glass reinforced thermosetting plastics (GRP) pipes – determination of initial longitudinal tensile properties.

ISO 8521 Plastics piping systems - glass reinforced thermosetting plastics (GRP) pipes – determination of the apparent initial circumferential tensile strength.

ISO/DIS 8533. glass reinforced thermosetting plastics (GRP) pipes and fittings – test methods to prove the design of cemented or wrapped joints.

ISO/DIS 8639. Glass reinforced thermosetting plastics (GRP) – test methods for leaktightness and resistance to damage of flexible and reduced-articulation joints.

ISO 10466. Plastics piping systems - glass reinforced thermosetting plastics (GRP) pipes – test method to prove the resistance to initial ring deflection.

ISO/DIS 10467. Plastics piping systems for pressure and non-pressure sewerage – glass reinforced thermosetting plastics (GRP) based on unsaturated polyester (UP) resin.

ISO/DIS 10468 plastics piping systems - glass reinforced thermosetting plastics (GRP) pipes – determination of the long-term specific creep stiffness under wet conditions and calculation of the wet creep factor.

ISO/DIS 10471. Plastics piping systems - glass reinforced thermosetting plastics (GRP) pipes – determination of the long-term ultimate bending strain and the long-term ultimate relative ring deflection under wet conditions.

ISO/DIS 10639. Plastics piping systems for water supply with or without pressure – glass reinforced plastics (GRP) based on unsaturated polyester (UP) resin.

ISO 10928. Plastics piping systems - glass reinforced thermosetting plastics (GRP) pipes and fittings – methods for regression analysis and their use.

ISO 10952. Plastics piping systems - glass reinforced thermosetting plastics (GRP) pipes and fittings – determination of the resistance to chemical attack from the inside of a section in a deflected condition

ISO 11119-1:2002. Gas cylinders of composite construction -- Specification and test methods -- Part 1: Hoop wrapped composite gas cylinders (available in English only)

ISO 11119-2:2002 Gas cylinders of composite construction -- Specification and test methods -- Part 2: Fully wrapped fibre reinforced composite gas cylinders with load-sharing metal liners (available in English only)

ISO 11119-3:2002 Gas cylinders of composite construction -- Specification and test methods -- Part 3: Fully wrapped fibre reinforced composite gas cylinders with non-load-sharing metallic or non-metallic liners

EN 13706: Fibre reinforced plastics – Specification for pultruded profiles

prEN 13923. Filament-wound GRP pressure vessels. Materials, design, manufacture and testing

ISO 14692:2002. Petroleum and natural gas industries - GRP piping (4 Parts)

ISO/DIS 14828. Plastics piping systems - glass reinforced thermosetting plastics (GRP) pipes – determination of the long-term specific ring relaxation stiffness under wet conditioned and calculation of the wet relaxation factor

Further information available from

www.npl.co.uk/cog/index.html www.materialssolutions.info
www.bsi-global.com www.iso.ch