

Fibre Reinforced Polymer Structures: Design Guidance or Guidance for Designers

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Status on Design Guidance – North America

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ASCE Manual No. 63 - 1984

Pultruded standard shapes:

Richard Chalmers – 2000 - promoted

Bruce Ellingwood - 2003 – structural reliability tools

ASCE/PIC of ACMA pre-standard project – **Load and Resistance Factor Design (LRFD) of Pultruded Fiber-Reinforced Polymer (FRP) Structures** - 2006-2010

Now with Fiber Composites and Polymers Standards Committee (ASCE) – from 2011 to date (35 ballots)

Code of Standard Practice for Fabrication and Installation of Pultruded FRP Structures ACMA - 2012

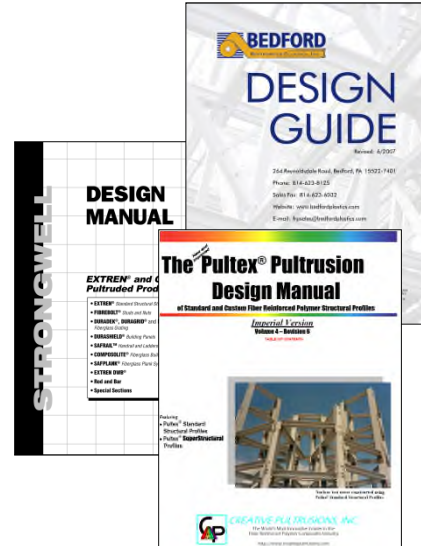


Status on Design Guidance – North America

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LRFD standard:

- Supported by pultruder's guidance
- Standard is a legal document if referenced by statute in the local building code
- Easier to market pultruded structures
- Competes better with conventional structural materials



Status on Design Guidance – Europe

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EUROCOMP – **Structural Design of Polymer Composites** - Design Code and Handbook - 1996 - 4 composite processing methods

Guide for the Design and Construction of Structures made of FRP Pultruded Elements, Advisory Committee on Technical Recommendations for Construction, National Research of Italy – 2007 – pultruded shapes

BÜV-Empfehlung - **Tragende Kunststoffbauteile im Bauwesen [TKB]** – Entwurf, Bemessung und Konstruktion - In German – 2014 - pultruded shapes and recognised



Ascione, L., Caron, J-F., Godonou, P., van IJselmuiden, K., Knippers, J., Mottram, T., Oppe, M., Gantriis Sorensen, M., Taby J. and Tromp, L., ***Prospect for New Guidance in the Design of FRP***, JRC Science and Policy Report, Policy Framework Existing Regulations and Standards, Prospect for CEN Guidance, European Commission, Joint Research Centre Institute for the Protection and Security of the Citizen, JRC99714, EUR 27666 EN, European Union, Luxembourg.- 2016 & 2017

BS EN 13706:2002. *Reinforced Plastic Composites - Specification for Pultruded Profiles*, British Standards Institution, London, UK, 2002.

CUR Commission C124, *Recommendation 96 Fibre-Reinforced Polymers in Civil Load Bearing Structures*, CUR Gouda, The Netherlands, 2003.

Design of FRP Bridges and Highway Structures, Design Manual for Roads and Bridges. Vol. 1 Highway Structures: Approval Procedures and General Design, Section 3 General Design, Part 17, Design Manual for Roads and Bridges, BD 90/05. The Highways Agency, Scottish Executive, Welsh Assembly Government (Llywodraeth Cynulliad Cymru), The Department for Regional Development Northern Ireland, (2005).

Preparing Standards – Why Long Time?

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My reasons are:

- rudimentary statistical data and rudimentary technical know-how; relatively short construction history
- continual development of new structural shapes and systems
- drafters working on design rules are not full-time - enthusiastic volunteers
- drafters need time to evaluate and analysis data/information, and to formulate rules that can be quantified and verified
- the biggest unknown is to have data/information for the state of FRP structures and FRP components at the end of their design working lives
- gaps in knowledge linked to the structural engineering of connections and joints and to the strengths and stiffnesses of sandwich panels
- engineering judgment' remains paramount - it takes years to assimilate knowledge and understanding, and to apply these appropriately with confidence and rigor

Preparing Standards – Why Long Time?

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Weaknesses with published research relevant to informing the preparation of design rules are:

- no clear definition of the domain of applicability of the work
- no critical review of previous research relevant to that domain
- test results that omit crucial data on properties of specimens
- test specimens with materials having strengths different to typical design strength
- theory that fails to allow for imperfections that can occur in practice

Weaknesses because of little historical precedence:

No official national or international design standard on which one can build valuable information and for template for the specification of targeted and beneficial Research and Development

Preparing Standards – Why Long Time?

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Catch 22: “to be able to write a codified standard (say for a Eurocode) the FRP R&D community needs (matured) practice to learn lessons from, and to have practice at this level we need the standard to overcome cost and an inherent reluctance to choose FRP as the structural material”

Preparing Standards – Resolutions

Publish online R&D reports that are detailed/complete not to have weaknesses – to prepare academics need RCUK funds

Use ASCE LRFD pre-standard and WG4 JRC Science and Policy Report as templates for research with added value for code writing

Expect a step change in practice when we have the ASCE LRFD standard

We need **Guidance for Designers** - Composites UK Construction Sector Group – **FRP Bridges – Guidance for Designers**, CIRIA in 2018

Preparing Standards – Gaps in Knowledge

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We need:

- mechanical properties of FRP materials and sandwich constructions that are appropriate and with statistical relevance – are there the coupon test standards to do this?
- test results for the strengths/stiffnesses of connections and joints having mechanical fasteners, adhesive bonding or a hybrid combination (details to correspond to what is designed and executed)
- to understand how to account for long-term durability effects; it is likely that for many years the best we can do is to have non-calibrated factors
- for SLS design rules to have information on the dynamic performance of FRP structures
- develop know-how for having other material components working structurally with FRP shapes or systems

Not in ACIC 2017 paper

Concluding Remarks

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It will be 20 years from conception to we have a recognised design standard for FRP structures, published by 2020

ASCE LRFD standard is limited to FRPs of standard pultruded shapes

Take a minimum of another 10 years to have an FRP Eurocode, one reason being that it scopes a number of composite material processing methods – Stage 2 is for a CEN Technical Specifications, by 2020(?)

We need reliable and relevant statistical data and/or technical information to inform the reliable formulation of specific design rules

A standard will provide the community with a template for executing targeted and beneficial R&D to inform further code development or refinement

In the meantime we must use state-of-the-art publications that have **Guidance for Designers**, such as *FRP bridges – Guidance for Designers* that the community in the UK has written

Slide show will be mounted on personal web-page for presentations

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