What should future design standards in the construction industry look like? The need for new value propositions

M. Angelino[*1,2], C. Taylor[1] and S.R. Denton[2]

[1] *University of Bristol, United Kingdom*
[2] *WSP Parsons Brinckerhoff, Bristol, United Kingdom*
[*] *Corresponding Author*

ABSTRACT Design standards play a fundamental role in the construction sector, in particular as a means by which the acceptability of designs can be verified and in enabling research outcomes to be translated for widespread practical application. Research has highlighted the need to address some usability issues with the structural design standards currently in use across Europe. Recognising the major changes that can be expected in the construction industry in coming years, it is worthwhile going beyond responding to these immediate issues and asking what future designs standards should look like to meet the emerging vision for the construction sector. From a study of the main changes affecting the construction industry and the current role of design standards and challenges in their development and use, the need for new value propositions for future design standards is established, particularly to meet needs, interests and capabilities of users of these documents. It is hoped that this paper will stimulate discussion, provide a better understanding of the research challenges in developing users-orientated design standards, and provoke interest among the research community to further explore this research area.

1 INTRODUCTION

Design standards occupy a key role in the construction industry. The scale of construction projects means that there are few opportunities to prototype designs, so design standards are used to verify the adequacy of designs to meet fundamental requirements for safety, serviceability, durability and robustness. Furthermore, design standards serve as a vital means for research outcomes to achieve widespread adoption within the sector and so provide a key means for the research community to achieve impact from their work. In recent years there has been an increasing interest in the role of standards in enabling or hindering the efficient delivery of construction projects in the UK (see Industry Standards Group report, 2012).

There exist some long-standing challenges in the development and use of design standards. For example, in 1970 it was observed that "*Like life in general our codes seem to get more and more complicated*" (IStructE, 2000). Forty years later, similar comments can still be heard in meetings and workshops with practicing structural engineers, clients and industry bodies. Despite such long-standing challenges and the impact of design standards on the working practices on many hundreds of thousands of structural engineers across Europe alone, research into design standards themselves and how they can best meet users' needs has been very limited (Angelino et al., 2014).

Set against this context, the construction industry is increasing recognising the potential of digital and smart technologies (building information modelling, automation, new sensor technologies, etc.), to positively impact how structures will be designed, built, managed, operated and dismantled. Recognising the major changes that can therefore be expected in the sector, it is worthwhile exploring what future designs standards should look like and the role they should play to meet this emerging vision for the future of construction.

The purpose of this paper is therefore to explore the potential need for new value propositions underpinning future design standards in the construction industry and to promote wider debate in an under-researched field. Literature review, open discussions, interviews and brainstorming sessions with practitioners, clients, industry bodies and standard writers, has been employed to explore this issue.

A "value proposition" is the statement of value that an organisation, product or service is going to deliver. It focuses on the value and benefits that will be experienced by customers. In the present context a "value proposition" therefore expresses key benefits which make design standards valuable to users.

2 THE CONSTRUCTION INDUSTRY

2.1 Why the construction industry places particular reliance on design standards

It is not rare to hear that the construction industry is considered different to other industries. Slaughter (1998) argued that constructed facilities differ from other manufacturing activities for (i) the physical scale of the components and the completed facility, which in turn do not allow full-scale prototypes, (ii) the complexity of facilities and the number of systems interacting with each other as well as with the environment, (iii) the longevity of use, (iv) the temporary alliance among independent organisations concentrated on a single specific project. In addition, construction is inherently a (v) site-specific project-based activity (Cox and Thompson, 1997), which is based on the (vi) coordination of specialised and differentiated tasks at the site level (Shirazi et al., 1996) (vii) often requiring local adjustment at the construction site (Dubois and Gadde, 2002). As a result, construction activities are (viii) discontinuous in their nature (Segerstedt and Olofsson, 2010). This in turn leads to discontinuity of demand for projects, (ix) uniqueness of each project in technical, financial and socio-political terms, and (x) complexity of each project in terms of the number of actors involved (Skaates et al., 2002). Vrijhoef et al. (2001) also argued that (xi) the actors involved in the design project organisation have no common and clear understanding of what should be designed. Lastly, Dubois and Gadde (2002) also note that (xii) the temporary nature of the construction project does not promote learning; consequently, the ability to form cognitive structures favouring learning is severely restricted. In addition, they argue that (xiii) too little effort appears to be devoted to transmitted knowledge and experience from one project to another and (xiv) learning takes place at an individual level rather than an industrial level. It can be argued that other fields may have similar features. However, the coexistence of all these aspects makes the construction industry *sui generis* and design standards so important (Angelino, 2016).

2.2 Changes in the construction industry

Advances in technology are transforming the way structures are designed, built, managed, operated and dismantled. Building information modelling, automation, crowd-sensing and crowd-sourcing, new sensor technologies, off-site construction, diagnostic tools and new materials are all changing civil and structural engineering. Based on interviews with industry leaders, Denton and Skinner (2014) identified eight key trends linked to advances in digital technology that are impacting the construction industry. These include how new ways of working will be unlocked, data will increasingly flow through and between projects, productivity will increase, and also that it is the opportunities associated with whole life asset management that offer the biggest prize for asset owners.

The vision for the UK construction sector in 2025 (HM Government, 2013) recognises the changes that the construction industry is going to face and the importance of adopting innovative technologies in sensors and data management to full understand assets performance. It is acknowledged that: "*This will result in smarter designs, requiring less material, reducing carbon and needing less labour for construction, whilst still ensuring full resilience of the assets*." Similarly, "The vision for civil engineering 2025" published by the American Society of Civil Engineers (2006) envisaged a future where the civil engineering enterprise is focused on fast-track development and deployment of technologies, which employ results from information technology and data management to significantly improve how facilities are designed, engineered, built, and maintained.

These changes would require design standards to evolve accordingly and defining clear value propositions would be helpful to support these changes.

3 DESIGN STANDARDS IN THE CONSTRUCTION INDUSTRY

3.1 Definition and scope

Generally speaking, standards are "*documents, established by consensus and approved by a recognised body, that provide for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context*" (ISO, 2004). In the construction industry a variety of standards exists, including standards for health and safety, quality management, environmental issues, codes of practice and management. Design standards are a specific sub-category. They are defined as technical documents that give provisions (i.e. statements, instructions, recommendations and requirements) to satisfy fundamental requirements of safety, serviceability, durability and robustness of both new and existing structures. For the purpose of this paper the term "design standards" refers to both design and assessment standards. Product, material, test and execution standards are outside the scope of this discussion.

3.2 Current role

Design standards play a key role in construction projects and are expected to serve a variety of purposes as summarised in Table 1. This table has been derived from literature, discussions with industry experts and clients, and workshops with practicing structural engineers. The list is not exhaustive, but demonstrates the inherent complexity in developing and using design standards, particularly due to the diverse and differing needs and expectations of the users of these documents. Having clear value propositions for future design standards would help preserve the core purposes of current design standards, as well as navigate these sometimes competing demands.

3.3 Challenges with current design standards

A number of challenges exist with current design standards. The following summary of issues is based on feedback from practicing engineers, clients and standards makers, derived from meetings, workshops and interviews. Developing specific value propositions would be helpful to recognise and address them.

Increases in technical requirements – In recent decades the construction sector has been affected by a tremendous increase in technical requirements developed by organizations acting at international, regional (European) and national level.

'Systems' of provisions – The cross-references among standards stemming from different normative sources can cause overlapping (and sometimes conflicting) requirements or gaps, which may increase the risk of misapplication. This also causes problems in accessibility and navigation.

Table 1. Purposes of design standards

1.	Assist competent designers in verifying structural adequacy (WP)
2.	Define and disseminate best practice (Shapiro, 1997)
3.	Reflect and shape the exercise of practitioner judgment (Shapiro, 1997)
4.	Codify and share technical knowledge taking account of practitioner judgment (Shapiro, 1997)
5.	Contribute to the delineation of an appropriate discretionary or judgement space for technological practice (Shapiro, 1997)
6.	Provide a common understanding regarding the design of structures between owners, operators and users, designers, contractors and product manufacturers (Roberts, 2010)
7.	Be a common basis for research and development in the construction industry (Roberts, 2010)
8.	Embody the most up-to-date research
9.	Provide a comprehensive system of provisions relevant to design (WP)
10.	Provide a concise system of provisions for design (WP)
11.	Enable economical design of structures (WP)
12.	Aid common design situations (WP)
13.	Enable innovative design (WP)
14.	Support sustainable design (WP)
15.	Be a practical knowledge base for structural design which can be trusted by industry (WP)
16.	Give technical provisions which enable to strike the right balance between design costs, construction costs and maintenance costs (OD)
17.	Increase the competitiveness of civil engineering firms, contractors, designers and product manufacturers in their global activities (Roberts, 2010)
18.	Provide a framework for achieving economies, efficiencies and interoperability (BSI)
19.	Provide technical contents which are consistent with the regulatory and legal framework they exist in (OD)
20.	Support public policy objectives (BSI)
21.	Ensure consistency in design approaches (OD)
22.	Handle uncertainty and risk (OD)

OD = Open discussion with industry experts and clients

WP = Workshop with practicing structural engineers

More complicated technical provisions – There has been an increasing call for practicing structural engineers to apply more complicated technical provisions in order to meet societal demands, achieve greater consistency of structural reliability, or enable better economy and/or sustainability.

Unduly prescriptive provisions – There seems to be a general perception that design standards are unduly prescriptive. Over-prescription can inhibit innovation and the efficiency of construction projects. A move towards performance-based (or outcome-based) standards has been advocated as beneficial by many voices. However, for design standards this is not straightforward. It requires the performance requirements to be clearly defined, which for construction projects are often complex, multi-layered and interdependent. It would also demand major changes in aspects of procurement and the transfer of risk (liability) between parties for long term asset performance.

Inconsistent use of standards – The UK Industry Standards Group (2012) recognised that "*inconsistent approaches to the application of technical standards lead to inefficient, bespoke solutions that block innovation, add to whole life costs and fail to deliver the required performance and service improvements*". Similarly, Wilson, Grose and Rawlings (2015) have acknowledged that "*inefficient and inconsistent use of codes and standards can hamper effective delivery of infrastructure projects*".

'Soft' issues – Standards are the product of a socially constructed, multi-stakeholders process aimed at defining agreed technical solutions between all those likely to be influenced by them. A variety of different stakeholders are involved in the standardisation process, including designers, regulators, industry bodies, clients, contractors, professional institutions, research organisations, universities, learned societies, educators, software producers and lawyers. Standardisation should be a transparent and open process of cooperation; however, some authors suggest that this is not always the case. For instance, Weiss (1991) suggested that, while the stated goal of developing a standard may be adopted by most of the committee members, other – secondary – goals may also exist and may be in conflict. Allen (1992) argues that different stakeholders may have competing views and they might contribute negatively to the standardisation process, thus affecting the usability of standards and their success. Nethercot (2012) highlights the tensions that exist between the aspirations of practitioners for greater economy, simplicity and all-embracing provisions and the desire of the research community for technically advanced provisions; the latter can become an "*exercise in vanity rather than the guarantee of intellectual rigour*". The risk is that the standardisation process can become "*a political or economic power game although the topics discussed are mostly of a purely technical nature*" (Takahashi and Tojo, 1993).

Limited focus on users' needs - There is an urgent call to have more users-orientated design standards. However, research into how design standards can best meet users' needs appears to be very limited. The importance of considering users and how they use standards has been explicitly acknowledged at European level in the work on the second generation of Structural Eurocodes, where a major focus will be on improving their usability (CEN/TC 250, 2015). Likewise, in the US the purpose of the recent review of the ACI 318 Building Code has been "*to provide a more user-friendly backbone for design*" (Poston & Dolan, 2012). Similarly, a consultation has been recently carried out to explore the view of different stakeholders on how usability, structure and content of the DMRB should be improved (CIHT website, 2015).

Tensions – Some inherent tensions exist in the development of design standards. The recognition of tensions is longstanding, as demonstrated by the comments to the debates held at the Institution of Civil Engineers and the Institution of Structural Engineers in the early 1980s stemming from the question "*How should rules of structural design be codified?*" formulated by Moffatt and Dowling (1981) and from the statement "*Simple codes can stifle structural technology*" proposed by Sunley and Taylor (1982). Examples of tensions include:

- the need to avoid technical provisions that are unduly complex, whilst also not inhibiting experts from applying their knowledge and deploying advanced method of analysis;
- the attractiveness of stability versus the drive for the introduction of new approaches;
- the aspiration to address all users' needs whilst not making the standard more complex;

- the aspiration not to inhibit innovation, yet also provide clear provisions for common design situations and also help ensure long term performance and appropriate whole life cost.

4 VALUE PROPOSITIONS FOR DESIGN STANDARDS

The previous sections suggest the need to define clear value propositions for future design standards. As far as the authors are aware, the first explicit attempt to define value propositions for design standards in the construction industry has been made at European level for the development of the second generation of Structural Eurocodes. The ambition of the European Committee responsible for the development and maintenance of the Structural Eurocodes (CEN/TC 250) is "*to create a more user-orientated suite of design standards that are recognised as the most trusted and preferred in the world*". To attain this vision, one of the guidelines explicitly recognised the importance of identifying the main categories of users and a primary audience to target drafting efforts. For each of these categories specific statements of intent to meet their needs have been developed and unanimously agreed (CEN/TC 250, 2015).

Recognising this need for clear value propositions guiding future design standards and building upon the success of this European work, what extra factors should we bring to our thinking about standards to develop future design standards without extending their scope significantly?

Anderson et al. (2006) recognise that developing an effective value proposition requires a detailed understanding of the customer's requirements, preferences and – most importantly – of their priorities to avoid the pitfalls of the pure "benefits assertion" and "value presumption", and to deliver the greatest value to target customers. The value propositions for future design standards should: (i) retain and reinforce the core accomplishments and successes of current design standards; (ii) embrace currently recognised needs and overcome current challenges in developing and using design standards; (iii) take account of future changes anticipated in the construction industry.

It is not the aim of this paper to provide definitive value propositions, rather to provide themes that could potentially underpin the value propositions for design standards. These themes have been presented below in three groups.

Themes for established value propositions of design standards (existing core accomplishments)

1. **Ensure safety, serviceability, durability and robustness whilst providing economy**
2. **Assist competent designers in verifying structural adequacy**
3. **Codify and share technical knowledge**
4. **Ensure consistency in design approaches**

Themes for value propositions of design standards to address current recognised needs and challenges

5. **Support users' ability to form cognitive structures favouring critical application of design standards and learning**
6. **Improve clarity and understandability**
7. **Improve accessibility and ease of navigation**
8. **Provide appropriate freedom for innovation**

Themes for value propositions of future design standards to support expected changes in the construction sector

9. **Better enable performance data from monitoring to inform the design of structural modifications or rehabilitation schemes**
10. **Better enable structural verifications to be incorporated into digital models**
11. **Adapt the format of design standards to be better suited to digital working and able to be updated more rapidly**
12. **Present design assisted by testing more extensively, supporting innovation in modularisation and off site manufacture**

5 CONCLUSIONS

The construction industry is undergoing some profound changes. Digital and smart technologies are increasingly transforming the way structures are designed, built, managed, operated and dismantled. Coupled with that, future assets are expected to be more resilient, sustainable and adaptable.

Design and assessment standards play a key role in construction projects and will continue to do so. However, from discussions, interviews and brainstorming sessions with practitioners, clients, industry bodies and standard writers, it emerged that current design standards could perform better.

To guide the necessary evolution, the authors argue that defining clear value propositions would be helpful. These express key benefits, which make design standards valuable to users. It is proposed that these value propositions should not only address issues and needs that have already been recognised, but should also consider the profound changes that can be expected in the construction sector.

In an effort to stimulate debate, twelve themes that could potentially underpin future design standards have been proposed. These have been derived by drawing together themes for established value propositions of design standards, those responding to known challenges for design standards and those relevant to a future and 'smarter' construction industry.

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