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Timber structures — Review of design standards

Structures en bois — Revue des normes de calculs

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC 165, *Timber structures.*

Introduction

In the 1980s ISO Technical Committee 165 prepared and circulated a draft International Standard based on a Structural Timber Design Code that was put together by a Working Group of CIB (International Council for Building Research Studies and Documentation). The stated purpose of the ISO/TC 165 draft and the CIB code was to "provide an agreed background for the national committees and international bodies responsible for formulating timber design standards, to ensure a reasonable and consistent quality of timber structures." Neither document included safety factors, partial coefficients, or loads, since they were considered to be the responsibility of national authorities.

Engineering material design standards demonstrate compliance with the structural requirements of building codes; therefore, they have a special relationship to national codes and related legal considerations and are even called "codes" in many places. Design standards provide regulatory bodies with information needed to protect public safety.

The standards also provide a mechanism for adopting advances in structural modelling, material behaviour science, reliability and other subjects. They are vehicles for introducing research into practice. They are also a means for receiving feedback and modifying design requirements based on practical experiences.

Beyond this, design standards also create a framework for specifications of construction products. This provides a context for recognition and approval of structural initiatives using referenced products.

In 2006 ISO/TC 165 prepared a business plan that identified "standards to support harmonization of design and building codes internationally" as a Committee priority. Around the same time, an ISO/TC 165 Framework document included design requirements on the list of work areas, although it did not specify what those requirements might include.

ISO/TC 165, at its 25th meeting in 2011, reviewed a report on current national design standards for timber and international design standards for other construction materials. The committee concluded that, at this time, there was not sufficient interest to undertake development of a structural timber design standard. However, the information provided was deemed to be a valuable resource that should be formally retained for use by ISO/TC 165 and member bodies in future development of timber design standards.

Timber structures — Review of design standards

1 Scope

This Technical Report documents the findings of a review of design standards undertaken by ISO/TC 165 to assess how an ISO International Standard for the design of timber structures might be developed and whether development of such an International Standard should be initiated.

NOTE Annex A summarizes the factors considered and the activity of the TC leading to the preparation of this Technical Report.

2 Current and draft ISO design standards

The five structural design standards and technical reports shown in the following table are published ISO structural design documents. They provide a selection of different approaches for review to help understand what is involved in preparing an international design standard and what the end product might look like.

Designation	Title
ISO/TR 11069:1995	*Aluminium structures — Material and design — Ultimate limit state under static loading*
ISO 10721-1:1997	*Steel structures — Part 1: Materials and design*
ISO 9652-2:2000	*Masonry — Part 2: Unreinforced masonry design by simple rules*
ISO 15673:2005	*Guidelines for the simplified design of structural reinforced concrete for buildings* (ISO/TC 71)
ISO 22156:2004	*Bamboo — Structural Design* (ISO/TC 165)

2.1 Basis for design

All structural design standards are based on a design philosophy that defines the relationship between load requirements and material resistances. International standard committees make basic choices on ground rules, leading to different design approaches in these standards.

Most of the reviewed ISO documents are established in Limit States Design format. It is instructive to see how the limit states are defined in each document, influenced to some extent by material-specific considerations. Limit States Design format also includes partial coefficients in the calculation of loading and resistance, and these factors are handled differently (or are unspecified) in the documents.

Although quantified reliability is implied by Limit States Design philosophy, none of the documents quantify reliability targets or indices. The overall view is that the subject is too dependent on regional conditions and applications to be defined in an international standard and so is left to the discretion of the adopting country or region.

Serviceability Limit States are even more dependent on regional cases and conditions than Strength or Ultimate Limit States, and are largely left out of these documents.

Annex B of this report provides a short summary for the reviewed documents.

2.2 Scope and limitations

In each of the reviewed ISO documents, the scope and limitations give an indication of intended purpose and audience. Since the general aim of material design standards is to facilitate engineering design of structures, the target audience is taken to be the professional community qualified in this practice.

In some cases, the scope of a standard is limited to make the task more manageable, or to make room for design aids such as rules-of-thumb or other tools for the purpose of design simplification. Simplification can be a particular priority where the primary audience is very diverse or is located in countries that do not have existing national standards for the purpose at hand.

It should be noted, however, that simplifying assumptions or design aids do not necessarily result in “simple” standards. There is always a need for professional engineering knowledge and interpretation of design requirements. In other words, scope limitations do not necessarily diminish the need for complete structural design.

In some cases, the limitations may be defined in terms of the geometry or layout of structures; in other cases, limitations are defined by the extent or application of design requirements (see Annex B for examples).

2.3 Standard or guide

Some of the ISO documents under review are written to guide as well as to standardize design requirements. Some put more emphasis on the guidance, others on the normative function.

Design shortcuts are provided in some cases where a more comprehensive design procedure would result in smaller sections. This is generally the role of a handbook or guide rather than a Standard; however, in the case of an international standard, there may be no handbook or guide to consult. Design shortcuts are included to simplify or facilitate the presentation, or to ensure that a requirement is not overlooked or misinterpreted.

Terminology used in the documents to express mandatory or non-mandatory actions can provide a clue as to which provisions are intended to “advise” or “guide” practice rather than “regulate” it. From an implementation standpoint, standards written in mandatory language with specific quantifiable requirements are easier to enforce. But this is difficult to achieve in a standard that is intended to be applied across national boundaries (see Annex B for examples).

2.4 Rules-based or engineered approach

The reviewed ISO documents, like most material design standards, are intended for use by engineers and are typically formulated on the basis of principles and assumptions that lead to calculated design solutions.

Prescriptive rules-based standards, on the other hand, are sometimes written for a non-engineering audience and are formulated to be carried out without further structural analysis or calculations. In the process, rules-based standards can yield more conservative solutions than would result from a fully engineered approach. Also, rules-based approaches are limited in applicability due to assumptions that don’t fit all cases.

From time to time, a rules-based engineering standard is developed for one of a number of reasons, such as: a) to illustrate a particular type of structural design problem and solution, b) to provide a readily-enforceable document for building regulators, or c) to provide a baseline for acceptable solutions.

Most standards combine elements of prescriptive and performance-based standards writing, and some include provision for interpolating or extrapolating beyond the scope of rules-based provisions. Standards can be placed on a scale ranging from fully-engineered to rules-based provisions (see Annex B for examples).

2.5 Material specifications

Before a product can be utilized in design, it must be clearly defined and the structural performance characteristics of the product defined. Product definition is generally done through material specifications and performance characteristics established by testing and evaluation protocols.

Design standards provide a framework for referencing standards for construction products because it is preferable to make normative references to specification or testing standards for this purpose. International standards have special challenges in this area.

Although ISO material specification and testing standards are referenced where available, the general trend in the reviewed documents seems to be to recognize that national material standards are at least as likely to be used and are referenced as well. This is done even though the specifications and the related properties may be based on standard dimensions and grade qualities that may not be recognized in all countries (see Annex B).

A further complication is the number of proprietary structural products that have emerged in recent years. Proprietary products can play a significant role in current design practice, which can vary regionally and over time. Generally such products have not been addressed specifically in the reviewed ISO standards.

Unless the design standard is to become an omnibus standard addressing many different subjects, it is preferable to have a separate referenceable standard to deal with basic material properties and the development of characteristic values. This helps to relieve the design standard from the need to address many material specification issues.

2.6 Load provisions

Load requirements are the domain of national building codes and standards, and it seems counterproductive for an international ISO design standard to specify load provisions incompatible with those that are already in use in interested countries. Complete load requirements include the factors or coefficients that are used to calculate load actions, as well as parameters or references for specified loads.

Nevertheless, some aspects of load requirements are inseparable from the design provisions in these standards. Examples include the limitations to application of a standard, load interaction effects. In the case of timber or timber-based products, there is also the special duration of load effect that ties load and resistance effects together.

Lateral load design complicates design standards significantly, and some standards avoid the topic entirely. Others provide partial lateral load design requirements (Annex B).

The ISO TC responsible for Bases of Design, TC 98, has developed a number of load standards, some of which are referenced in the design standards as listed below.

ISO 15673 (concrete) references:

ISO 4354, *Wind actions on structures*

ISO 2103, *Loads due to use and occupancy in residential and public buildings*

ISO 2633, *Determination of imposed floor loads in production buildings and warehouses*

ISO 3010, *Basis for design of structures — Seismic actions on structures*

ISO 4355, *Bases for design of structures — Determination of snow loads on roofs*

ISO/TR 11069 (aluminium) references:

ISO 2394, *General principles on reliability for structures*

ISO 3898, *Bases for design of structures — Notations — General symbols*

ISO 8930, *General principles on reliability for structures — List of equivalent terms*

ISO 10721-1 (steel) references:

ISO 2394, *General principles on reliability of structures*

ISO 3898, *Bases for design of structures — Notations — General symbols*

2.7 Assemblies or components

Most of the reviewed ISO documents address structural members and typical connections, focusing on the most basic and generally applicable design cases. The material behaviour formulae are based on generally accepted models, and some of these are specific to material types and connections. In general, the standards do not address more complex structural assemblies or components.

Connection design can be quite involved and complicates even a limited-scope standard. Today's practice also includes proprietary types of connections and designs, which have not been included specifically in the reviewed documents.

Although a few of the standards address specific types of applications, or assembly design procedures, none of them go into detail (Annex B).

2.8 Construction practice

The reviewed ISO documents include general comments on construction and workmanship, without going into much detail. Construction practice requirements are not always included in national design standards, and it is even more difficult to develop construction requirements that would be applicable across different countries or regions.

In some cases, the reviewed standards refer to other documents that cover construction and fabrication details (Annex B).

2.9 Commentary

The reviewed ISO documents include varying amounts of commentary, ranging from very little to more than half of the document. In general, commentary is an important part of any structural design standard because the user needs to understand the principles behind the requirements, and standards are written to be enforceable rather than easy to understand. In the case of an international standard, however, the need for commentary may be overlooked (Annex B).

2.10 Relationship of the draft laminated bamboo structural design standard

The Draft design code for laminated bamboo submitted by INBAR in 2010 is in most cases identical to the existing bamboo standard (ISO 22156). A few differences of note in the laminated bamboo draft are as follows:

- Terms and definitions are added for glubam, plybamboo and lamination joint.
- Design by "concepts based otherwise" are permitted in lieu of calculations, as in the bamboo standard, although design based on "experience from appropriate timber construction requirements" has been substituted for design based on "previous generations."
- The formula for calculating characteristic values from test data are retained, with the suggestion that a smaller sample size is possible for glubam.
- The factor of safety and duration of load factors are retained, including the same assumption about standard deviation.
- The design assumptions have been amended with respect to joints, initial curvature in shape, and shear stresses.
- A new section on "shear walls," defined as panels formed with framing elements and sheathing panels, has been added.

3 Adoption or use of these design standards

As discussed in the Introduction, a draft International Standard (designated N95) was prepared in the 1980s based on the CIB Structural Timber Design Code. The CIB document received input from both ISO and CIB committees, and a revised version was eventually adopted as the European Structural Timber Code (Eurocode 5). Later in the 1990s, ISO TC 165 agreed that work on the draft (N95) should be suspended until Eurocode 5 was finished. No further activity has been recorded.

The most recent "systematic review" of current ISO material design standards resulted in two positive responses on the question of whether they had been adopted: Austria for ISO/TR 11069 (aluminium) and Colombia for ISO 15673 (concrete). A few of the other countries indicated that they made use of one or more of the design standards in some way, without adoption.

In the ballot responses, there were a few comments coming mainly from European countries, indicating lack of interest at the national level or suggesting the standards be modelled after Eurocodes. A lengthy comment from Germany noted the intensive effort required by Eurocodes to reconcile national differences, and indicated that ISO work had been put on "standby" due to priorities. This comment went on to say: "Now this work is complete and it is time to think about the next step in the internationalization of masonry construction and about applying the experience gathered by others. It is also an opportunity to streamline the work on and for masonry and its worldwide application."

4 Relationship to selected national timber standards

The next step is to compare and contrast the nature of some current national timber design standards in the same terms that have been discussed for the ISO standards. The timber design documents shown in the following table are all long-established standards that have been adopted and used widely in design practice. These standards are referred to here as "national" standards even though the Eurocodes are applied beyond national boundaries.

Reference	Designation	Title
NDS	ANSI/AF&PA NDS (2005)	National Design Specification for Wood Construction ASD/LRFD
CSA O86	CSA O86-09 (2009)	Engineering Design in Wood
EC 5	Eurocode 5 (EN 1995-1-1:2004+A1)	Design of Timber Structures, Part 1-1: General, Common rules and rules for buildings

4.1 Basis for design

All of the above timber design standards include Limit States Design (or Load and Resistance Factored Design) requirements. The NDS also provides design requirements in Working Stress Design (or Allowable Stress Design) format, which is more commonly used in the US.

Target reliabilities and partial coefficients for loading and resistance in these standards are different, since they are determined by code bodies in various countries and are influenced by other engineering materials besides timber. The Foreword to Eurocode 5 notes that the same partial coefficients and reliability parameters have to be assigned when the standard is used as a base document by other TCs. CSA O86 states that any load requirements other than those given in the standard would necessitate review of the appropriateness of applicable factored resistance values. The NDS refers to the applicable building code or, in the absence of a governing code, the ASCE standard on minimum design loads.

Serviceability limit states are also very important for timber design, perhaps more than for other structural materials, and are treated in detail in these standards. EC 5 addresses serviceability criteria for beam deflection, floor vibration and joint slip; CSA O86 addresses beam deflection and floor vibration; NDS addresses beam deflection. Details of deflection provisions are significantly different in the three standards, although the overall goal of preventing unacceptable deformation is the same.

4.2 Scope and limitations

All of the national timber standards are designed to address fully engineered structures, regardless of occupancy or size. In general, the scope of these standards is not limited for purpose of design simplification, since there are many design tools like handbooks and software to aid in interpreting and applying the design requirements of each standard. Where limitations are imposed, they are typically related to material properties or environmental conditions.

In addition to purely structural concerns, the standards include some provisions for durability and fire resistance. While not the main subject of the standards, selected requirements have been included in recognition that structural integrity can be impacted by these issues. EC 5 has a separate section (1995-1-2) for structural fire design, and the NDS has a section on design procedures for exposed timber members.

From time to time, some timber committees have considered the possibility of creating a “two-level” standard: one level for a novice or occasional timber designer, and a higher level for an experienced timber designer. The typical reason for this suggestion is that novice designers find some aspects too complicated or unfamiliar for occasional use. A two-level approach could facilitate design at the basic or lower level, while enabling selection of smaller sections at the higher level. Although this is an appealing idea, it has not been acted upon at the national level, primarily because enforcement requires a single level of regulation.

4.3 Standard or guide

All of the listed timber documents are written to be enforced as regulatory standards, i.e. they are written in mandatory language with specific quantifiable requirements, and guidance is reserved for notes or informative appendices.

The Foreword to EC 5 identifies specific clauses where alterations may need to be made by a country in adopting the standard. Some of these clauses include: assignment of loads to load-duration classes, assignment of structures to service classes, and partial factors for material properties. This provision for national choice is a version of the “boxed” value concept noted earlier in some ISO standards.

Other more limited types of timber standards have been produced to address specific applications and are written more like a guide. Examples were reviewed in ISO/TR 12910. They are based on the parent engineering design standards and supplemented with selection tables and graphics to facilitate understanding and implementation for specific design cases.

The success of a guide document depends on a clear definition of the specific design application and the intended audience.

4.4 Rules-based or engineered approach

All of the national timber design standards are formulated as engineering documents rather than rules-based or prescriptive documents. On the other hand, light-frame construction standards are typically written as prescriptive documents.

This division between engineered and light-frame timber construction design arises partly from building code policy allowing relaxation of full engineering design in view of performance history and reduced consequences of failure, and/or other considerations for small buildings. Some examples are noted in ISO/TR 12910. Although an accepted tradition within countries, it is difficult to extrapolate beyond national boundaries since it depends on conditions and knowledge located at home.

4.5 Material specifications

Materials are specified in national timber design standards in accordance with product and test standards, grading rules and other specifications of the host country or region. Beyond these specific references, the design standards provide a framework for technical specifications of products. This is more difficult to achieve at the international level.

In addition to generic timber and panel products, the reviewed design standards also cover proprietary products to some extent, recognizing the important role played by these products in current construction practice. CSA O86 includes a section on Proprietary Structural Wood Products which addresses ground rules for determining material resistances. The NDS includes sections on Prefabricated Wood I-joists and Structural Composite Lumber, covering design values, adjustments and special design considerations. EC 5 includes a section on Laminated Veneer Lumber covering design adjustments and considerations.

Partial coefficients for material resistance are handled somewhat differently in North American and European standards. For one thing, North American standards multiply strength values by reduction factors of less than 1,0 while Eurocodes divide by material partial factors greater than 1,0. More importantly, the NA factors vary by property and are the same for all "wood-based" products, whereas the EC factors vary by product type and are the same for all properties (see table).

Material resistance property	CSA O86	EC 5 (timber)	NDS
Bending	0,90	1/1,3	0,85
Tension parallel	0,90	1/1,3	0,80
Compression parallel	0,80	1/1,3	0,90
Compression perpendicular	0,80	1/1,3	0,90
Horizontal shear	0,90	1/1,3	0,75
Connections	0,60-0,80	1/1,3	0,65

It is likely that the scope of products under the "wood-based" umbrella will continue to grow in the future. There will be a need to demonstrate that new products can be specified and characterized using traditional parameters.

4.6 Load provisions

The reviewed timber design standards are formulated to work with partial load coefficients and load combination factors applicable in their countries or regions. These effects are largely beyond the control of the design committees, being influenced by other materials and building code considerations.

Timber design straddles the gap between load and resistance, i.e. "duration of load" (DOL) effects. DOL is handled differently in these timber standards (see table). In the EC 5 approach, DOL is inseparable from product type and service class (SC1 to SC3). In the NDS, the ASD approach differs somewhat from the LRFD (time effect) approach.

Load type (alone or in combination)	CSA O86[a]	EC 5 (timber)		NDS	
		SC1	SC3	ASD[a]	LRFD
Permanent/Long term	0,52	0,6	0,5	0,56	0,6
Standard/Long term (or ten years)	0,8	0,7	0,55	0,63	0,8
Standard/Medium term[b] (or two months)	0,8	0,8	0,65	0,72	0,8
Short term (or seven days)	0,92	0,9	0,7	0,78	1,0
Instantaneous (or ten minutes)	0,92	1,1	0,9	1,0[c]	1,.0

[a] ASD values divided by 1,6 to make them comparable with other values in table. CSA values multiplied by 0,8 to make them comparable with other values in table.

[b] The 2nd Standard or Medium term corresponds to snow load duration (the 1st corresponds to occupancy live load duration).

[c] The ASD values allow a further increase (25 %) for impact loading.

As the family of "wood-based" products continues to grow, it carries forward the need to demonstrate that new product types can be characterized using the same DOL adjustment factors as traditional timber products.

4.7 Assemblies or components

For single member design, the basic approach is much the same in the timber standards for bending, tension and compression parallel to grain properties, despite some minor differences. There are greater differences in the way horizontal shear and compression perpendicular to grain properties are handled in the three standards. Some modification values, such as system or repetitive member increase factors, are also different in the three standards.

Nearly half of the content of the timber standards is devoted to connection and assembly topics. This is an indication of how important and complex those subjects are. It is also an indication of how difficult it is to develop a “simple” timber design standard.

All of the standards have adopted a design procedure for metal dowel resistance based on the same basic “yield theory” model for ductile yielding. Nevertheless, each standard has implemented the theory differently and has different requirements to address the brittle failure of these same connections.

Design procedures for other types of connections, ranging from nails to split-ring and shear-plate connectors, are also implemented differently in these standards. Modification factors, such as for service conditions, are also different (see table).

Service conditions/classes (approximate comparison for dowel-type connections)	CSA O86	EC 5 (timber) Long term[a]	EC 5 (timber) Short term[a]	NDS
Dry (or SC1)	1,0 (or 0,4)[b]	0,7	0,9	1,0 (or 0,4)[b]
Intermediate (or SC2)	—	0,7	0,9	—
Wet (or SC3)	0,67	0,55	0,7	0,7

[a] The EC 5 service class factor is dependent on load duration classification. Also, the service classes do not necessarily relate specifically to the “dry” or “wet” conditions used in North American standards.

[b] The 0,4 factor applies in cases where unseasoned timber is used for joints in dry conditions; however, higher values can be used in specific joint configurations.

4.8 Construction practice

The NDS includes a non-mandatory Appendix A on Construction and Design Practices, covering basic topics of erection, bracing and lateral support, and dimensional changes. EC 5 has a Section 10 on Structural Detailing and Control. Detailed construction, fabrication and erection provisions, however, are beyond the scope of these design standards. CSA O86 includes a general section that covers structural integrity, basis of design, quality of work and design drawings.

4.9 Commentary

There are commentary documents for each of these standards. The NDS Commentary is published by the American Wood Council. The CSA O86 Commentary is published by the Canadian Wood Council. The Eurocodes include commentary and worked examples from various sources.

5 Considerations for an ISO/TC 165 design document

In the Introduction, several functions of a structural design standard were identified with a note that the standards have an ongoing role in moderating between practice and research. This is why structural design committees are standing committees tasked with updating their standards on a regular basis.

Another desired objective for a design standard committee is to have a “balanced matrix” of membership: users—producers—regulators—general interest groups. The rationale for balance is not just to protect against dominance of any one group, but to actively engage each stakeholder group in the development of the standard. This helps to ensure that the standard will serve the needs of the entire design and construction community.

The TC should consider whether it is appropriately structured to develop and maintain a structural design standard. This might include consideration of a special working group to look after such a standard, and it might involve recruiting other participants to help carry out the work. It might also involve setting up liaison with other committees.

Beyond the procedural issues, it would be desirable for the TC to identify a potential rationale for getting involved in a design-related standard or technical report, before considering options for moving forward. Some possible reasons that have been suggested are as follows:

- to grow awareness of design requirements,
- to seek greater compatibility among national standards,
- to build consensus on design methods,
- to promote state-of-the-art design methods,
- to streamline existing design procedures.

It should be noted that a design standard may not fulfill all, or any, of these objectives, and that resistance to adoption is a significant hurdle to overcome. The TC needs to consider whether it is appropriate to undertake this level of challenge and responsibility.

Another key consideration is how the material specifications are to be referenced. If provision can be included for utilizing national, regional and/or proprietary product specifications, there will be a greater liklihood of an ISO design document being used as a framework at the national level.

6 Conclusions

At the September 2011 discussion of this review, the TC chose not to proceed with any particular design standard initiative. It was suggested that the best fit, were an initiative to be undertaken in the future, would be a standard addressing a selected type of member(s) or connection(s) focusing on the underlying analysis and design methodology. The goal of this option would be to build consensus on design methods, as well as to grow awareness and seek greater compatibility, and to lay out the engineering principles rather than exact numerical solutions.

The following four elements should be included early in the decision-making process for the initiation of a work item for a Timber Design standard.

a) Rationale and commitment to developing a structural design document,

b) Selection of an intended target audience and purpose for the standard,

c) Decision on structure of committee for maintaining the document, and

d) Selection of an option for type of document.

If ISO/TC 165 decides at some future time to move forward with a design standard initiative, it would be preferable to model a standard on a basic template for a structural design standard rather than on an existing timber design standard. An example of such a template can be found in the contents listing of a handbook such as the Wood Design Manual published by the Canadian Wood Council (see Annex C).

It should also be remembered that the ISO strategic plan emphasized the need to “review the procedure for New Work Items to better identify when the deliverable may be developed and promoted for use in a regulatory context, and to adjust its development accordingly.”

Even if an international timber design standard is not adopted by a country or region, it may accomplish other objectives such as education. But the need for a commentary should be considered as part of the decision process because a standard may not be sufficient to raise awareness and result in improved design methods. Perhaps it will need to be accompanied by a commentary to accomplish these goals.

In addition, it may be appropriate to use a boxed value or similar method to highlight specific provisions or parameters that require special attention before the standard should be adopted.

7 References

A. ISO standards and draft standards

ISO N95 (1985), *Timber Structures — Design* (ISO/TC 165, draft)

ISO/TR 11069:1995, *Aluminium structures — Material and design — Ultimate limit state under static loading* (ISO/TC 167) (including Technical Corrigendum 1:1996)

ISO 10721-1:1997, *Steel structures — Part 1: Materials and design* (ISO/TC 167)

ISO 9652-2:2000, *Masonry — Part 2: Unreinforced masonry design by simple rules* (ISO/TC 179)

ISO 22156:2004, *Bamboo — Structural design* (ISO/TC 165)

ISO 15673:2005, *Guidelines for the simplified design of structural reinforced concrete for buildings* (ISO/TC 71)

NXXX (2010), *Laminated bamboo structural design* (Y Xiao, draft)

ISO 4354:2009, *Wind actions on structures*

ISO 2103:1986, *Loads due to use and occupancy in residential and public buildings*

ISO 2633:1974, *Determination of imposed floor loads in production buildings and warehouses*

ISO 3010, 2001, *Basis for design of structures — Seismic actions on structures*

ISO 4355, 1998, *Bases for design of structures — Determination of snow loads on roofs*

ISO 2394:1986, *General principles on reliability for structures*

ISO 3898:1987, *Bases for design of structures — Notations — General symbols*

ISO 8930:1987, *General principles on reliability for structures — List of equivalent terms*

ISO 3898:1987, *Bases for design of structures — Notations — General symbols*

B. ISO/TC 165 Reports and documents

N449 (2006), *Business Plan of ISO/TC 165* (secretariat)

TC 165 AG Mtg (2007), *Overview of ISO/TC 165 and CEN/TC 24 Standards and Projects* (secretariat)

N644 (2009), *ISO Technical Programme Manager Presentation to TC 165* (A Rossi)

N620 (2009), *Draft Potential Framework for ISO TC 165 Standards* (C Wilson)

N680 (2010), *Report of 24th meeting of ISO TC 165* (secretariat)

ISO Focus (2010), *Timber Structures: Building on Solid Standards* (E Karacabeyli)

ISO/TR 12910:2010, *Light-frame timber construction — Comparison of four national design documents* (ISO/TC 165)

C. Timber standards

CIB-W18 (1980), *Structural Timber Design Code* (5th Edition)

ANSI/AF&PA NDS (2005), *National Design Specification for Wood Construction ASD/LRFD*

CSA O86-09 (2009), *Engineering Design in Wood*

Eurocode 5 (EN 1995-1-1:2004+A1), *Design of Timber Structures, Part 1-1: General, Common rules and rules for buildings*

D. Other documents

ISO Strategies (2004), *ISO Strategic Plan 2005-2010* (ISO)

ISO TMB N 84 (2008), *Status report on international activity on design of structures*

Annex A
(informative)

Factors, issues and options considered by ISO/TC 165

A.1 ISO perspectives

A number of ISO and ISO/TC 165 strategy papers and reports have touched on the question of whether or how to address structural design and related topics in International Standards. The following are more recent instances (from 2005 to the present) of these reports, summarized to provide background to this review.

A.2 ISO strategic plan

The ISO strategic plan for 2005-2010 puts forward a global vision and seven strategic objectives for ISO International Standards and deliverables. The vision is defined as "facilitation of global trade; improvement of quality, safety, security, environmental and consumer protection, as well as the rational use of natural resources; and global dissemination of technologies and good practices."

One of the seven objectives relates to the use of voluntary standards as an alternative or as a support to technical regulations. Among actions suggested to accomplish this objective is to "review the procedure for New Work Items to better identify when the deliverable may be developed and promoted for use in a regulatory context, and to adjust its development accordingly."

The purpose of this review is to examine this question in relationship to a structural timber design standard.

A.3 ISO/TC 165 business plan

A draft business plan was prepared for ISO/TC 165 in 2006. The business plan listed the committee priorities as follows:

- Development of product, classification, testing, and performance standards to support harmonization of design and building codes internationally.
- Facilitation of the global adoption of international standards governing the use of timber in structural applications.
- International cooperation in the development and expansion of the use of structural timber products and systems.

Benefits expected from the work of the Committee identified in Section 3 of the plan included the following:

- Adoption of uniform test methods to… facilitate international exchange… and eliminate costly duplication of testing for regulatory recognition of imported materials.
- Adoption of a uniform basis for the classification of design properties… to provide a mechanism for the international utilization of design information.
- Identification of unified approaches to the evolution of design philosophy and the establishment of a common basis for design of timber structures to increase the cost-effective utilization of timber products and facilitate international trade.

Although this implies significant activity in the area of structural design, there has been little activity in that area. Section 5.2 of the plan laid out priorities for work on specifications, test methods, characteristic values or design requirements by product..

A.4 Framework for ISO/TC 165 standards

In 2009, the Chairman of ISO/TC 165 prepared a draft potential Framework for current and new ISO/TC 165 standards, based on input over several years from TC participants. The goal was to revise and update the Framework document as the standards progressed and evolved.

The review process included an "Overview of ISO/TC 165 and CEN/TC 124 Standards and Projects (dated 2007-09-24)"—which was updated in the Framework document—and solicited input from TC members.

The document notes the objectives in the TC's business plan (see above) and the areas of standards development as found on the ISO/TC 165 web page, but then breaks down the work of the Committee into four broad categories:

- specifications,
- test methods,
- characteristic (strength) values, and
- design requirements.

This breakdown was used to prioritize standards work at the time as shown in the following table:

Product	Specifications	Test methods	Characteristic values	Design requirements
Sawn timber	1	1	1	2
Jointed sawn timber	2	3	3	4
Laminated sawn	1	2	2	3
Laminated veneer	TC 89/SC 3	2	2	4
Composite strand	4	5	4	5
Panels — Veneer	TC 89/SC 3	1	1	2
Panels — Non-veneer	TC 89/SC 2	1	2	1
Round timber	1	1	1	2
Bamboo	5	5	5	5
Composite I-joist	1	1	1	1
Composite panel	TC 89	2	3	1
Composite beam and post	4	5	3	4
Component — Trusses	1	1	1	2
Component — Panels	4	3	4	4
Joints	1	1	2	2
Trusses	1	1	1	2

Category 4 (design requirements) could mean different things to different people. It could mean using design values and behaviour equations to calculate section properties, or it could mean basic assessment of material properties for use in structural applications.

The discussion reports that the TC consensus was to limit category 4 standards work to characteristic values, or related testing or analysis, and not to get involved in determination of design values and material behaviour equations linked to other regional or national decisions. It is noted that regional criteria for design values and material behaviour may be interrelated with criteria for other major structural materials.

The draft business plan raises some strategic questions arising from work underway on ISO standards, some of which relate to category 4-type standards, e.g.:

- How to determine the level of precision in relation to timber properties?
- How to decide to reference a set of test methods vs. alternative methods?
- How to reference diverse climate conditions in a standard?
- How to define characteristic values throughout all ISO/TC 165 standards?
- How to avoid confusion between characteristic values and design values?
- How to make a generic characteristic value standard referenceable in other standards?

NOTE ISO/TC 165 is currently working on the development of a “generic” characteristic value standard, as well as a timber structural classification standard.

A.5 New committee framework

In 2011 the TC adopted a new framework document for development of future ISO/TC 165 standards and, where appropriate, for revision of existing standards. The goal was to promote greater consistency in the committee’s standards, to clarify how the standards related to “design requirements” and to respond to some of the questions listed above.

The new framework sorts each standard into discrete subject areas so that they do not overlap or cover the same ground, and each unit represents a step in the hierarchy supporting national design standards (see the end of this annex). Also, the framework is predicated on common “base” standards to be referenced in other ISO/TC 165 standards.

The four distinct areas in this ISO/TC 165 framework are as follows:

- product specifications,
- test methods for the product,
- requirements for determining characteristic values, and
- strength classifications or performance ratings.

The framework also reserves a place for overarching “design standards,” which may be either national standards or, should the TC decide to undertake such work, ISO standards. At this date, no such work is planned within ISO/TC 165.

In adopting the new framework the TC also took steps toward greater consistency in other aspects of standards writing, e.g. terminology and moisture classes.

A.6 ISO policy on global relevance

A presentation given by ISO staff at the 2009 Bordeaux meeting of ISO/TC 165 described the ISO “global relevance” policy. It suggested options to improve the fit between International Standards and local conditions, including the following:

- ‘Deemed to satisfy’ approach — identifying national or regional standard requirements recognized to address the same intent as a clause in an ISO standard.

- Boxed values — identifying specifications that are expected to be modified by the authorities having jurisdiction to suit regional or national needs.
- Alternative clauses in a standard — inserting clauses to include reference to significant specifications or conditions (such as climate) that may vary from the general case.
- Alternative annexes — providing a reference (normative or informative) to major variations in design or specifications where necessary to meet regional or national needs.
- Separated alternative documents — moving specific requirements that may not be applicable in some regions to separate Technical Specifications.

A.7 Recent ISO/TC 165 review (2009-2010)

Discussion at the Bordeaux ISO/TC 165 meeting focused on feasibility of developing timber design standards that could be used at the national or regional level. Based on individual national situations, it was generally conceded that the differences in regulatory structures, geographic and climate conditions, and design framework would make it difficult to develop a comprehensive ISO standard for design of timber structures.

It was suggested that a simplified design or design framework document using common principles from regional and national standards might be achievable. It was noted, from the TPM presentation (N644), that ISO 15673 contained boxed values that could be modified by the national standards body due to local design and construction requirements and practices. Authorities in each member country are expected to review the boxed values and substitute alternative definitive values where appropriate in the national application of the document.

It was agreed that the simplified concept be investigated further and Mr. Karacabeyli undertook to look at it in detail with the Chairman to see if the same strategy could be adapted for timber. The initial goal was to draft a conceptual document to be further developed after discussion at the meeting in 2010.

At the 24th meeting in Victoria, Working Group 2 received a Draft design code for laminated bamboo, but indicated that a product standard would first be needed for Laminated Bamboo to identify the basic characteristics of the product. There was also a suggestion that the draft might be used to start developing a broader structural design standard or technical report for timber. The ISO/TC 165 Chairman agreed to undertake a review of the general issue and report back to ISO/TC 165.

The Chairman also wrote an article in the May 2010 issue of ISO Focus about ISO/TC 165 priorities. The article suggested that international standards could present, particularly to countries without substantial resources for standards development, a unique opportunity to accelerate adoption of wood-based construction by being part of the consensus-building and having access to state-of-the-art technology.

This review was prepared originally for the 25th ISO/TC 165 meeting in Bali, and the results of that discussion are reported in the following section.

A.8 Summary of 2011 review by ISO/TC 165

At the 25th ISO/TC 165 meeting in Bali, the Technical Committee examined this paper and considered potential options for getting involved in the development of a structural design standard(s).

The Chairman’s Advisory Committee expressed interest in opportunities afforded by design standard initiatives including: facilitation of trade for both products and design services, recognition of mechanics-based models, and a forum for discussion of design differences between countries or regions. It was recognized that some past and present work items appeared to come close to the definition of a design standard (e.g. bamboo standard, cross-laminated timber standard).

There was also discussion of the history of the 1980s involvement with the CIB Structural Timber Design Code (see Introduction).

Notwithstanding the history and level of interest, participants expressed concerns about the following aspects of an ISO design standard initiative for timber:

- Size of the task(s) and the work commitment,
- Complexity of design solutions, in terms of failure modes in connections and structures,
- Difficulty in generalizing solutions involving ductility of structures,
- Existing agreements between CEN and ISO bodies on standards development, and
- Uncertainty as to which specific problems would benefit most from international solutions.

The TC discussed various options ranging from “no action” to undertaking a complete structural timber design standard. In view of the concerns identified, there was no support for the latter option. There was some support for a limited standard approach that would address only a selected type of member(s) or connection(s) and focus on the underlying analysis and design methodology.

At this time, the TC chose not to undertake any specific design standard initiatives. This is not to say that the TC did not support the rationale as listed in Section 6, particularly the following:

- To grow awareness of design requirements, and
- To seek greater compatibility among national standards.

It was recognized that the TC could still work on these objectives in other ways. For example, the TC could circulate reports related to innovative or important design requirements and could meet from time to time in conjunction with other international groups interested in these issues.

The option to develop a limited-scope form of design document as either a standard or a technical report would be available in the future if the opportunity and interest were to arise. Meanwhile this report has been prepared with the intent of having the information available for future reference by the TC.

It should be noted that factors such as fire resistance, durability and serviceability (e.g. creep, vibration and sound transmission) are beyond the scope of this Technical Report but will require consideration for future standards development, coordinated with other TCs having responsibilities relating to these issues.

A.9 Lessons from review of current standards

The review of ISO structural design standards has identified a few points that should be kept in mind with any new initiative:

- Basic reliability or safety levels are dependent on national or regional decisions and so are difficult to standardize on an international basis.
- Scope limitations do not necessarily make a standard easy to use. First, one must decide how to design the standard to serve its intended target audience. Then it may be possible to develop a standard on the basis of simplified assumptions or requirements.
- It is good practice to develop a commentary, perhaps as an annex, at the same time as the standard. This provides a place for contents that are advisory or difficult to formulate.
- It is preferable to specify materials by reference to other standards. This includes proprietary products as well as traditional or generic products.
- Structural design standards are not simple. In particular, connection design is quite involved and complicates even a limited-scope standard.

The question of “boxed values” also deserves discussion. One might wonder why boxed values are needed in an international standard if the purpose is to draw attention to provisions for review by a national or regional authority prior to adoption. Typically, everything in the standard needs to be reviewed prior to adoption, so why highlight anything?

There may be some value in using boxed values as placeholders to ensure that the adoption of the standard includes systematic input of quantitative values and also a systematic evaluation of the resulting output. The usefulness of the boxed value approach depends somewhat on its focus, i.e. if every number in a standard is boxed, it does not add much to the process. It is more useful if it draws attention to specific parameters that are particularly sensitive to variables that can be explained in commentary or background material.

This is all based on the assumption that a decision is made to develop a normative document. If the decision is made to proceed with a Technical Report instead of an International Standard, boxed values are less important.

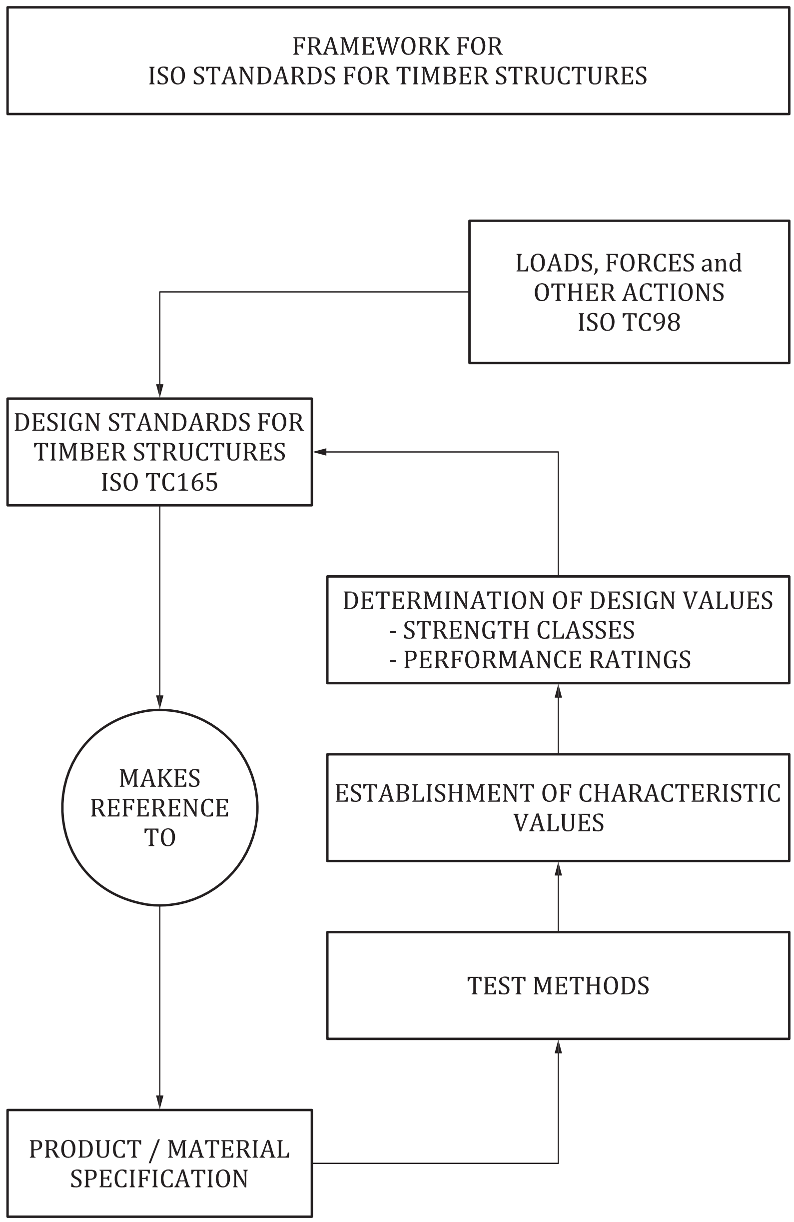

Figure A.1 — Framework for ISO standards for timber structures

Annex B
(informative)

Overview of ISO structural design documents

The following table provides an overview of ISO structural design documents.

NOTE In this table, ISO 9652-2 makes reference to ISO 9652-1 and ISO 9652-3. These parts were not completed, but were used as a basis for CEN documents EN 1996-1 and EN 1996-3. These documents may be consulted for additional information.

Table B.1 — Overview of ISO structural design documents

Standard or document	ISO 15673:2005	ISO 10721-1:1997	ISO 9652-2:2000	ISO/TR 11069:1995	ISO 22156:2004
Basis for design	ISO 15673 is presented in Limit States Design format, except that soil design and bearing requirements are presented in working stress (allowable stress) design format. The term "allowable" is also used to apply to serviceability requirements, e.g. minimum dimensions of floor members to resist deflection. 6.2 indicates that the limit states include consideration of: structural integrity, lateral load storey drift, durability, fire, and ultimate and serviceability limit states. No equations are given for serviceability design, which is generally addressed in ISO 15673 by minimum dimensions. Design load requirements are included in the form of complete equations covering load factors and combinations, although the loads themselves (nominal loads) are not given and are to be determined by the potential adopter of ISO 15673. Nearly all of the numerical values are "boxed" (put in brackets) to show that they need review before adoption.	ISO 10721-1 is presented in Limit States Design format. Unlike ISO 15673, it does not provide complete design equations including load factors and combinations, instead covering basic concepts and referring the user to ISO 2394. ISO 10721-1 refers the user to national codes for target reliabilities for structural design. It notes that reliability should be chosen to account for the possible consequences of exceeding limit states, ranging as follows: — risk to life is negligible and economic consequences are small or negligible, — risk to life exists and/or economic consequences are considerable, or — risk to life is high and/or economic consequences are great. It suggests that the target reliability could be set at different levels within a standard, depending on the structural systems, design values, environmental conditions or other circumstances (5.3.2).	ISO 9652-2 is designed to provide specific cases of masonry design without the need for structural calculations. For unreinforced masonry designed by calculation, the user is referred to ISO 9652-1. ISO 9652-3 addresses reinforced masonry designed by calculation. Where ISO 9652-2 refers to load limits, it identifies unfactored loads. Minimum strength requirements are unfactored strengths. Clause 5 of ISO 9652-2 mandates the general principles of "Stability and Robustness" as objectives of design. These principles are tied loosely to the rest of ISO 9652-2. The overall approach to establishing safety factors or reliability is undefined. ISO 9652-1 would seem to be the appropriate choice for a structural design standard; however, it was not available at the time of this review.	ISO/TR 11069 is presented in Limit States Design format although it does not provide complete design equations with partial factors for load and resistance (similar to ISO 10721-1). The Introduction explains that ISO/TR 11069 provides the ultimate load capacity of aluminium members and its connections used in stressed applications, under the action of static loads, and states that the characteristic resistances may be factored to provide capacities in applications that do not use Limit States Design. However, the Foreword points out that no values are given for resistance factors or other safety margins due to the diversity of applications considered in ISO/TR 11069. It goes on to say that safe design procedures are readily obtained using the specified resistances, if the load spectrum and desired reliability are known. Serviceability limit states are to be handled in standards specific to the application, and so are not discussed in ISO/TR 11069.	ISO 22156 permits the use of either limit states or allowable stress design. Beyond that, it permits experience-based or evaluation-based designs in lieu of calculated engineering designs. Further, it permits alternative designs that are "at least equivalent." For allowable stress design, ISO 22156 provides a specific factor of safety calculation. "Experience-based" design differs from what is found in the other ISO documents, and is identified as a local, non-codified standard for use in certain areas. Evaluation-based design makes specific reference to post-disaster experiences. Serviceability design is identified as a design condition, without detailed guidance.

Table B.1 *(continued)*

Standard or document	ISO 15673:2005	ISO 10721-1:1997	ISO 9652-2:2000	ISO/TR 11069:1995	ISO 22156:2004
Scope and limitations	The Introduction to ISO 15673 states that it is intended for design of low-rise small concrete buildings in "less developed areas of the world," for countries that do not have existing national standards. It is also suggested as an alternative to existing national concrete codes, presumably as a simplification, where evaluated by the appropriate regulatory body. It is stated that the design rules are based on simplified worldwide-accepted strength models. Although the scope is limited and simplified, ISO 15673 is a very extensive stand-alone document covering gravity and lateral load design requirements, as well as analysis procedures and construction practice guidelines. Earthquake provisions are included in recognition that many underdeveloped regions are located in seismic-active areas. Limitations in scope apply to: — occupancy types, — number of storeys, — floor area, — storey height, — span length, and — other building parameters. In addition ISO 15673 identifies a number of provisions that are beyond the scope, e.g. procedures for transverse or shear reinforcement in concrete slabs.	ISO 10721-1 is intended to provide a high-level framework for drafting national standards on steel structural design to ensure adequate and consistent measures regarding safety and serviceability. It does not provide specific numerical requirements which, it states, should be obtained from national codes to be optimal with respect to the state of economy and development. This suggests that the primary intent may be to provide a template for producing national standards in underdeveloped regions. ISO 10721-1 addresses material design (members and connections) rather than overall building design, so it does not place limits on the scope for building occupancy or size. ISO 10721-2 deals with fabrication and erection, and ISO 10721-1 notes that these fabrication and erection issues should be taken into consideration in establishing safety factors or reliability. The scope of ISO 10721-1 does not cover some design aspects, as the special requirements of seismic design. There is a sizeable section dealing with fatigue, as well as an informative annex on the subject.	The scope of ISO 9652-2 is basically restricted to low-rise dwellings of not more than two floor levels plus a basement (or other small single-storey buildings) located in non-seismic areas with moderate winds and limited vertical loading. The scope is supplemented by provisions for basements (any building), internal non-loadbearing walls (any building), external non-loadbearing walls of a certain size and location, as well as an annex with design requirements for certain seismic zones. Load limits suggest that ISO 9652-2 is not intended for use in northern climates (roof snow load no greater than 0,9 kn/m^2), or hurricane/cyclone regions (wind load including pressures no greater than 1,2 kn/m^2). Limits are placed on spans, minimum thicknesses and bearing lengths, sizes and locations of openings, and wall heights. If loads, strengths or dimensions fall outside the limits, then calculations can be made for that part of the structure affected. This provision positions a "grey zone" between rules-based design and engineered design. Some restrictions to application of ISO 9652-2 suggest awareness of the record of unreinforced masonry structures in natural disasters.	ISO/TR 11069 is designed as a high-level document like ISO 10721-2, dealing with general principles of failure modes and behaviour formulae. Design procedures are based on steel design methods, adjusted to suit aluminium. The Scope says ISO/TR 11069 provides design expressions to determine characteristic values of components and connections in aluminum assemblies. Commentary on the Scope (A.2) says ISO/TR 11069 is aimed at general engineering areas such as building components, latticed towers, cranes, vehicles, rolling stock and bridges. The commentary in A.1 explains that "the aim of this Technical Report is to provide means to predict the various modes of failure which have general acceptability, while leaving the choice of values for mechanical properties and coefficients in the design formulae to be selected later, should the Report be used as the basis for an International Standard." Serviceability limit states are not addressed. Also,ISO/TR 11069 does not consider dynamic loads nor, in particular, design against fatigue failure.	The scope of ISO 22156 is not restricted in terms of structural type or size or by applications of design. Primarily, ISO 22156 addresses design of members and joints. It notes that bamboo used as a composite structure may require additional considerations. The provisions allowing design based on experience or evaluation (6.2.2 and/or 6.2.3) are explained on the basis that building processes in the "informal sector" need a long period of teaching and training, and also as a means to promote the self-reliance of lower income groups.

Table B.1 *(continued)*

Standard or document	ISO 15673:2005	ISO 10721-1:1997	ISO 9652-2:2000	ISO/TR 11069:1995	ISO 22156:2004
Standard or guide	ISO 15673 includes many design aids such as tables, graphics and other shortcuts that might be considered "handbook" information. The Introduction calls attention to approximate procedures as a substitute for complete engineering solutions. Minimum dimensions of members are prescribed in cases where a more complete design procedure might result in smaller sections. On the other hand, ISO 15673 includes extensive requirements. The Introduction says a great effort was made to include self-explanatory tables, graphics, and design aids to provide foolproof procedures. ISO 15673 mainly uses "should" instead of "shall" for mandatory provisions. Much of ISO 15673, including Clause 5 and early parts of Clause 7, reads like a Handbook; e.g. 7.4.1.2.3 discusses advantages of the slab-on-girder system. Some provisions do not appear to be fully resolved; 7.3.12.7 allows the use of interaction diagrams for columns if "employment of the strength reduction factors as set forth in this Standard is warranted." It is not clear how one would determine whether the factors are warranted, or which sources to use.	ISO 10721-1 is generally written in mandatory language ("shall"). "Should" is used with philosophical points such as reliability levels and designing for ductile behaviour, although in other areas it seems almost interchangeable with "shall." "Permitted" is used in relationship to welding practice. In most cases, permission is indicated by the word "may." ISO 10721-1 includes buckling models and formulae for structural steel members. The main body does not include too many design equations, but some of these can be found in the non-mandatory Annex A of ISO 10721-1. Commentary in Annex A of ISO 10721-1 is written in both mandatory and permissive language, even though the annex is identified as informative. Annex A of ISO 10721-1 serves as a kind of reference handbook or manual with formulae and graphs as well as commentary. While the decision to leave specific formulae and numerical solutions out of the body of ISO 10721-1 means that it is more "performance" oriented and less likely to be in conflict with other national standards, this decision might also limit its utility for adoption as a legally enforceable document.	ISO 9652-2 is at the other end of the spectrum of standards-writing, being mainly a prescriptive document without calculations. It makes use of the term "should" rather than "shall" throughout for all mandatory provisions — as well as any advisory provisions that exist. There are also a few "permitted" provisions. ISO 9652-2 is primarily prescriptive , so the selection tables and graphics are not very different from what would be found in a handbook or manual. However, it is a fairly short document and does not include a lot of detail. For example, 8.2 states that "the stiffening wall should be bonded or securely tied to the wall, or loadbearing leaf of a cavity wall, which it is restraining..." without adding specific guidance. The prescriptive nature of ISO 9652-2 should make it easier to adopt as a legally enforceable standard, to the extent of its scope and detailed design provisions.	ISO/TR 11069 is a Technical Report rather than an International Standard. The Foreword explains why it was put forward as a Technical Report. Although it is not an International Standard, it was written with the intent of becoming one, and includes mandatory language, with "shall" being used almost exclusively. The Commentary in Annex A of ISO/TR 11069 provides background and guidance with respect to behavioural models and formulae, in some cases drawing comparisons with steel behavioural models and formulae.	ISO 22156 includes many qualitative or performance-based provisions. Although written in mandatory "shall" language, it would be difficult to determine whether a specific design was in or out of conformance with ISO 22156, since most of the requirements are not quantified. Guidance is provided in very broad terms.

Table B.1 *(continued)*

Standard or document	ISO 15673:2005	ISO 10721-1:1997	ISO 9652-2:2000	ISO/TR 11069:1995	ISO 22156:2004
Rules-based or engineered approach	ISO 15673 is intended to be used by a registered civil engineer or architect to design the reinforced-concrete structural framing of a low-rise building conforming to the scope limitations. As noted earlier, minimum dimensions of members are prescribed in cases where a more complicated design procedure might result in smaller sections. This includes provisions in 7.4.5 for the minimum depth of elements of the floor system. ISO 15673 includes specific guidance for analysis of structures. 7.6.4.3.4 permits the use of a frame analysis to determine substitute moment and shear values for those prescribed in ISO 15673, 7.6.4.5.1 permits the use of T-beam effects in analysis. Overall, ISO 15673 is a mixture of calculation methods and prescriptive rules-of-thumb, some overlapping one another.	ISO 10721-1 takes more of a "performance" oriented approach than ISO 15673 by specifying requirements in terms of general principle or objectives, and not including some specific provisions or prescriptive (rules-based) approaches that might limit the scope. This appears to be a more fully-engineered approach to standardizing design requirements and also less likely to contain provisions that would be in conflict with other national standards. On the other hand, the decision to leave out specific design equations and numerical solutions may have limited the utility of ISO 10721-1 for adoption as a legally enforceable document — the classic tradeoff between "performance" and "prescriptive" approaches to standardization. The informative Annex A of ISO 10721-1 provides more specific guidance for design.	ISO 9652-2 is designed to be a rules-based standard, specifically so that calculations of loading and strength criteria are not required. This is achieved by limiting the scope and field of application, and providing solutions in terms of material types and dimensions for ready use. Although design calculations are avoided, ISO 9652-2 includes requirements related to load and capacity limits that suggest the intended user would be familiar with engineering principles. 6.1 states that calculations should be made for parts of a structure where loads, strengths or dimensions fall outside the given limits. The Introduction suggests that the calculated approach in ISO 9652-1 and some national codes may be more restrictive than ISO 9652-2.	ISO/TR 11069 is conceived as an engineering design document, although limited because specific mechanical properties and numerical coefficients could not be included in its current form. Commentary A.1 maintains that ISO/TR 11069 provides a more consistent level of reliability, although it is difficult to understand how that can be accomplished without having final design numbers. 5.5 states that "predictors given in this Technical Report have been targeted to give values for the characteristic resistance that are the mean value from test results less two standard deviations." This may refer specifically to the buckling formulae for aluminium members (A.7.4).	ISO 22156 includes basic engineering principles for the design of bamboo members and structures. Without describing specific rules-based designs, ISO 22156 states that such designs are deemed to comply provided that they are based on old, well-preserved traditions and are located in a community with an undisturbed social structure, and so on. This provision could be difficult to interpret from a regulatory position. For bamboo trusses, ISO 22156 permits the use of a simplified analysis model in place of a global analysis.
Material specifications	ISO 15673 includes many normative references to ISO standards on material specifications, test methods, loading provisions, and basis for design. Where referenced in the body of the document, these standards are added to the requirements, but national standards are also referenced in a number of ways. For materials, the reference is to either ISO or the corresponding national standards. The strength reduction factors (φ) are quantified, although the actual resistances are not. These values are "boxed" to indicate that they are to be reviewed before adoption.	In ISO 10721-1, materials are specified in accordance with ISO standards or the requirements of appropriate national standards. This includes a standard for mechanical properties of fasteners. The design equations include a symbol for characteristic value of resistance without a specific reference for the value. The material resistance factor is also represented but not quantified. Member shapes are also classified in terms of their capacity to resist local buckling (8.3).	ISO 9652-2 specifies masonry units and mortar type by reference to ISO 9652-1, *Masonry — Part 1:Unreinforced masonry design by calculation*, and masonry unit strength is measured in accordance with ISO 9652-4, *Masonry — Part 4: Test methods*. ISO 9652-2 is restricted in application to cases where the minimum compressive strength of masonry units is at least as specified, among other specifications. ISO 9652-2 does not make other references to material properties or resistance, except briefly in terms of connections, or bonding for non-loadbearing walls.	In ISO/TR 11069, materials are specified in a broad, performance-oriented manner: suitability will be assessed on the basis of conformity to an International Standard, or European or national standard and on the following considerations, as applicable: — strength: yield and ultimate; — ductility: elongation and reduction in area; — weldability and welded properties; — corrosion resistance in the intended environment; — formability; — machinability; — surface finish. Mechanical properties will depend on the alloy selected. Properties of some of the more popular alloys are tabulated in the annex.	ISO 22156 has a normative reference to ISO 22157-1 and gives a formula to calculate bamboo characteristic values from test date. Clause 17 of ISO 22156 identifies the need for approved grading rules without a specific reference, and Clause 18 identifies need for overall grading quality control procedures without a specific reference. ISO 22156 also includes panels made of bamboo without a standard reference.

Table B.1 *(continued)*

Standard or document	ISO 15673:2005	ISO 10721-1:1997	ISO 9652-2:2000	ISO/TR 11069:1995	ISO 22156:2004
Load provisions	In the case of loads, ISO 15673 refers first to national standards; if not available, then an ISO standard is referenced. Regardless of this mix of load options, ISO 15673 identifies specific partial load coefficients and load combination factors. ISO 15673 includes a design procedure flowchart in Clause 5 beginning with gravity design, then earthquake design of structural walls and the foundation, followed by review and re-design of the floor slabs, girders and columns.	ISO 10721-1 refers to loads in general terms, without specific reference to standards or quantities. For fatigue loading, ISO 10721-1 identifies a minimum confidence level for amplitude and frequency. Overturning requirements and consideration of sway effects are in Caluse 7, "Analysis of Structures." Lateral loading is considered in member design provisions, although the scope explicitly excludes the special requirements of seismic design. Generally, ISO 10721-1 is focused on member design.	ISO 9652-2 is restricted in application to locations where the imposed loads are limited to specified values. ISO 9652-2 includes additional rules-based limits for structures built in moderate seismic zones. For higher seismic zones, the rules-based approach is not permitted and the user is referred to ISO 9652-3, *Masonry — Part 3: Reinforced masonry design by calculation*. The ISO 9652-2 approach is also restricted to lower wind speed zones.	ISO/TR 11069 addresses only static loading. In addition, it does not include full design equations, so does not address loading provisions in any detail. ISO/TR 11069 notes that characteristic loads are usually selected on the basis of a required return period.	ISO 22156 refers to design using loads prescribed in the "National Building Code" (Clause 9). ISO 22156 has a brief section in a subclause on design practice (11.4) that requires attention to the effects of typhoons and earthquakes. Like wood, bamboo includes a load duration factor, which is given specific values for three loading cases.
Assemblies or components	ISO 15673 addresses specific building systems of concrete walls, columns, beams, joists and floor slabs, subject to geometrical and dimensional requirements. The vertical-load supporting elements transmit loads all the way to the foundation, and the lateral-load resisting system acts as diaphragms and shearwalls. Clause 7 of ISO 15673 discusses the use of frame analysis for joists and beams supported on beams, girders or walls. There are some rules-based solutions for joints, such as column-girder connections.	ISO 10721-1 addresses material design (members and connections) rather than overall building design. 8.5 and the commentary adds information on bracing of beams and trusses, and 8.6 on design of webs and stiffeners. Bolted and welded connections are addressed in some detail, (about one quarter of the document) without reference to specific assemblies.	ISO 9652-2 provides rules-based procedures to design small unreinforced masonry buildings, subject to geometrical and dimensional restrictions. ISO 9652-2 does not address design of individual components or connections, other than through general terms of guidance.	ISO/TR 11069 focuses on components and connections, similarly to ISO 10721-1. The commentary indicates that the document is also expected to be applied to aluminium assemblies of all types for which there is no separate design code. Clause 7, "Methods of Analysis" includes a brief discussion of analysis options. A.5 notes that aluminium assemblies do not have the steel's range of ductility. About one third of ISO/TR 11069 is used to address bolted and welded connections.	ISO 22156 includes a brief section on bamboo trusses (Clause 12). Clause 8 (Schematization) lays out basic modeling assumptions for bamboo design. Clause 11 on joints allows for test-based or experience-based designs, based on general guidance.
Construction practice	ISO 15673 includes a short section (5) on design and construction procedure, and includes basic documentation requirements.	ISO 10721 has a Part 2 that deals with fabrication and erection requirements. It also includes some construction details in 8.9 on welding and in the commentary.	ISO 9652-2 doesn't include specific construction practice provisions, although it has some general comments.	Section 6 of ISO/TR 11069 includes requirements for product identification and dimension tolerances.	ISO 22156 includes a section requiring sound construction practice in general terms, and a section on product quality control.

Table B.1 *(continued)*

Standard or document	ISO 15673:2005	ISO 10721-1:1997	ISO 9652-2:2000	ISO/TR 11069:1995	ISO 22156:2004
Commentary	Although no commentary is included in ISO 15673, guidance is provided in the body of the document. The annex deals with an alternative approach to material reduction factors. This annex results, to some extent, from the decision to include specific reduction factors in ISO 15673.	Annex A of ISO 10721 is a specific clause-by-clause commentary on the document. The annex is a key part of the document, and takes up more than half of the document's pages.	ISO 9652-2 does not include a specific commentary, and both of its annexes are normative. The user is referred to ISO 9652-1 for design by calculation.	Annex A of ISO/TR 11069 is a clause-by-clause commentary on the document, similar to that in ISO 10721.	ISO 22156 does not include a specific commentary. There is a one-page background and history in Annex A of ISO 22156; some assumptions are listed in Annex B of ISO 22156.

Annex C
(informative)

Outline for a Basic Level Standard

1. Introduction
2. Bending Members
3. Compression Members
4. Tension Members
5. Combined Loads
6. Bearing
7. Fastenings
8. Applications
9. Shearwalls and Diaphragms
10. Design for Fire Safety
11. Reference Information
12. Commentary

NOTE The sections that are appropriate will depend on the selected option.

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