CONCEPTS FOR PERFORMANCE-BASED TIMBER BUILDING CODES AND STANDARDS

Greg C Foliente PhD, Robert H. Leicester PhD and Lam Pham PhD
CSIRO Building, Construction and Engineering, Melbourne, Australia

SUMMARY

A conceptual framework for building codes and standards, using performance based criteria, is presented. It is proposed that there be three levels of building control. These comprise the specification of building objectives, design for in-service performance and the evaluation of characteristic values. At each level the target performance is defined in quantitative probabilistic terms. Also at each level there are four methods for achieving the required performance; these are through deemed-to-comply specifications, computation, testing and combined computation and testing; the last three methods are referred to as performance-based methods. All four methods are intended to produce the same in-service performance quality. Other matters discussed include the use of reliability-based methods, the specification of multiple levels of quality for in-service performance, the format for serviceability criteria and methods for incorporating durability and fatigue considerations.

1 INTRODUCTION

Most building regulations have commenced with the use of compliance procedures. These procedures, also known as deemed-to-comply or prescriptive procedures, usually relate to well established building practices that are known to have been acceptable. The focus is mainly on solutions rather than the target performance.

There are however, some fundamental difficulties associated with the use of compliance criteria. The first is that since the building performance is not quantified, then it is not possible to cost-optimise building construction. A more serious problem however, is that the type of building cannot be changed and hence compliance criteria cannot be used for innovation. In fact, the history of building regulations are full of examples in which the existence of compliance criteria has acted as a barrier to innovation; one example of this is the restriction against the use of timber for certain types of construction. Finally, it may be stated that the use of compliance criteria can act as a barrier to international trade in building products. This is because if two trading countries both use compliance criteria, then it is often difficult to establish the equivalence between the two sets of criteria, and accordingly it is difficult to establish fair trading agreements.

The corollary to the above then is that the use of performance-based criteria is useful for:

- cost-optimising construction,
- promoting innovation, and
- facilitating international trade.

Major non-tariff trade barriers that inhibit building and construction trade are prescriptive or compliance building codes and standards. The World Trade Organisation (WTO) has addressed this issue in Clause 2.8 of the Agreement on Trade Barriers to Trade, which states that [28]:

> "Wherever appropriate, Members shall specify technical regulations based on product requirements *in terms of performance* rather than design or descriptive characteristics" (italics supplied).

Member economies that are signatories to the WTO General Agreement on Tariffs and Trade (GATT) have therefore committed themselves, whether wittingly or not, to the use of performance requirements in evaluating a product's fitness for purpose and in accepting new and/or innovative products in their market, or, in other words, to use the language of performance in trade.

In this paper, some concepts, issues and implications related to the development of performance-based codes and standards are discussed. In such a discussion there is usually a difficulty with the definitions of the terms used; hence all important terms will be defined as they occur.

2 PERFORMANCE CONCEPT

2.1 Historical Background

The *performance approach* is, in essence, the practice of thinking and working in terms of ends rather than means [6]. In the performance approach, the target performance is described rather than providing a direct solution. It is concerned with what a building or building product is required to do, rather than prescribing how it is to be constructed. This concept as applied to building and construction is not new; its development has been reviewed by Gross [18].

The first known building regulation record attributed to King Hammurabi, who reigned in Babylonia from about 1955 to 1913 B.C., contained a performance statementon structural safety. Upon an obelisk in the Louvre in Paris is inscribed a quote from the Hammurabi Code:

> "Article 229: The builder has built a house for a man and his work is not strong and if the house he has built falls in and kills a householder, that builder shall be slain."

This statement does not say anything about the ways and means of buildings, e.g., the type of material, the thickness, dimension and size of building parts or the method of construction, but it clearly states the required end result – that the building should not collapse and kill someone.

In 1925, the US National Bureau of Standards, the predecessor of the National Institute of Standards and Technology (NIST), published a report on *Recommended Practice for Arrangement of Building Codes* [25], which states:

> "Whenever possible, requirements should be stated in terms of performance, based upon test results for service conditions, rather than in dimensions, detailed methods, or specific materials. Otherwise, new materials, or new assemblies of common materials, which would meet construction demands satisfactorily and economically, might be restricted from use, thus, obstructing progress in the industry."

This statement is as true today as it was then.

Developments in the last couple of decades can be found in the proceedings of the series of joint CIB-ASTM-RILEM conferences on the Performance Concept in Buildings. These were held in Philadelphia in 1972 [17], Lisbon in 1982 [24], and Tel Aviv in 1996 [4]. The group of sponsoring organisations was joined by ISO in the Tel Aviv conference. Other helpful publications include the various CIB publications on the topic [6, 7, 8, 9] and the Tsukuba proceedings of a workshop on performance based structural design standards [5]. Most recently, the major research and development activities that are still needed to better implement the concept have been identified [3, 12].

2.2 Paradigm Shift – From Parts to Attributes

If a building is viewed as a matrix of parts and attributes, the main difference between the traditional prescriptive or compliance method and the performance approach can be illustrated as shown in Fig. 1 [19]. In the prescriptive approach, the building parts are described, specified and procured, resulting in a building with a unique but implicit set of attributes [Fig. 1(a)]. In the performance approach, the building attributes are described and specified, and many combinations of different building parts can be procured for which it can be demonstrated that the specified attributes will be provided [Fig. 1(b)].

This paradigm shift brings into building technology whole new areas of research. Since human requirements are the defining parameters for the building attributes, their proper definition and articulation are required in the development of performance criteria. This process requires research on human requirements, and human response to the built environment – the study of which covers areas of physiology, psychology, sociology, anthropology, ergonomics and special populations (such as geriatrics and the disabled) [19]. And its quantification requires the application of uncertainty modelling and probabilistic methods [2, 10]. This is necessary if multiple performance levels are to be developed.

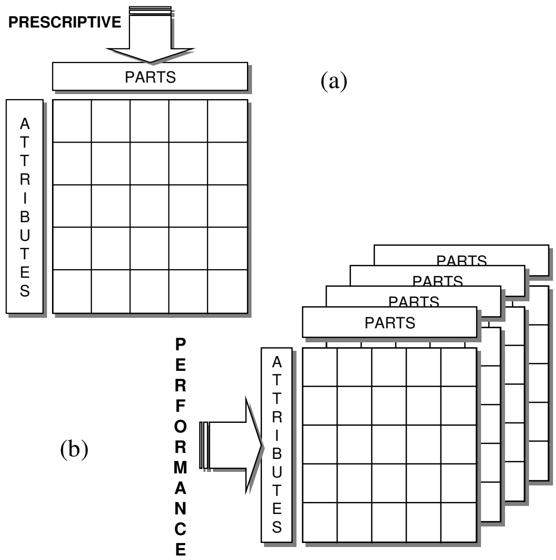

Figure 1 – Building as a matrix of parts and attributes: (a) Prescriptive; and (b) Performance approach (from ref. [19])

2.3 General Applications

The performance concept is applicable to both:

- building procurement (project initiation, design and construction process), and
- building quality control (regulation).

In the case of building production (an initiative action), the freedom encouraged in preparing the brief and in design and construction lends to more innovative, economical and better performing buildings. In the case of regulation (a permissive action), the performance concept allows innovative and cost-optimised construction while at the same time protecting the safety, health and general welfare of society [18].

3 BUILDING REGULATION

3.1 Regulations and Standards

Internationalisation of standards is possible only if a distinction is made between “standards” and “regulations”, and if their relationship is clarified. The importance of this is often overlooked or taken for granted. Some countries have a building regulatory structure that makes it difficult to separate the two but in most countries, a distinction between them can be made.

In this paper, a *building code or regulation* is defined as a document used by a local, state or national government body to control building practice, through a set of statements of “acceptable” minimum requirements of building performance. This is typically a legal document. Since the acceptable requirements are typically established based on socio-political and/or community considerations, they naturally differ from country to country or from locality to locality. Building standards, on the other hand, are essentially technical documents that standardise, generally in terms of quality or performance, but sometimes in terms of size or procedure, some activity in relation to building and construction [27]. They serve as some kind of benchmark. There are different levels and types of building standards (e.g., product, design, workmanship, etc.)

When building regulations cover technical aspects of performance, they typically incorporate or refer to relevant standards. Thus, building regulations are a user of standards. But this is not the sole purpose of standards; they have other uses. For example, in countries having low levels of regulation, clients rely on standards for their own assurance of performance. The insurance industry is also now beginning to use them in rating buildings for catastrophe insurance [27].

3.2 Basic Framework and Contents

Most performance-based regulatory frameworks are variations of what is called the Nordic Five Level System [9]. In this system, Level 1 (Goal) addresses the essential interests of the community at large and/or the needs of the user-consumer; Level 2 (Functional Requirement) addresses one specific aspect of the building or a building element to achieve the stated goal; Level 3 (Operative or Performance Requirement) specifies the actual requirement to be satisfied; and Levels 4 (Verification) and 5 (Examples of Acceptable Solutions) deal with the specifics of meeting the goal. The last two levels can actually be combined because compliance to a given prescriptive solution (Level 5) is just one of several possible methods of verification (Level 4), as shown in Fig. 2. The Building Code of Australia [1], for example, has a four-level framework like that shown in Fig. 2.

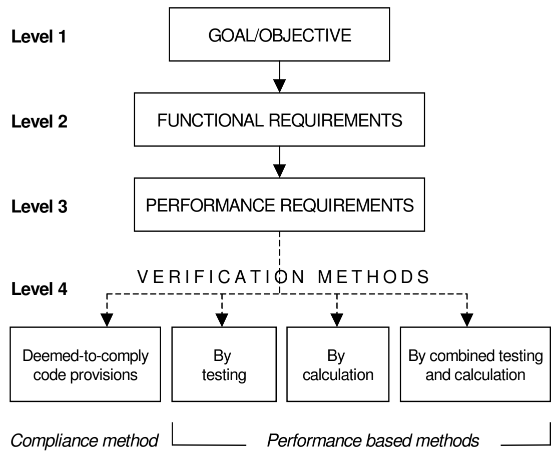

Figure 2 – General four-level regulatory framework

Here, the term *Building Objective* refers to the purpose of a building regulation. This may relate to the desire to minimise the risk to life, to minimise the loss of property or to reduce human discomfort in the use of a building.

Performance Criteria means the quantified statement of the operative or performance requirement. To properly define the context of performance (which is needed to state the criteria), we need to identify the relevant agents and performance parameters. *Agents* are natural or man-made events (e.g., biological, climatic, natural disasters, human activities, etc) that ‘act’ on the building and its components; regarding structural performance, these are the loads acting on the building. *Performance parameters* are the properties of a product or a building that closely reflect or characterise its attribute. As far as possible, these should be quantifiable parameters, and thus, can be readily calculated or measured. An attribute is the characteristic of a building or a product that the consumer or user requires. Under the performance concept, the human requirements, or user needs, define the building attributes (Fig. 1).

3.3 Performance Matrix

Following the description of a building as a matrix of parts and attributes (Fig. 1), a *Performance Matrix* such as that given in Appendix A, can be prepared. Ideally, functional and performance statements, and quantified performance criteria for each cell or group of cells in the Performance Matrix should be given. Practically, such a matrix serves as a guide on what performance statements and criteria need to be developed or revised to support a performance-based code.

4 LEVELS OF QUALITY CONTROL

It is convenient to focus on the performance targets for three levels or stages of building quality control. These will be designated as follows:

- Specification of building objectives;
- Design for in-service performance; and
- Evaluation of characteristic values.

In-service Performance refers to a particular aspect of building performance. Here the performance is defined as the probability or risk of attaining a specified ultimate or serviceability limit state. The risk levels used are chosen so that the building objectives can be achieved. (Clarification so as not to confuse in-service performance with "product" performance is given in Appendix B.) Most frequently, computations according to design codes are used to achieve a target performance. The computations are based on the use of characteristic values of materials, loads and other design parameters.

Characteristic Values are properties of materials, loads, building configuration, human behaviour etc., that are used in design codes for buildings. The structural resistance may be stated in terms of the properties of materials, structural elements or building systems. These values are usually obtained by experimental measurements and their definition is stated in statistical terms. If target values are specified for the characteristic values of building products, then these tests become *product acceptance tests*. Note that in the case of loads, there are often no formal standards for the evaluation of characteristic values.

It is possible and desirable that all target performances (including those at Level 1 in Fig. 2) are quantified. This is probably the most important feature of the performance approach. Once a building objective has been stated in quantified terms, it is feasible to draft a whole suite of design codes and product standards that ensure attainment of that objective. Unfortunately, building objectives are rarely quantified, and as a result the target in-service performance of buildings tends to be set in an uncoordinated fashion by the various committees that draft design codes and product standards. Furthermore, quantified performance criteria are needed to:

- develop objective procedures for evaluation;
- obtain international consensus for trade and information exchange (through equivalencing and harmonisation); and
- facilitate the development of multi-level performance (or performance band).

To illustrate the above concepts, the use of composite timber I-beams in building construction is considered.

The required target levels of performance are shown in Table 1.

Performance control	**Performance target**
1. Specification of building objective	Probability of loss of life within the design life of the *building* is less than 10^{-6}
2. Design for in-service performance	For a *particular I-beam*, the probability of failure in-service (during the design life) is given by $\Pr(\phi R_k < S_k) = 10^{-4}$
3. Evaluation of characteristic values – Structural element – Load	 $R_k = R_{0.05}$ $S_k = S_{0.95}$

Notes:
ϕ = material factor
R_k = characteristic value of I-beam strength
$R_{0.05}$ = 5-percentile value of I-beam strength
S_k = characteristic value of load
$S_{0.95}$ = 95-percentile value of peak load within a design life

Table 1 – Example of performance targets for use of composite I-beams

Let us say that the building objective is to reduce the probability of risk of loss of life to 10^{-6} within the design life of the building. Loss of life can occur due to a variety of causes such as structural failures and fires. It is considered that to achieve this the risk of failure in-service of any particular I-beam should be less than 10^{-4}. The intent of structural design codes is that this level of safety will arise from applying these codes. The characteristic values of strengths and loads used in these design codes refer to the 5th-percentile strength of I-beams and the 95th-percentile value of the peak loads within the design lifetime of the building, respectively.

Methods for achieving the performance targets are shown in Table 2. For each stage it is possible, at least conceptually, to achieve the target through compliance procedures, computation or by test. Regardless of the procedure used, the target performance remains the same. An interesting aspect of performance targets is that for each control stage this involves a different set of parameters. For the example considered, the parameters are shown in Table 3. The higher levels of control involve more parameters in the definition of performance and accordingly are more complex to define.

4 SCOPE OF PERFORMANCE CRITERIA

It is useful to classify all performance criteria in terms of either ultimate or serviceability limit states.

Ultimate limit states denote structural collapse and may lead to loss of property, injury or loss of life. The exceedance of *serviceability limit states* tends to have less effect on people and buildings and are usually reversible and repeatable. Typical types of serviceability limit states (in increasing order of impact) are as follows:

Performance Control	**Method for Achieving Performance Targets**		
	Use of Compliance Criteria	**Use of Performance Criteria**	
		By computation	**By test**
1. Achieve building objectives	Specify the use of a specific set of design codes and standards	Undertake an assessment of risk to life	*Survey of existing buildings for loss of life**
2. Obtain in-service performance	Use published span tables	Design using loading codes and engineering design codes	*Survey of existing buildings for structural failures**
3. Evaluate characteristic values			
– structural element	I-beam accepted by description	Computation of strength of I-beam based on properties of components	Strength test of I-beams
– load effect	Load specified by law	*Computation of loads**	Load survey
* Not usual			

Table 2 – Methods for achieving performance targets given in Table 1

Performance control	**Generic groups of parameters that affect performance**
1. Achieve building objective	People + structural element + loads
2. Obtain in-service performance	Structural element + loads
3. Evaluate characteristic value	
– Structural element	– Structural element
– Loads	– Loads

Table 3 – Generic groups of parameters that affect the performance targets given in Table 1.

- aesthetic (e.g. discolouration)
- functional (e.g. moisture penetration of outer walls)
- psychological (e.g. fear induced by the occurrence of large cracks in a structure)
- physiological (e.g. sickness due to building sway).

To assess performance, these limit states must be predicted for buildings subjected to all kinds of hazards, whether man made (e.g. floor loads, fires) or natural (e.g. wind, earthquake, flood).

Some literature contains definition of other types of limit states. Common examples are durability and fatigue limit states. This is unnecessary and confusing. It is possible to define all failure in terms of ultimate or serviceability limit states. Fatigue and durability effects are best considered as parameters to be taken into account in predicting ultimate or serviceability limit states as defined above. In this context, it is of interest to note that within Australia there is currently a major research initiative in progress to develop probabilistic prediction models related to the durability of timber construction [15, 20].

5 RELIABILITY CONCEPTS

Since the target performance is expressed in terms of risk, it is obvious that reliability analyses will play a major role in evaluating performance {10, 26]. Some major studies of this type have been made for the design codes of USA [11], Canada [16] and Australia [22]. For legal reasons, it is often preferable to state risk in terms of a safety index rather than the probability of failure.

In the above studies, performance targets were related to the concept of acceptable risk based on existing risk levels in buildings. Where it is not known, an acceptable target performance may be established based on relative risks a society is willing to take. For example, to establish an acceptable target performance against seismic events, it is helpful to compare the annual risk probability caused by fire, earthquake, suicide, traffic accident and disease (Fig. 3) [26].

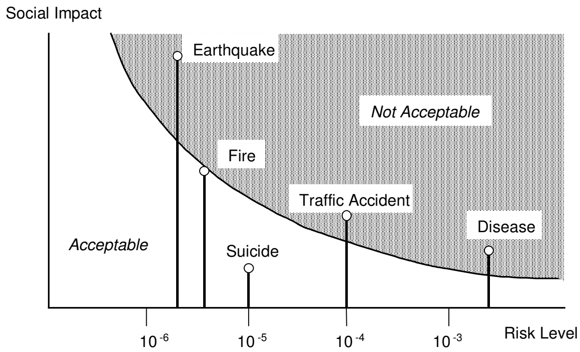

Figure 3 – Annual probability of risk in Japan (from ref. [26])

Current building codes have implied levels of risk of non-performance. Quantifying this will help code writers and building regulators develop multi-level performance criteria and encourage industry to innovate (i.e., develop and use new products or processes that meet or exceed the code's acceptable risk of non-performance). Design tools can be developed to balance cost and risk [22], allowing cost-optimisation of construction. This will also allow formal studies of effects of changes in building codes and standards on costs and risks.

6 FORMAT FOR DESIGN CODES AND PRODUCT STANDARDS

In using performance criteria for the development of design codes, it is possible to predict and hence to control the level of performance in buildings. This opens the possibility of having design codes that specify procedures for achieving a range of quality in performance (i.e., multi-level or banded performance criteria) [6]. This could be very useful for cost-optimising the performance within a building by placing high performance only where it is required; it would also be useful in international trade as the optimum performance required would be expected to vary from country to country.

With regard to serviceability, it is important to decide whether the definition of the design limit state is to be one that can be measured directly and quickly in the event of a legal dispute. For example, it is easy to assess by direct measurement the permanent sag of a floor, or the crack width in a wall; on the other hand, it is impossible to assess by direct measurement the sway of a building in a 50-year return wind. The benefit of being able to undertake a direct measurement of failure is that it simplifies litigation; however this approach is not popular with design engineers because of the difficulty of making accurate predictions of structural behaviour, i.e. of building performance. This topic has been discussed in a previous paper [21].

Finally, a comment should be made on procedures used to assess products on the basis of testing. Obviously the closer the test approaches the in-service condition, the more useful the evaluated parameters will be for predicting performance. Unfortunately, tests that approach in-service conditions are very costly; for example, to test a structural joint under a variety of load effects (e.g. tension, compression, bending, shear, etc.) due to a variety of simulated earthquake loadings would be prohibitively expensive; in practice this extensive testing could only be used to calibrate simpler procedures. However, test procedures tend to vary from country to country and it is worth bearing in mind that the test which most closely simulates in-service conditions produces the most valid results for use in predicting in-service performance. In Australia and New Zealand, there is a draft procedure for evaluating timber joint systems under simplified "in-service" loads that are intended to simulate gravity, cyclonic and non-cyclonic wind, and earthquake loads [13]. The current ISO draft for testing of timber joints under reversed cyclic loads follows the same principle [14].

7 CONCLUSIONS

The future of building codes and standards points towards a performance-based approach. They free the building regulatory system from the limitations of the current prescriptive or compliance approach. Performance based codes and standards are useful for:

- cost-optimising construction,
- promoting innovation, and
- facilitating international trade.

The key concept described in this paper is that there are three stages of building performance control; these are related to:

- building objectives,
- in-service performance, and
- characteristic values.

At each stage, four procedures may be used to assess performance:

- compliance methods,
- computational methods,
- testing methods, and
- combined computational and testing methods

The last three are defined as performance-based methods; however, all four methods are intended to produce the same in-service performance.

Reliability methods are extremely useful in establishing target performance and evaluating performance. Formats for performance-based design codes are more flexible and useful if they include procedures for obtaining several values of performance. Test procedures become more effective the closer they approach in-service conditions. Finally, consideration should be given to the benefits and difficulties that would arise if serviceability limit states were defined in such a way that the occurrence of a failure could be checked by simple and quick measurements.

8 REFERENCES

1. Australian Building Codes Board, *Building Code of Australia*, ABCB, Canberra, Australia, Vols. 1 and 2, 1996.
2. Ayyub, B.M. (Ed)., *Uncertainty Modeling and Analysis in Civil Engineering*, CRC Press, Boca Raton, 1997.
3. Becker, R. and Paciuk, M. (Eds)., *Applications of the Performance Concept in Building*, Proc 3rd CIB-ASTM-ISO-RILEM Intl Symposium, National Building Research Institute, Haifa, Israel, Vols. 1 and 2, 1996.
4. Becker, R., Research and development needs for better implementation of the performance concept in building. *Automation in Construction* (in press).
5. BRI. *Procs. Intl. Workshop on Harmonization of Performance-based Building Structural Design in Countries Surrounding the Pacific Ocean*, Building Research Institute, Tsukuba, Japan, 1997.
6. CIB, Working with the performance approach to building. Report of Working Commission W60, Publication 64, CIB, Rotterdam, 1982, 30p.
7. CIB, Performance requirements in buildings. Key papers, CIB, Rotterdam, Vol. 1, 1988. 1–263.
8. CIB, Some examples of the application of the performance concept in building, Publication 157, W60 Working Commission, CIB, Rotterdam, 1993.1–252.
9. CIB. Final report of CIB task group 11 – Performance-based building codes. Report of Working Commission TG11, Publication 206, CIB, Rotterdam, 1997.
10. Ellingwood, B.R., Reliability-based performance concept for building construction. *Structural Engineering World Wide*, Paper T178-4 (CD-Rom), Elsevier Science Ltd., New York, 1998.
11. Ellingwood, B., Galambos, T.V., McGregor, J.G. and Cornell, C.A.. *Development of a Probability Based Load Criterion for American National Standard A58*. National Bureau of Standards, US Department of Commerce, US Govt Printing Office, Washington DC, USA, 1980, 222 pages.
12. Foliente, G.C., Leicester, R.H. and Pham, L., Development of the CIB proactive program on performance based building codes and standards, *BCE Doc 98/232*, CSIRO Building, Construction and Engineering, Highett, Australia, 1998.
13. Foliente, G.C. and Leicester, R.H.. Evaluation of mechanical joint systems in timber structures. *Procs of the 25th Forest* Products *Research Conference*, CSIRO Forestry and Forest Products, Clayton, Victoria, Vol. 1, Paper 2/16, 1996, 8pp.
14. Foliente, G.C., Karacabeyli, E. and Yasumura, M., International test standards for joints in timber structures under earthquake and wind loads, *Structural Engineering World Wide*, Paper T222–6 (CD-Rom), Elsevier Science Ltd., New York, 1998.
15. Foliente, G.C., Leicester, R.H., Cole, I.S. and MacKenzie, C., Development of a reliability based durability design method for timber construction, *Procs. 8th Intl. Conf. On Durability of Building Materials and Components*, National Research Council Canada, Ottawa, Ontario, 1999.
16. Foschi, R.O., Folz, B.R. and Yao, F.Z.., *Reliability-Based Design of Wood Structures. Structural Research Series*, Report No. 34, Dept of Civil Engineering, University of British Columbia, Vancouver, Canada, 1989, 282 pages.
17. Foster, B.E. (Ed.), *Performance concept in buildings - Invited papers, Joint RILEM-ASTM-CIB Symposium Proceedings*, NBS Special Publication 361, Vols. 1 and 2, US Government Printing Office, Washington DC, 1972.
18. Gross, J.G., Developments in the application of the performance concept in building, *Proc 3rd CIB-ASTM-ISO-RILEM International Symposium*, Tel Aviv, Israel, Becker. R. and Paciuk, M. (Eds),Vol. 1, 1996, I–1.
19. Hattis, D., Role and significance of human requirements and architecture in application of the performance concept in building, *Proc 3rd CIB-ASTM-ISO-RILEM International Symposium*, Tel Aviv, Israel, Becker. R. and Paciuk, M. (Eds), Vol. 1, 1996, I–3.
20. Leicester, R.H., Durability analysis of timber construction. *Procs Pacific Timber Eng. Conf. PTEC'99*, Roturoa, New Zealand, 1999.
21. Leicester, R.H., Serviceability criteria for building codes*, Procs of Colloquium on Structural Serviceability of Buildings*, IABSE, Goteborg, Sweden, June, 1993, 69–84.
22. Leicester, R.H., Closed form solutions for cost-optimised reliability*, Procs. IUTAM Symposium on Probabilistic Methods in the Mechanics of Solids and Structures*, Stockholm, 1984.

23. Leicester, R.H., Pham, L., Holmes, J.D. and Bridge, R.O., Safety of limit-states structural design codes. *Procs. of Seminar*, Institution of Engineers, Australia, Melbourne, March., 1986.
24. LNEC, Performance concept in building. *Proc 3rd ASTM/CIB/RILEM Symposium*, Laboratorio Nacional de Engenharia Civil, Lisbon, Portugal, Vols. 1 and 2, 1982.
25. NBS, *Recommended practice for arrangement of building codes*, National Bureau of Standards, US Department of Commerce, US Govt Printing Office, Washington DC, USA, 1925.
26. Saito, T., Establishment of target performance levels, *Procs. International Workshop of Harmonization of Performance-based Building Structural Design in Countries Surrounding the Pacific Ocean*, Building Research Institute, Tsukuba, Japan, 1997, II-74–II-89.
27. Walker, G.R., Internationalisation of housing standards, *Procs. 1997 International Building Construction Standards Conference/Workshop*. Department of Industry Science and Tourism, Canberra, Australia, 1997, 102–108.
28. WTO, First Triennial Review of the Operation and Implementation of the Agreement on Technical Barriers to Trade, Document G/TBT/5 Attachment, Committee on Technical Barriers to Trade, World Trade Organization, Geneva, Switzerland, 1997.

APPENDIX A. Building Performance Matrix

PRODUCTS/PARTS \ ATTRIBUTES	SAFETY	Structural	Fire	Accident (Safety in Use)	HABITABILITY	Structural Serviceability	Thermal Comfort	Tightness (Water and Air)	Air Quality	Acoustic	Lighting	Access	Security	Condensation	Health and Hygiene	Functionality	Adaptibility	Aesthetic	SUSTAINABILITY – LCP	Maintainability	Durability	Economic	Decommission	Environmental Friendliness
WHOLE BUILDING																								
SPACE																								
Functional Space																								
Building Envelope Space																								
STRUCTURE																								
Sub-structure																								
Super-structure																								
EXTERNAL ENCLOSURE																								
Below ground																								
Above ground																								
Vertical																								
Horizontal																								
Inclined																								
INTERNAL ENCLOSURE																								
Vertical																								
Horizontal																								
Inclined																								
SERVICES																								
Plumbing (Water and waste)																								
Heating, Ventilation and AirCon																								
Fuel system																								
Electrical system																								
Communication system																								
Mechanical transport																								
Security and protection																								
Fittings																								

APPENDIX B. In-service and Product Performance

One of the main sources of confusion in discussions related to performance based codes and standards is unclear references to performance. Here, a distinction is made between 'product' performance and 'in-service' performance. *In-service performance* refers to the performance of a 'building product' *in use*. The performance is defined as the probability of 'failure' or 'non-performance'. On the other hand, *product performance* refers to the performance of a product under evaluation. The objective of performance evaluation is to obtain a *performance rating* for the product. The key component is the agreed *method of evaluation*. The measured or calculated performance may or may not relate to its performance in-service; it relates only to the specific environment by which the evaluation was undertaken.

As an example, the structural performance of a house under wind load is given below to demonstrate these differences:

IN-SERVICE PERFORMANCE	PRODUCT PERFORMANCE
Objective: safety of people in house under strong wind (user requirements)	**Objective**: to assess the structural capacity of a house to resist wind load.
Required Information: • Information on the true characteristics of wind loads (e.g., identification of relevant agents in ISO terms) • Information on the true characteristics of the house resistance to wind.	**Required Information:** • Information to convert wind speeds to wind loads. • Information on how to determine the resistance of a house under wind.
Measure of performance: Probability of failure, i.e. Pr (Wind Load > House resistance)	**Measure of performance:** Wind resistance of house in terms of wind speeds.
Evaluation procedure: • Probabilistic Modelling of Wind loads • Probabilistic Modelling of House resistance • Computation of prob. of failure for the intended life of the house	**Evaluation procedure**: By computation or testing in accordance with agreed procedures.