New Zealand Institute of Architects Incorporated

Building for the 21st Century – Review of the Building Code
Submission to the Department of Building & Housing
By New Zealand Institute of Architects

A) Preamble

1) These comments have been prepared by the New Zealand Institute of Architects Incorporated.

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2) The New Zealand Institute of Architects Incorporated (NZIA) represents some 95 per cent of registered architects in New Zealand.

3) Registered architects must :
a] possess an internationally validated degree ;
b] undertake a minimum of three years' practical experience followed by a registration exam ;
c] complete a mandatory continuing professional development (CPD) programme each year ; and
d] are covered by the Registered Architects Act 2005 and its disciplinary provisions.

4) First established in 1905, the Institute was later re-formed under the Architects Act 1963, which split its previous functions in two. The NZIA became the professional organisation for Architects, and regulatory functions were transferred to the Architects Education and Registration Board (AERB). Subsequently, the NZIA elected to become an incorporated society, and upon the passing of the Registered Architects Act in 2005 the AERB was dissolved and replaced by the NZ Registered Architects Board (NZRAB).

5) The NZIA provides practice support (such as publications and contracts), plus educational events (linked to CPD), and promotional activities (such as Awards) for its members. It maintains active links with the building industry, government and the wider community. At an international level it is a member of the International Union of Architects (UIA) and the Commonwealth Association of Architects (CAA).

6) Members elect representatives to the NZIA Council, which also includes representatives from the Schools of Architecture at Victoria University, Auckland University and UNITEC, and the chairman of the NZRAB. Policies set by Council fit broadly into the following areas : protection of public interest, practice support and membership services, professional development, education, and environment. The Institute works to provide services in these areas and to ensure members are kept abreast of developments.

7) A small management team is based in Auckland, and a network of eight branches around the country provides a local focus for members. The submission has been prepared following discussion of its contents amongst members and other industry bodies.

B) General Comment

1) The NZIA supports the submission prepared by the technical issues group of the Auckland Branch, which represents some 1,370 members of the Institute. This submission is attached.

2) The NZIA supports the Part 2 submission prepared by Roger Hay, registered architect, Wellington, attached as Appendix 1. This document has been informed by extensive dialogue on our web chat group.

3) The comments that follow in **Section C) Specific Comment** pertain predominantly to the context of the Building Code (BC) review. In this regard NZIA :

a) has taken into account input from a number of experienced architect members, some of whom have also made their own independent submissions.

b) has maintained dialogue with ACENZ / IPENZ and other industry bodies who have also submitted their professional opinions and answered questions where relevant to their interests and expertise.

4) It has not been our intention to achieve immediate consensus on certain contentious issues. The building industry is experiencing or facing serious dislocations arising from uneven application of provisions in the Building Act 2004, as amended 2005, and currently subject to further amendment proposals.

5) It may be unreasonable for us to expect a stable state to be achieved again until 2013, when Stage 3 regulations pertaining to BCA technical qualifications come into force.

C) Specific Comment

1) **Stakeholders in the BC**

a) By current definition, restricted work (the majority of building work designed and constructed in New Zealand) requires a building consent.

b) Designers (Design LBPs, Architects & Engineers) are required to demonstrate in their consent applications that their proposals, if built in accordance with their drawings and specifications, may be reasonably expected to comply with the BC.

c) Building officials on behalf of their Building Consent Authority (BCA) are required to :

- Assess if compliance can be reasonable expected or not, and grant consent accordingly.
- Inspect the works being constructed to assure themselves that compliance with consent documentation, and thus the BC, is continuously achieved.
- Upon completion issue a code compliance certificate (CCC) confirming their observation that the works have been constructed in accordance with the BC.

d) Consequently, designers and building officials are the prime stakeholders in the BC at the point of consent, and designers, contractors and building officials are the prime stakeholders at the point when CCC is granted.

2) **Structure of the BC**

a) The prime competence of Design LBPs as set out in the licensing rules will be to "comprehend and apply knowledge of the Building Act and Regulations, the BC and BC compliance documents".

b) BCA accreditation will have at its core a requirement that building officials are technically competent and capable of exercising their responsibilities in relation to the BC as set out in C)1)c)

c) The current review of the BC is in fact a radical re-write, where a new structure is proposed to re-accommodate some existing material and to introduce new material.

d) Neither the existing BC nor the proposed BC structures are particularly helpful for designers to describe the project with adequate clarity for construction purposes, and concurrently to demonstrate compliance with code.

e) Consequently, in order to avoid massive disruption of the building industry arising from uncertainty regarding core competencies of LBPs and building officials as changes are introduced, we are of the view that either :

- Change must be incremental, and built from the existing code structure, or
- The BC must be structured so that there is a logical connection between aspirations of the law, underlying regulation, means of compliance, and the actual construction process.

f) We prefer the latter, and refer to Appendix 1, prepared by Roger Hay, which is a refinement of the proposal which we published as part of our August 2006 submission.

3) **Application of the BC**

a) Statistical evidence points to the majority of building consent applications nation-wide being for relatively simple buildings. 2006 figures indicate :

- Alterations and additions (not including D.I.Y. undertaken without consent) : 40.000
- New residences : 25,000
- Apartments : 1,000
- Commercial work (generally but not exclusively larger and more complex construction) : 17,000

b) We are of the view that the BC may benefit from being structured in two parts, or as two separate documents, as follows :

- Part 1 – intended to achieve BC compliance for at least 80% of all consent applications through provision of prescriptive specifications supported by broad range of standards, acceptable solutions and certified materials, components & systems. Capable of being administered promptly with greater certainty than currently exists, reducing liability for all competent stakeholders.
- Part 2 – intended to achieve BC compliance for the remaining consent applications through outline of performance based requirements that may be demonstrated by employment of acceptable or alternative solutions, supported by consistent, well developed verification methods. Stakeholders on both sides of the BC must have greater experience and skill, and understand when collaboration with other experts is required.

4) **Certainty and the BC**

a) The “Part 1” type BC could be introduced almost immediately, to support the voluntary licensing of LBPs and the accreditation of BCAs, both targeted for November 2007. We deem this to be an appropriate response to the current condition of the building industry, where there is :

- Considerable uncertainty as to the educational background and practical experience of the majority of potential LBP Design candidates,
- Acknowledged capacity and ability limitations existing in a significant number of BCAs.

b) The “Part 2” type BC may be rolled out within a reasonably short time frame if it is recognized that :

- Registered architects, chartered engineers, and potentially some Design 3 LBPs will inevitably work together in a team environment to enhance and support the specialized skills necessary to achieve competent design for large / complex works, and
- There is no expectation that BCAs will be in a position to mirror the expertise of expert designers, so
- Responsibility to assess and confirm compliance may be satisfied by self certification by designers, or by producer statements for which design practices take full responsibility, or expert consultants may provide assessment services to BCAs in critical situations.

c) Leadership by the DBH is essential if certainty is to be achieved without delay. The effects of uncertainty are evident in the poorly structured responses to the leaky home “crisis” and uneven application of the BC in circumstances where remedial works must be consented. A brief paper on this topic by Tom Dixon, registered architect, Auckland, follows as Appendix 2.

5) **Affordability**

Statistically, the building industry contributes between 4% and 5% of the country’s GDP, and if related industry is taken into account, this figure may exceed 11% of GDP.

Uncertainty, complexity, and fear of liability are generating delays around compliance with the BC, with the direct effect of increasing building costs. The fiscal drag so created is having a profoundly negative effect on the New Zealand economy, and on the wellbeing not only of those contemplating building, but all end users who must live with the consequences of active value engineering to reduce actual construction costs in favour of compliance costs.

The review of the BC was required by the Building Act 2004, and despite enormous efforts by the DBH, this review has not progressed adequately in response to market urgencies. The NZIA would be pleased to nominate expert individuals from amongst its registered architect members to help the DBH reduce and eventually reverse the current delays and associated costs of compliance.

Prepared on behalf of the NZIA by Christopher Mason, Manager, Practice Services
30 September 2007

APPENDIX 1

PROPOSED NEW NZBC STRUCTURE

0 The *means of compliance* with this Code
- 0.1 The purpose of *means of compliance*
- 0.2 The legal status of *means of compliance*
- 0.3 The range of possible *means of compliance*

1 Uses of buildings
- 1.1 Hierarchy of hazards to buildings
- 1.2 Hierarchy of user vulnerabilities to hazards
- 1.3 Hierarchical matrix of hazards and user vulnerabilities
- 1.4 Categories of building uses
- 1.5 Compartmentation & unit titles within buildings

2 Scope of regulatory requirements
- 2.1 New buildings
- 2.2 Alterations with no change of use
- 2.3 Alterations with a change of use
- 2.4 Changes of use without alterations
- 2.5 Maintenance of compliance
- 2.6 Existing buildings: annual warranties of compliance
- 2.7 Existing buildings: extension of life
- 2.7 Hazardous existing buildings
- 2.8 Demolition of buildings

3 Sequence of building control processes
- 3.1 Title verification
- 3.2 LIMs and PIMs
- 3.3 Resource consent
- 3.4 Requirements for licensed building practitioners
- 3.5 Building consent
- 3.6 Construction inspections
- 3.7 Compliance schedule
- 3.8 Code compliance certification
- 3.9 Certificates of acceptance
- 3.10 Public use certification

4 Site performance criteria
- 4.1 Land usage constraints
- 4.2 Building over two titles
- 4.3 Site access & services
- 4.4 Natural hazards zoning
- 4.5 Site-specific hazards
- 4.6 Stability and ground bearing

5. Structural performance criteria
- 5.1 Floor loadings
- 5.2 Site-specific loadings
- 5.3 Natural hazards
- 5.4 Special Risk & Importance factors
- 5.5 Structural materials: Durability and Maintenance criteria
- 5.6 Structural materials: Embodied energy criteria
- 5.7 Specific (non-prescriptive) design criteria
- 5.8 Non-specific (prescriptive) design criteria

6. External Envelope performance criteria
- 6.1 Thermal performance criteria
- 6.2 Fire separation criteria
- 6.3 Fire venting criteria
- 6.4 Daylighting and outlook criteria
- 6.5 Natural ventilation criteria
- 6.6 Solar and wind energy installation criteria
- 6.7 Noise control criteria
- 6.8 Disability access criteria
- 6.9 Balconies and decks, etc: Safety in use criteria

7. Access & Circulation performance criteria

- 7.1 Disability access criteria
- 7.2 General circulation spaces: safety in use criteria
- 7.3 General circulation spaces: lighting criteria
- 7.4 Fire safe exitways criteria
- 7.5 Fire service access criteria
- 7.6 Stairs & ladders: safety in use criteria
- 7.7 Escalators and lifts: safety in use criteria

8. Internal Spaces performance criteria

- 8.1 Disability usage criteria
- 8.2 Lighting criteria
- 8.3 Ventilation criteria
- 8.4 Thermal & humidity control criteria
- 8.5 Sound control criteria
- 8.6 Personal hygiene facilities criteria
- 8.7 Food preparation facilities criteria
- 8.8 Laundry facilities criteria

9. Fire Spread Control performance criteria

- 9.1 Provision of fire cells criteria
- 9.2 Provision of smoke and fire alarms criteria
- 9.3 Fire safety of surface finishes and furnishings criteria
- 9.4 Smoke spread control criteria
- 9.5 Fire spread prevention criteria
- 9.6 Fire and smoke ventilation criteria
- 9.7 Use of automatic sprinklers criteria
- 9.8 Fire fighting equipment criteria

10. Equipment & Services performance criteria

- 10.1 Disability usage criteria
- 10.2 Durability & Access for maintenance criteria
- 10.4 Water supply criteria
- 10.3 Hot water supply criteria
- 10.5 Solar power and heating use criteria
- 10.6 Electricity supply: fire safety & safety in use criteria
- 10.7 Gas supply: fire safety & safety in use criteria
- 10.8 Waste water & foul water disposal criteria
- 10.9 Solid waste disposal facilities criteria
- 10.10 Industrial materials & waste: safe storage & disposal criteria

APPENDIX 2

REVIEW OF THE BUILDING CODE

There is a level of uncertainty in the wider community required to deal with the performance Building Code but who are not "industry" trained. In particular, this includes the legal profession – solicitors and barristers regularly involved in disputes particularly involving existing buildings.

The introduction of the "performance" based code in 1992 and then progressively since the expansion of prescribed means of compliance (approved solutions) particularly E2 and B1, introduced uncertainty at both the BCA level and at the legal interface with the community that which cannot be interpreted as an existing approved solution becomes a defect.

An "industry" has emerged as a result (and a newly invented consultant group) dealing with the buildings constructed inadequately to resist weather and ageing but which may have "complied" with Building Consent requirements at the time of their construction.

"Weathertight building" no longer has any room for reasonableness when litigation and dispute arises. The Code with tiered levels of compliance from generalised performance to particularised detail and gaps in between has created dispute and has forced extreme "black or white" solutions.

The proposed code does not appear to address the issue of the degree of certainty necessary to do a range of essential things in a competitive essential industry.

a) to design and document with clarity and certainty

b) to obtain a Building Consent in reasonable time and with certainty of its credibility

c) to permit unambiguous assessment of legal liability when things go wrong

Unacceptable delays and litigation costs are being generated as a result. Unnecessary refurbishment, recladding and reframing of buildings is occurring recommended by "experts" largely to remove possible future risk not necessarily to the building, but certainly to those involved. Introduction of drained cavities has become a panacea.

Ideology is overwhelming practicality. The proposed Code does not address this. There exists inadequate definition of verification of alternative solutions and breadth in acceptable solutions to allow simple judgements of compliance. If broad performance statements such as "E2.3.2 roofs and exterior walls shall prevent the penetration of water that could cause undue dampness or damage to building elements" are to exist the definition and the quantum of external moisture requires definition for the range of conditions and materials that exist in buildings.

As an example, NZS 3602 identifies treatment and end use but judgement is necessary to determine that ±18% is probably okay for H1.2 treated Radiata – (not zero %).

These judgements will remain in a normal industry and there will continue to be unnecessary and escalated remedial work undertaken to satisfy presumed BCA minimum standards. In some cases "unnecessary" wholesale stripping and reconstruction to introduce drained cavities, to previously approved "direct fix" clad homes and commercial buildings. (Because the BCA will not accept the presumed risk of approving anything else).

Many "leaky" home owners will continue to have difficulty to find anyone competent or willing to undertake reasonable repair of their homes due to the uncertainty of what is reasonably acceptable and the excessive costs of the alternative. Existing restrictive conservative approved solutions are inadequate in scope.

The inequitable background of Joint & Several Liability does not assist the community in solving the problem.

In summary, if the Performance Code is the internationally accepted direction for codes then greater emphasis or definition and verification to remove the excessive uncertainty demonstrated to presently exist. Excessive costs of extravagant remedial work and costs of litigation will continue to rise. This must be addressed by a wider audience than the Building Industry and DBH. Experienced representation from the Law Society and the insurance industry is essential to a healthy future community.

NEW ZEALAND INSTITUTE OF ARCHITECTS INCORPORATED

AUCKLAND BRANCH SUBMISSION

Building for the 21st Century

Review of the Building Code - Performance Requirements

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Introduction

This submission has been prepared by an expert group of experienced registered architects led by Michael Middlebrook and Alex Shaw on behalf of the NZIA Auckland Branch. The preparation has involved consultation with both Auckland Branch members and universities, and presentation to a special Auckland Branch meeting which enabled us to review our approach and ensure that we had captured the critical issues. Because some of the issues raised did not fit the question structure we have expanded the submission to include overview comments.

Key Issues

Risk of making reductive performance metrics mandatory

Currently performance is defined in quite general terms such as “adequate” and “safe” within the first schedule of the building regulations. These metrics are mandatory, gross simplifications, assumptive, are not parametrically linked and must be met regardless of other design factors. There are risks that (say) environmental sustainability aspirations may be overruled by overwrought wellbeing requirements, so that informed users do not have the freedom to design to their intended use.

New standards for thermal conditions

While ASHRAE 55-2004 has gone some way to address adaptive comfort there is still too much bias for mechanical systems. Code Review assumptions have only increased this bias.

Sustainability

A CO^2 emission criterion as the only means of achieving sustainability does not tackle the real issues. This section needs a great deal more specialist attention and should also look at risks and benefits of other clauses that may result in increased environmental demands.

Design Furniture

Culturally, what is standard furniture? Different user groups have different expectations. This should be part of an acceptable solution in order to achieve general space performance statement. There is no advantage in hardwiring design furniture as a performance requirement.

Light and connection to outdoors

As a wellbeing requirement, the range is too small. Need to look at broader use than the Canadian Government users that this technique was developed for, as there are many individual wellbeing issues that can be designed for but that cannot be codified. Wellbeing is complex and individuals have different and often opposing requirements and weightings. This is revealed through the design process. The Building Code needs to protect those that are disadvantaged while allowing freedom to those that are not.

General Overview

The following are some general comments which represent the broader views of architects who are a diverse group. Generally they are consistent but because of the timeframe for submissions are only partially coordinated and structured. While some of the views relate to how architects work, generally they relate to the desire to get better buildings whether architecturally designed or not.

It is important that the new Building Code increases the level of certainty with Code Compliance. Lack of certainty has been costly to the building industry.

The Act is supposed to be encouraging sustainability. Overall the code review is doing exactly the opposite. Part of the problem is the lack of definition and direction. Another part is that no one wants to make the necessary commitment to sustainability. Sustainability is based on diversity and complexity. If we began with the idea that sustainable architecture will always be diverse and complex we would be able to get somewhere.

Applying simple mandatory metrics to complex issues results is reductionism. This results in inefficient use of resources, a stifling of innovation, mediocrity and loss of wellbeing.

One of the aims of the Building Act 1991 was to ensure that building would be easier to achieve, cheaper and more innovative. The overall cost impact of the proposed changes should be neutral and additional requirements financed by trade off. Where additional or new requirements are put in place these should only be included to the degree that existing requirements can be modified in order to have either a neutral or a positive impact on innovative ability and affordability.

New Zealanders' building needs re the environment, sustainability, warmth and safety, well designed and well built homes are mentioned. But the review ignores the major priority "affordability"; the other items should be further down the priority list. Buildings are less affordable for New Zealanders now than they were in the past.

The complexity of additional compliance requirements continually being introduced means that improvements to skill levels will struggle to keep up with the changes.

The core idea of the new code appears to be that we can create high performance flexible buildings using inflexible metrics supported by the idea that engineers and building officials need performance statements they can easily test building performance against. An alternative to this is to allow flexibility of interpretation of how to achieve the performance requirements and therefore have flexibility in the housing stock. An example of this is the car industry where manufacturers meet safety requirements but have flexibility in achieving wellbeing and other aspirations. There is no universal vehicle, the consumer has choice in which vehicle they select.

It is assumed that you can design / build a building now and know that it will be useful in 100 years time and relevant to the community it sits in. You can't know what changes will occur in society and in a local community. So therefore, you can not know what use the building will have. Large loose fit buildings are easily adaptable but cost more to start with.

BCAs are conservative to avoid liability, and it is not in their interest to entertain innovation. They already make their own interpretations and their own rules (by stealth) and are generally adding to an already cumbersome process. BCAs are trying to eliminate risk but in reality this is not possible. A new Code will not achieve the desired outcome without the removal of the liability from BCAs so they don't feel so threatened. The concept that BCAs should be totally responsible for the quality of building is incorrect, and with the inherent costs of liability, unsustainable. It has to change, or the system will eventually fail. This is probably the single most important issue for the success of a new Code.

There is an assumption that our standard makers are capable of getting it right. Was the approval of untreated timber a robust and evidence based standard? They said it was at the time. Standard makers need better financing and more independence.

Still embedded in the Code are areas complicated by separate Acts, covering, for example, swimming pool fencing and provisions for the disabled. There is no mention of rationalizing these and they need to be replaced by performance standards and acceptable solutions to ensure consistency.

The structure seems to be a slightly confused artificial segregation of basic human needs on the one hand, building needs on the other and political / intellectual aspirations overlaid. It would probably be better if the Code decided what it was and stated it clearly. For instance "Safety in Use" is section 4 but safety is a major part of every other section. In fact the whole Code could be written with 'safety' as the basic principle (it may be more relevant). Building needs may be structural safety etc; human needs may be safety from external noise. The political / intellectual aspirations on the other hand are not generally related to safety or to an individuals immediate needs or indeed necessary to build the building, they are on overlay of 'somebody's' view of what is desirable.

So the question is, *what is the purpose of the Code*? This review does not really make that clear. If its purpose is not clear how do you set rules to achieve the purpose? How do people judge the rules and how do people know that they have complied with them?

We should not be trying to eliminate all risk. Risks that are easy to perceive and react to are good. Risks that require skill to overcome can be desirable. Insidious risks that cannot be easily perceived are bad. Risks which are difficult to calculate and which have catastrophic results are bad. Risks and the stress of risk taking are part of being alive. When the environment is safe then we often look for other ways of introducing risk. We should only compel build out risks where they are insidious or where the results will be catastrophic and then arguably only to protect third parties. A hammock on a cliff face is the temporary shelter of a rock climber. Freedom to live is the core of Wellbeing.

Why are building requirements more stringent than other areas of life? Is it because we can rather than that we need to? Just as NZ cannot influence car design, our few rules are retrospective to overseas developments and regulation and market forces probably have more influence. Yet far more people are killed by cars than by buildings. Similarly our roads kill far more people than buildings but to improve this takes more political / public effort and money, whereas tightening building requirements just puts more effort and increasing cost on the individual. So is the increasing effort and cost imposition on building owners just because politicians can, while avoiding cost and liability themselves?

The set of basic principles underpinning the Building Code appears to be incomplete. We need to establish base principles that define how the Code should respond to the aspirations contained in the Building Act. Base principles include yet are not limited to : Owners need to be able to do building work; Metrics need to be symmetrical applying to both ends of a scale; Allow building as an optimized response to a specific set of user requirements; Users are intelligent and will make good decisions when they have good information; Code requirements should aim at reducing building costs so that more New Zealanders benefit; Recognize that user groups have individual requirements and that there is no such thing as Universal Design;

There needs to be a definition of “prescriptive” other than the default one under “performance based code”.

Code structure

Question 1: What comments do you have about the way we are considering structuring the code?

General Comments

Sectional structure of the Code is logical and will suit designers with minor changes. The general section appears like a catch all. Better to create a new section for B2, E2 perhaps called Fabric. This will enable a loose definition which will enable innovation in achieving the performance requirements while providing a better place for the VM/AS required for 99% of building.

Resource efficiency - check to ensure that fire risk to property is handled correctly in terms of cost of protection versus cost of loss in terms of CO^2 emissions and replacement cost. Is the saving in not requiring property protection greater than losses due to fires? Check to ensure that fire combustion and energy required for replacement risks are not higher than the savings in requiring an optimized value of property protection. For specialised uses include equipment and artifacts. Look at wellbeing impact of loss of property

Security is sometimes difficult to achieve for some user groups and housing types and a lack of security is detrimental to Wellbeing. Renters are less able to secure their dwellings because of the cost of lock replacement and additional security features. Many window systems are currently impossible to secure as the glass is fitted from the outside. The marginal costs of changing aluminium window profiles for adequate security are minimal and would be timely with changes required to allow double glazing.

Underlying Principles

Define a series of logical principles and assumptions that inform the setting up of the Building Code. These need to be transparent and inline with other legal principles and would help align this document with other legislation as well as ensuring a consistency of approach within this document. The principles would allow testing clause content across the code to ensure consistency.

Symmetry : If we are defining one of the extremes of a range, because of the likelihood of a deleterious effect happening and there is a likelihood of a deleterious effect of similar magnitude (but perhaps not type) at the other extreme of the range then we should also define the extrema at that end. Examples are fire alarm sound level, indoor temperature, riser height.

Optimization : If we are defining the extrema, then discuss or define the optimum or target metric by way of formula or constraints and benefits of approaching that optimum.

Performance Statements in the regulations: Performance requirements need to be defined directly in terms of the aspiration or objective they are addressing, and they need to be consistent in structure across the clauses. Where the existing statement is unclear it needs to be better described to ensure that the original intent is not lost in the metric. A performance design should always be best fit against the underlying objective, not simply against a metric which is always a simplification and can not capture the whole objective. The interpretive metrics which embody assumptions and current knowledge need to be contestable and therefore contained within a compliance guideline, a verification method or an acceptable solution. This enables current research to be used, new ways of achieving the performance statement developed and unique/innovative solutions.

Informed Users : We need to ensure that users are informed of criteria that affect their critical decisions, especially when are multiple competing criteria. For market economics to optimize quality then the consumer needs information on that quality and the likely effects of accepting a particular level of quality.

Cost/Benefit : Compare societal aspirations with cost / benefit both across the BC and with other legislation & systems to ensure that limited resources are used optimally.

Compliance assessment costs reduce the ability to provide an optimum solution. Need to streamline assessment to ensure work is not being duplicated. For BCAs assessing the work of professionals the assessment should be an audit rather than a point by point check. This is in line with on site QA processes which are cost optimized focusing on safety issues with in built redundancy where high level checking is not cost effective.

User adaptation and variability : There is no such thing as a universal design. We design for cross sections of the population. We should not limit the ability to customize metrics for users groups or individuals who differ from the norm.

Safety : We need to treat different types of safety differently depending on the size of the user group. Catastrophic incidents such as falls where the user is pre-aware of the danger have risks that vary between individuals. Others such as risks from asbestos exposure are not immediately evident and we need to have a more blanket level of protection. Some people choose to skydive and similarly they should be able to choose not to have balustrades on a stair.

NZBC Clause Structure

The regulatory part of the code is a performance document, so should be based on the Building Act immutable aspirations such as safety, comfort, health, wellbeing and environment, described in the old code in terms of objectives, functional requirements and performance statements (which much of the time were in general terms such as "adequate, sufficient...". This was a good approach and is the correct level of definition for the building regulations. To go further is to make assumptions about the types of design solutions that can meet these. The the other parts of the BC should consist of a verification guideline and then a series of verification methods and acceptable solutions that follow the guidelines. These should meet both typical client aspirations and those of the code.

The Verification Guidelines are the sections that the Designers and BCAs would use to test alternative solutions. This is where suitable metrics should appear along with their application, so that other applications can be compared, along with relevant solutions, to determine whether they meet the regulations. The research and analysis would be provided by the designer and perhaps supported by a peer review or producer statement. The problem with performance Metrics is that they are one size fits all and they will seldom fit individual requirements or aspirations, and generally need to be separated from the regulations. They also fail to take into account more than one section of the BC where conflicting aspirations require a multi criteria optimized solution. Acceptable solutions could be more multiple and tailored to users from green to minimal cost to owner-builder friendly. They should be clearly headed up with their targeted user group. In many ways most buildings due to the complexities of the constraints fall a long way short of what they could be that producing all of these metrics is going to result in mediocrity. It also seems to be about engineering buildings rather than designing them. This will not result in spiritually uplifting buildings.

An example of regulatory metrics approach is: Sanitation : Water Supplies (currently G12) (refer review p53). Re-forming this to performance statement and guideline approach, we might arrive at the following:

"Water supplies should be designed with adequate capacity for their intended use." Guideline: BRANZ SR159 WEEP Final Report indicates that the expected minimum volume of water (potable?) per person per day for buildings provided with a water supply for domestic use is 250 litres based on 80% certainty. This is based on x toilet flushes/person/day at y litres/flush, v minutes/person/day of showering at w l/m ... u litres/outside irrigation, 0.48 toploader washloads/person/day. Consider grey water for toilet flushing and irrigation (formula required). Consider Rainwater harvesting (formula for collection area and TA maps for rainfall required - showing expected average and minimum rainfalls).

This approach rather than the suggested mandatory 250lpd performance requirement allows the use of perhaps more expensive water saving fittings that meet all of the water requirements with a mix of water types: potable / rain / grey and may allow properties to economically collect sufficient water separate from the municipal supply meet the performance requirement where the mandatory requirement does not allow this. 250 litres/day is not a designed performance requirement; it is an assumption of what might be an adequate water supply and does not allow the assumptions to be questioned. For some users it will probably be inadequate if the housing type does not match the WEEP study group. Note that the WEEP report is not based on modern housing and appliances but mostly aging houses located on the Kapiti coast. It recommends further research to establish NZ regional data and expected savings from water collection and reuse. This highlights another issue which is the use of mandatory metrics based on incomplete or inappropriate research.

If the IRCC eight tier structure is adopted this might place the performance risks groups, levels and criteria in the legal building code where they become mandatory. This will cause problems for both innovative and complex buildings unless the criteria are expanded to include formulae, matrices, tables, graphs and maps to establish targeted metrics along with assessment guidelines to allow innovative design around metrics. Where on code objective is in conflict with another then there should be across clause links so that data form on clause feeds into another. This will allow the designer/client to optimize the value of the building, for example heating requirements to achieve increasing thermal comfort against the resource cost of doing this. Such optimization is likely to result indifferent thermal environments for different building scenarios.

Type 1 changes

Structural performance

Question 2: What comments do you have about the requirements we are considering for structural performance?

Comments

We agree.

Question 3: What comments do you have about the performance requirements we are considering for variability and uncertainty in the design and construction process?

Comments

We assume that the requirements for structural design already implicitly capture this uncertainty. If we are going to be more explicit about these uncertainties then can we assume that safety factors will be reviewed to ensure we are not simply adding further over-design?

Safety in use

Question 4: What comments do you have about the performance requirements we are considering for barriers?

Comments

There are more factors involved than the distance of the fall. The properties of the impact surface have a considerable effect on injury related to falls. Perhaps the performance requirement is better set in terms preventing the risk of injury from falls. Therefore a greater distance would be acceptable above a garden than above concrete and where a there is a possibility of falling say 1.2m then a soft garden may be another means of meeting the performance requirement. Conversely a fall of 900mm onto concrete will may cause considerable injury and perhaps barriers should be required for falls of less than 1m onto some surfaces. Height factors could be handled in a table similar to slip resistances.

For acceptable heights for barriers within household units 900mm/1000mm may be too low for tall users. Most accidents happen in our own homes. It might be better to have a consistent barrier height. Where other design objectives conflict with a barrier solution then alternative means need to be able to be considered for safety from falling such as fall restraint systems and safety nets.

Question 5: What comments do you have about the performance requirements we are considering for slip resistance?

Comments

Agree generally with the requirements though why 0.4? What is the evidence to back up this figure? A coefficient of 0.4 may not be the best figure for all user groups. The wet slip resistance of timber decks and exterior timber stairs is a contentious issue that might be handled with required maintenance or a treatment that prevents mould growth. Roughness that aids a surface initially can allow mould and moss growth that reduces the slip resistence. Recoverability, that is ability to regain balance before a slip becomes a fall is much better for young people than it is for those that are either old or very young. Therefore slip resistances for buildings, other than stand alone dwellings, that cater for these groups could be more stringent.

Should also consider slip resistance of showers, areas where water flows across the surface, situations where water spills are common, situations where other liquids common on that surface might affect the slip resistance. Other means of preventing falls on surfaces where slip resistance is low or likely on ocassion to be low.

Should change the angle formula to provide an slope measure that is consistent with the industry and other sections of the document. Such as the angle in degrees if the fall method (1 in 20 for example) is unworkable.

Question 6: What comments do you have about the performance requirements we are considering for lighting?

Comments

Lighting has several aspects including 'safety in use' but also wellbeing. Lighting provision is generally easily supplemented and improved work performance is sufficent incentive to optimize lighting in particular workplaces. Therefore the only mandatory provisions should be based on safety and probably defined in terms of contrast. Safety in use is dependent on perception of risks. Lighting is one aspect of perception. The other aspects are visual contrast, age / visual acuity. A robust metric would be a formula with these aspects as inputs. A counterexample to minimum lighting levels for safety in use is self illuminated stair nosings currently used in cinemas on the stairs (access route).

What is the evidence for 20 lux? Should this be varied for some user groups, as the aged need more light for a given level of safety (performance). Need to define when this lighting level is required and perhaps the means of controlling it to ensure that it is on when required.

Need to capture lighting for working safety such as cooking and achieving hygeinic cleaning. The performance metric could be in terms of providing acceptable lighting levels for safety with an AS/VM setting the metrics. Another means might be a layer between the performance statement and solutions but outside the code of acceptable metrics (which then do not need to be exclusive).

Indoor climate

Question 7: What comments do you have about the performance requirements we are considering for indoor air quality?

Comments

Need to cover indoor air quality for naturally ventilated buildings even if it is just a referral to part 5.

Question 8: What comments do you have about the performance requirements we are considering for internal moisture control?

Comments

Good for schedule 1 but change item 3 to "Buildings shall have the means of adequately removing moisture generated by" Need to clarify that this requirement covers water originating in one apartment penetrating into another apartment.

Sanitation

Question 9: What comments do you have about the performance requirements we are considering for wastewater disposal?

Comments

Nil

Question 10: What comments do you have about the performance requirements we are considering for solid waste disposal?

Comments

We agree.

Question 11: What comments do you have about the performance requirements we are considering for industrial liquid waste disposal?

Comments

Perhaps a bit more on reliability. If there are any environmental or health risk resulting from failure of any particular component then we should not expect any failures in 15 years and therefore there should be a maintenance plan to ensure that there are no failures from these critical components.

Question 12: What comments do you have about the performance requirements we are considering for personal hygiene facilities?

Comments

A bath is not a reasonable option for buildings where people engage in active recreation, childcare / learning centres or workplaces. This statement could be split to provide showers for these while not disallowing baths as well. With a view to water saving this idea might extend to residential / accommodation so that showers must be provided and so the change would be simply removing the word bath.

Gyms and swimming pools as part of a hotel / motel may not require specific showers. Users can return to their rooms to for personal hygiene. This needs to be clarified.

Why do basins need to be private? Private from whom, and to what degree of privacy? Do we mean private from the same sex, and if so does that include basins, urinals, WC's etc.? Privacy from your spouse or family should not be a code requirement. Privacy based on age? Privacy based on sex? Privacy as a concept includes sight, sound and smell, are all these included and to what degree? Basins do not require the level of privacy as defined in the discussion documents. Privacy issues vary depending on whom.

Question 13: What comments do you have about the performance requirements we are considering for laundering facilities?

Comments

All household units should have access to laundry facilities. For multi-unit dwellings these could be communal for 1-2 person accommodation.

If there is no access to external lines then adequate provision for drying clothes should be provided – at minimum a space, ventilation and electrical connections for a dryer.

Question 14: What comments do you have about the performance requirements we are considering for food preparation facilities?

Comments

We agree.

Question 15: What comments do you have about the performance requirements we are considering for protection of water quality?

Comments

We agree.

Question 16: What comments do you have about the performance requirements we are considering for distinguishing between drinking and non-drinking water systems?

Comments

Need to protect all users if non-drinking water is hazardous if drunk but a special type of tap and outlet attachment probably difficult to achieve in practice.

Question 17: What comments do you have about the performance requirements we are considering for preventing the growth of harmful organisms in stored heated water?

Comments

There may be other means of ahieving the desired performance in the first statement such as silver or copper ionization. Should move the minimum temperature requirement to either a VM or an AS. Bringing the water temperature up above 60ºC or more periodically by automatic control is one alternative solution that meets the performance objective and will result in lower energy use. This is particularly important for solar heated systems with electric backup. Should compare this risk with the risk of scalding to get common temperature that does not require tempering valves to achieve.

One study has found that 60ºC in the hot water cylinders does not preclude legionella at the outlet. Refer "A Probabilistic Approach to Risk Analysis - A comparison between undesirable indoor events and human sensitivity", Katarina Ljungquist, Luleå University of Technology - 2005:45

Features for wellbeing and physical independence

Question 18: What comments do you have about the performance requirements we are considering for wayfinding provisions in the Building Code?

Comments

We agree.

Type 2 changes

General

Question 19: What comments do you have about other factors that affect the performance of buildings?

Comments

Security : There are aspects of security which the building owner may not consider and which if not addressed would be difficult to remedy later by either owner or tenant. These include ensuring windows assemblies are strong enough to resist intrusion and cannot be quickly deglazed from the outside; ensuring that external doors and door hardware are strong enough to resist entry. New Zealand has very high burglary rates and NZ homes have very weak security. Aluminium window frames for instance could be easily redesigned to both make them stronger and to provide for glazing from the inside at low additional cost. This is really the converse of your comments under storage provision as security weaknesses are not easily determined prior to purchase.

Question 20: What comments do you have about the approach we are considering for addressing tsunami risk?

Comments

Agree with provision for very important buildings such as hospitals and refuges such as schools in smaller coastal communities.

Question 21: What comments do you have about the performance requirements we are considering for flooding?

Comments

Agree with change to 1 % AEP (statistically this is slightly different from a 1 in 100 year flood i.e. 1% AEP = 1 in 99.5 years) for most building types but should exclude garages and ancillary buildings. Provision for extra protection for buildings in Civil Defence plans for refuge from flooding related to less frequent storm events might be considered. Refer New Orleans Superdome use post Hurricane Katrina.

Question 22: What comments do you have about tolerable impacts?

Comments

Need to look at post event modes and what is required of the building to meet these. For hospitals it means maintaining services, access and circulation. Need to review non-structural components and related detailing for seismic resistance. This was the major issue following the 1994 Northridge earthquake in California for hospitals.

Refer: Whittaker & Soong ATC-29-2 "An Overview of Non-structural Components Research at three U.S. Earthquake Engineering Research Centers" and FEMA guidelines

Question 23: What comments do you have about the assignment of buildings into the Performance Groups in Table 9?

Comments

Agree. Might add radiation and biological hazards as examples in PG5. There are major steps in performance requirements at minor steps in user group population. This step is at an arbitary value and perhaps this should be handled by a linearly increasing risk multiplier applied to the PG2 buildings so that the arbitary step into PG3 is not so high that it affects project viability or the ability to expand capacity for buildings just under the thresholds.

Support a wider use of performance groups for other code objectives (but of course different groups) where these are useful such as wellbeing objectives and non structure related safety. This would allow the setting of more appropriate metrics increasing the cost efficiency of code measures.

Water treatment facilities should be included in PG4 as they are an essential post disaster health requirement.

Question 24: What comments do you have about the performance framework that we are considering?

Comments

Where metrics are specified, will need further definition. 1% AEP for surface water entering a hospital does not match the tolerable impact for PG4 for flooding. Any surface water in the clinical areas of in a hospital would be catastrophic because of contamination and the probability of infection. For hospitals this should be at most 0.02% AEP. Absence or presence of flooding and the related infection risk are almost discrete i.e. it either exists or it does not exist. Therefore the effects of surface water will not follow the impact scale but jump from insignificant to severe over a very small range of likelihoods.

Moderate impact for earthquakes on the other hand means that the building is still fully operational, and any effects can be remedied within a short period. The argument is that there needs to be exceptions within performance groups for specific types of events where there is a disproportionate impact for that event compared with other uses in that group i.e. based on real impacts for a specific use. Flooding within building carrying highly toxic gases may be far less significant than an earthquake while in a biotechnology facility any flooding may be catastrophic.

We agree that Tsunamis should only be considered under PG4 and PG5 groups. This is because of their very low probability and very catastrophic nature (therefore high compliance cost compared with benefit. There is higher uncertainty in calculating the risk compared with weather and local seismic events. There is ususually sufficient warning for lower performance user groups to evacuate.

Question 25: What comments do you have about the requirement we are considering for buildings to meet the performance requirements for their intended life?

Comments

Agree in principle but compliance costs may mean that this is not cost / energy effective to monitor. Also we would expect some deterioration during a product's life which may affect performance such as sagging of insulation, deterioration of seals in double glazed units which should be left up to the owner to decide whether replacement is cost effective or not. Best way generally is to ensure that degradation is considered at design phase, require a maintence manual for the performance items and let the owner manage. One municipality in the UK has done aerial photographs of all houses using a a thermal camera so that they can identify houses emitting the most energy and alert the owners, but this is a hit and miss approach.

Intended life is based on a concept of use and the buildings ability to comply with the requirements of the Code for that use. Changing use and changing codes theoretically changes the intended life. So the intended life of a building could be longer than the initial use life, but you can't forecast what future use will be, therefore what the intended life will be. Long term intended life for the whole building is a fraught concept; however intended life of essential safety elements may be appropriate and more realistic. For argument's sake, structure may be considered for 50 years while an infill panel might only need to last 25 years (without requiring maintenance).

Question 26: What comments do you have about the performance requirements we are considering for durability?

Comments

We Agree.

Question 27: What comments do you have about the requirement we are considering for designers to nominate an intended life for a building?

Comments

Nominating a lifespan for a building is reasonable for resource efficiency calculations but it may be harsh to require demolition / removal at the end of its life, or to allow BCA's discretion in relation to this. The building should by right be able to be reassessed at the end of its nominated life and any deficiencies of the building in relation to the building code in force at that time remedied to provide for a further nominated life if this is economic and best use of resources. It is only if this cannot be achieved, and the building has no historic significance, that the building might be required to be demolished.

Question 28: What comments do you have about the requirement that an 'intended life' of at least 100 years must be used where the building or building work has 'permanent' effects on other property?

Comments

Agree that 100 years is an ideal period for building work that is required to provide support or protection to neighbouring property, but putting a life of 100 years on ground anchors seems very optimistic, we do not believe they are capable of lasting that long without unrealistic maintenance.

Question 29: What comments do you have about the performance requirements we are considering for building maintenance?

Comments

Agree that maintenance requirements should be included with the Building Consent documents as part of overall resource efficiency. Owners Manual could be a building fixture perhaps adjacent to the hot water cylinder but need to assess the value of this versus cost. Optimum maintenance strategies change with time. Agree that owners should not be compelled to carry out maintenance. The cost of BCA record keeping will be increased and passed on to building owners, adding to the growth in cost increases.

We should design buildings and building components to ensure safe maintenance. Windows for example, should be designed so that they can be glazed from the inside. This would also greatly enhance security. Some manufacturers (particularly NZ manufacturers) provide limited information on maintenance. Many manufacturwers overstate the requirements (some ridiculously so) for maintenance to avoid liability and to limit guarantee claims. This brings into question the true relevance of maintenance information and whether the 'required' maintenance is really cost effective for the owner. Regular washing of roofs is currently required for profiled roofing guarantees. This is potentially dangerous for those that can only afford to do it themselves.

Type 2 Changes, Performance for Intended Life (1) – Maintenance – "Designer shall satisfy the BCA that the proposed maintenance and replacement arrangements are practical and are a viable means of achieving compliance for the life of a building". This is unrealistic if acceptance is subjective; BCA's are difficult to satisfy if their acceptance is discretionary and involves accepting an element of risk. They tend to avoid liability without consideration for the financial position of the building owner. Maintenance information should not be linked to building consent.

Structural performance

Question 30: What comments do you have about the requirements we are considering for structural performance?

Comments

If demands might alter the capacity, then like the intended life, some possible future demands might be opted out of, supported by a plan to improve the structural performance if this is required in the future for a likely future demand that has been excluded. Example – undeveloped loft storage in a garage being developed but requiring strengthening to achieve.

Deflection causes more problems than structural failure, even structurally acceptable deflections can cause issues for the rest of the building and the feeling of wellbeing. Although deflection can be accommodated if the building is designed to do so, it is difficult and increases the risk of other building failures. We do not believe that enough is understand about deflection, both during construction and post construction, on the whole building. It is a complex area of short term and long term effects that needs more consideration.

Question 31: What comments do you have about the measure we are proposing for concurrent demands?

Comments

Can't use annual probability of demands happening at the same time in this way. 1/100/annum * 1/100/annum = 1/10000 of both events happening within a year but not of happening at the same time. Unless safety systems take a year to reinstate and the building continues to be used then the probabilty of concurrent demand is much lower. Likelihood of a random event is an exponential function and the real probabilities need to be calculated using the correct function with reinstatement time stated. More likely is increased risk of fire after earthquake or flood pressure and wind pressure happening concurrently from a single event.

In addition, if concurrent events are implemented, then embedded safety factors should not be accumulated in the solutions.

Question 32: What comments do you have about the requirements we are considering for the performance framework for structural performance?

Comments

We agree.

Safety in use

Question 33: What comments do you have about the performance requirements we are considering for restricting access to hot surfaces for buildings with vulnerable populations?

Comments

We agree that that there may be a need for these but only for very restricted populations. In housing, hot surface burns from portable appliances are more likely (toasters, irons and heaters - how can these be controlled?) and vulnerability is only for a few years and best handled with temporary measures such as screen around a wood burner or supervision. Burn times are not discrete as indicated, but a continuum and there is no sudden change between children and adults. Burn times depend on actual age especially for children and are likely to continue to increase through early adulthood. Therefore temperatures providing for burn avoidance will depend on actual age.

The graph will not be linear but dependent on skin thickness, reaction time and learning. An intermediate school may be adequately served with a temperature of 55ºC while very young children may be seriously burnt at 50ºC. Very old people have problems with reflexes and 55ºC might be too hot for aged care facilities. Solid surfaces should be treated differently from liquids as the burn risk is very different for a given temperature. Some very hot surfaces will not burn because their conductance and heat capacity are low. Solid surfaces present less of a risk and beach sand / tarmac will often be at much higher temperatures than 55ºC in summer). To rationalise you could use a simplified risk matrix based on population size, age of youngest user, accessibility of surface.

The average household contains many items, such as small appliances and equipment that are much hotter than 50°C. The average household could not function without most of them, so they can not be removed from the environment that the old or young live in. Risk from hot items has been around since the beginning of civilization and will continue for some time yet. We learn about these risks as children by touching hot surfaces but our reflexes enable us to avoid serious injury. Why use the basis that it takes 10 seconds to burn a child at 55°C? 10 seconds is a long time when pain is involved and reaction times are measured in fractions of a second. This is not good evidence on which to base these metrics.

To make only cooking elements the exception from surface temperature restrictions is too restrictive and again unrealistic. There are lots of appliances and equipment that get hot. and under certain circumstances can burn, but we need them in our lives. Most of these are loose appliances and not subject to a building consent, so unless you ban the sale of them they will always be there. This is an impractical approach; you cannot get rid of hot surfaces totally, so why heavily restrict those under the control of the Building Code?

Question 34: What comments do you have about the change we are considering to align the Building Code requirements for hazardous substances with the Hazardous Substances and New Organisms Act 1996?

Comments

Agree that the documents should align.

Question 35: What comments do you have about the performance requirements we are considering for a maximum sound level for fire alarms and other alarms used for evacuation?

Comments

Agree in principle, but query 1.8m as this is not the average ear height for most user groups. 1.6m might be better for adult user groups. Better still would be to change the wording to "any normally accessible point in the room at or below a height of 1.8m". Perhaps the base performance should be written in terms of any sound source and alarms picked up in the acceptable solution.

Indoor climate

Question 36: What comments do you have about the performance requirements we are considering for indoor air quality?

Comments

VOC's need to be handled more comprehensively including but not limited to chlorocarbons (dry cleaning) and alkanes (paint solvents, LOSP), phthalates (vinyl plasticizer) etc. Longterm formaldehyde release.

Asbestos is probably correct but is not realistic. Risk is overstated if an unacheivable level of 0 is accepted. Particulates such as carbon are a much bigger killer and are accepted in the environment (older diesel vehicles and poorly tuned petrol vehicles) Need to risk manage this whole group both in building and across all legislation.

Question 37: What comments do you have about the performance requirements we are considering for control?

Comments

Question the validity of the universal WHO recommendation because of later research which contradicts it, and the apparent withdrawal of the document from the WHO website. Mortality related to temperature varies from country to country. Health may be more related to ventilation and humidity and how these vary internally as the external temperature changes. For symmetry there should be a maximum temperature for child and aged care as mortalities related to temperature are immediate (causal), more likely with environmental change and symmetrical if a lower temperature limit is placed. For most users a minimum temperature of 16ºC on the coldest days may be more appropriate. If air changes are reduced to achieve 20-21ºC at low external temperature then there will still be mortality from cold related illness due to increased relative humidity and recirculation of pathogens. If reducing sickness and mortality are the objectives then a formula / matrix based on a wider research base may better met the objective.

Adaptive comfort will vary depending on location. Will need different parameters for different parts of New Zealand perhaps using effective temperature contour maps to provide inputs to a tool for calculating the design temperatures for particular buildings.

Assumptions:

Expectation will influence the degree of dissatisfaction at any given temperature

There is a degree of physiological adaptation to environments which can be linked to potential energy savings

Relative humidity will be higher for naturally ventilated spaces and especially for Auckland

Naturally ventilated spaces might use ceiling fans with air velocities greater than 0.18 m/s to adequately achieve comfort above 28.5ºC and this needs to be part of the "metric"

Where there is a predictable expected temperature then people can dress more appropriately. Where there are swing temperatures there will be a discomfort lag while clothing is adjusted.

Thermal effects of radiative surfaces may be greater than the Olesen & Brager model

The Olesen & Brager paper was done for ASHRAE and as such is biased toward HVAC systems. While discussing natural ventilation models it accepts that users in naturally ventilated buildings have lower PPD's for a wider range of temperatures but then offers an untested hypothesis as to why that might be so, which does not contradict the study. The finding that users in naturally ventilated buildings tolerate a wider range of temperatures indicates either of two conclusions. The first is that if we accept the untested hypothesis then it means that the PMV PPD only applies to spaces thermally conditioned by mechanical HVAC and second if we don't accept the hypothesis then the Olesen & Brager conclusion is incorrect and that the PMV-PPD conclusions are flawed.

The proposed thermal comfort range seems to be more stringent and more simplistic than ASHRAE 55-2004. This document handles the full range of humidities which greatly affect comfort. There is a big difference in comfort at 70% humidity over 40% for a given temperature. Further why 85% satisfaction? If anything we should be aiming lower than this as NZ has lower per capita income and would probably spend building capital in a different way.

Another way of ensuring thermal comfort which is also much more environmentally sustainable is use adaptive comfort. This is a more complex approach and study findings for naturally ventilated spaces should to be tested over a period sufficient for thermal adaptation in HVAC conditioned ones that are set up to replicate the temperature profile for the naturally ventilated findings. For HVAC conditioned buildings it might well be found that an even greater range of temperatures can be adapted for as the thermal swings may be more controllable allowing greater ability to adapt by adjusting clothing. Results from studies looking at the effects of psychological and physiological conditions appear contradictory depending on the interest group that has undertaken them, but studies suggest a range of 17.8 <Tn<29.5 (Szokolay) would meet an adaptive PMV 80. This ties in with the health aspects of temperature, would allow a greater range of buildings to be able to use natural ventilation and passive systems, result in reducing energy demands over time as society readapted through fashion and behaviour to wider seasonal indoor temperature differences.

A general comment on code symmetry is that for wellbeing, air quality is only one aspect and perhaps we should not delink some aspects and make them mandatory when other aspects are not even considered. Overall wellbeing is complex and air quality for wellbeing is a very small part. Perhaps it is better to concentrate on codifying the health aspects of air quality while giving good guidance for best practice for the wellbeing aspects of air quality.

We also question why a PMV of 85% rather than the ASHRAE 80% or a lower figure. If we are considering design minimums then the effects of using a PMV 80 will have an impact only on the days and times where the temperature sits outside the PMV 85 range and then only if the user group is as sensitive as the PMV sample group.

In summary, the metric for optimising thermal comfort will be complex and needs to be informed by ongoing research. It needs to take into account humidity for naturally ventilated buildings in humid environments and be flexible enough to favour naturally ventilated buildings in most NZ sites. It needs to acknowledge a wider use of CLO, air velocity radiative surfaces and localised conditioning to achieve thermal comfort. Certain environments with casual users will need closer control as there is less ability to achieve adaptive comfort. Health facilities and users with special needs may also need to be treated differently as ill people have less ability to regulate their temperature but this is more for health than wellbeing.

Refer also to the appendices: "Thermal Comfort Models", Dr Regan Potangaroa, Associate Professor of Architecture, Unitec, which is a specific response to this question.

Question 38: What comments do you have about the performance requirements we are considering for internal moisture control?

Comments

High relative humidity is not a health problem in itself; it only becomes one when associated with high temperatures or the growth of pathogens / detrimental organism. Some detrimental organisms flourish at relatively low relative humidities and the correlation between health issues and relative humidity is moderate. Lowering humidity is only one component of reducing the health issues associated with these organisms. Organisms grow on surfaces not in the air and other important factors include the hygroscopic properties of materials, surface temperatures and air movement/humidity adjacent to surfaces. These need to form part of a energy/cost optimised solution, the metric should be in a form that allows this optimization and the AS should set out a simple way of achieving this. Refer: "Indoor Humidity and Human Health: Part II - Buildings and Their Systems" Arens & Baughman.

Actual metric is therefore a contributer to the performance objective and should not be a performance requirement but perhaps an acceptable means of establishing the performance requirement, as part of a VM or AS. A VM might use multicriteria to allow an optimum solution for a specific design. I.e. take into account temperature, humidity, radiative surfaces, occupancy and surface contaminants.

Sanitation

Question 39: What comments do you have about the performance requirements we are considering for recycling facilities for solid waste disposal?

Comments

We agree.

Question 40: What comments do you have about the performance requirements we are considering for water temperature for personal hygiene?

Comments

Do we know that 50ºC is the correct temperature for all applications? Is there a problem with 55ºC for all user groups. This metric might better be described in terms of the intended user group with the VM picking up 50ºC for public facilities, 45ºC for Childcare facilities, perhaps a higher temperature is appropriate for facilities where the water supply is heated to 60ºC, line losses are 5-10ºC and the outlet temperature varies between 50ºC and 55ºC. This might save having a tempering valve where the there is no risk of scalding for the intended user group. (Surf Club, Shearers Quarters, Milk Shed). Our home tank is set at 60ºC and basin outlets vary between 52ºC and 55ºC with no appreciable risk of scalding for our children. The additional cost of tempering valves would be inefficient use of resource.

Question 41: What comments do you have about the performance requirements we are considering for accessibility for laundering facilities?

Comments

We agree.

Question 42: What comments do you have about the performance requirement we are considering for storage space for cleaning equipment?

Comments

We agree. The "according to intended use" is good.

Question 43: What comments do you have about the performance requirements we are considering for capacity of water supply systems?

Comments

Strongly disagree. This figure takes no account of the user, the type of connection, landscape irrigation requirements. Mix of drinkable and non drinkable water. The 80% household water use from the WEEP study is a poor indicator because the user group is atypical of new houses and the water use was so variable across the households. The WEEP study was conducted on 12 Houses on the Kapiti Coast. We discussed this in the introduction but a bette rmetric might be:

"Water supplies should be designed with adequate capacity for their intended use." Guideline: BRANZ SR159 WEEP Final Report indicates that the expected minimum volume of water (potable?) per person per day for buildings provided with a water supply for domestic use is 250 litres based on 80% certainty. This is based on x toilet flushes/person/day at y litres/flush, v minutes/person/day of showering at w l/m ... u litres/outside irrigation, 0.48 toploader washloads/person/day. Consider grey water for toilet flushing and irrigation (formula required). Consider Rainwater harvesting (formula for collection area and regional authority maps for rainfall required - showing expected average and minimum rainfalls).

This approach rather than the suggested mandatory 250lpd performance requirement allows the use of perhaps more expensive water saving fittings that meet all of the water requirements with a mix of water types: potable / rain / grey and may allow properties to economically collect sufficient water separate from the municipal supply meet the performance requirement where the mandatory requirement does not allow this. 250 litres/day is not a designed performance requirement it is an assumption of what might be an adequate water supply and does not allow the assumptions to be questioned. For some users it will probably be inadequate if the housing type does not match the WEEP study group. Note that the WEEP report is not based on modern housing and appliances but mostly aging houses located on the Kapiti coast. It recommends further research to establish NZ regional data and expected savings from water collection and reuse.

Question 44: What comments do you have about the performance requirements we are considering for drinking water?

Comments

Agree with the provisions for the use with people with disabilities. Quality of drinking water should look at the minimal safe level for water collected on site which may not need to be to the same standards as the NZ Drinking Water Standard 2005. After all, many public supplies fail to meet this standard without apparent health afects. This provision may result in new houses requiring additional treatment in order to get a BC if the public supply is sub standard. Water provided to a large user group needs to be to a greater consistent standard than for individual households as there is less individual control of quality for the larger group. Standards for individual housing need to be based more on health than taste and be economically achievable so may not eliminate all health risk.

Referring to Table 5: More attention needs to be paid to hose taps and irrigation connections because of their potential to allow water supply contamination.

The wording in Table 18: Drinking Water – The description “must be suitable for disabled.” It could, if worded badly, include commercial kitchens and similar activities. This is probably not the intention and would be very unreasonable if it is.

Question 45: What comments do you have about the performance requirements we are considering for raw water?

Comments

Raw water for drinking should be allowable if contamination can be controlled.

Schedule 1 should only concern itself with water quality and not make assumptions about the suitability for drinking of raw water which might then prevent innovative solutions. The VM can discuss the procedure for checking the design to see if it results in safe water. The AS might include an acceptable strategy for ensuring safe water for rainwater collection.

Question 46: What comments do you have about the performance requirements we are considering for continuous identification between drinking and non-drinking water systems?

Comments

Agree, but there may be a need for further differentiating water quality and grades for users that are highly managing their water conservation. For instance, grey water 1 (from personal hygeine uses) – suitable toilet flushing untreated, greywater 2 (laundry, kitchen) – suitable for direct subsoil irrigation after filtering, treated rainwater – suitable for drinking, raw rainwater with initial diversion - suitable showering. These of course are additional to the base requirement. A more general requirement might be that there needs to be continuous identification of different qualities with an NZ standard code for drinking water, and codes for other water types to ensure easy identification throughout the reticulation.

Question 47: What comments do you have about the performance requirements we are considering for water reuse?

Comments

Should be able to use grey water for domestic use within guidelines, especially within a VM but also within an AS. Should be able to use untreated filtered grey water for subsoil irrigation (refer NSW guidelines). Need to keep compliance costs to a minimum therefore systems for domestic use should have minimal monitoring requirements. Outdoor use should allow higher E-coli than internal uses. Contradiction between test and performance changes.

Features for wellbeing and physical independence

Question 48: What comments do you have about adding multi-unit dwellings to the list of buildings that must provide an accessible route with features for people with disabilities?

Comments

Agree but need to define scale, multistorey yes, semidetached, no. Percentage of disabled units in multiunit with accessible routes. Aim should be to make a whole development accessible if possible but requirement would be too onerous for many sites.

Type 3 changes

Resource efficiency

Question 49: What comments do you have about using CO2 emissions to measure the resource efficiency of buildings?

Comments

Should codify CO^2 equivalents but write VM and AS to CO^2 initially with guidance on equivalencies so manufacturers understand direction and consider all appropriate green house gases in their planning. Construction waste in landfills can produce CH4 by anaerobic decay. Need incentive to capture landfill CH4 and burn off or use as energy source. Some greenhouse gases are extremely problematic at any level such as SF6.

Starting with CO^2 allows development of he record keeping path but enables other gases to be easily picked up once established especially CFC's, HCFC's and methane. The Schedule 1 performance requireemnt should be written in terms of minimizing green house gases (not minimizing CO^2). The VM/AS should be written in terms of CO^2 emissions and the VM should also discuss the other gases and their equivalencies. Equvalencies should be by formula based on environmental persistence and green house effect. SF6 is extremely bad on both counts and should not be permitted as an emission in the manufacture of building materials used in NZ. Considering life cycle emissions is fraught as processes for recycling materials after 20 years + are unknown today but recycling missions need to be considered.

Refer: "Recent Greenhouse Gas Concentrations", T.J. Blasing and Karmen Smith, 2006 l appendices.

Question 50: What comments do you have about limiting the maximum heating or cooling for maintaining the indoor temperature within the comfort range?

Comments

We should allow designers / clients to select the design temperature range in order to optimize individual user groups requirements against energy use and cost for local conditions. There will always be a trade off. PMV 80 may be too high a hurdle and refer comments under that section. Option of higher user interaction (adjusting clothing, lifestyle) to ensure comfort over a wider temperature range versus decreased energy use and cost. Could also relax the likelihood of the design temperature range failing to be met (increase the allowable risk of this).

Because of the complexities involved, building owners need the freedom to develop their own criteria based on actual use and current environmental data. With well designed passive solar in much of NZ there should be little need for HVAC heating and cooling. When it is required we need to extend the load period or use a long term storage medium to reduce peak demand for power. Much power is wasted by poor energy management, that is heating and cooling spaces that either do not require it or where the loading will shortly change between heating and cooling. Need to be clear what on what if any environmental conditions are required for various spaces in a building. Spaces used only at specific times duing the day or buildings that allow movement for comfort reasons between spaces could have those spaces designed only to achieve the design conditions when required and be otherwise outside the environmental range. Natural ventilation is an option for nearly all NZ building and the BC needs to support/promote its use rather than subvert it.

Refer " Sustainability and the Role of Natural Ventilation for High Rise Buildings in New Zealand", Potangaroa, Unitec, 2004.

Question 51: What other comments do you have about resource efficiency?

Comments

Agree on resource efficiency objectives as one of the strategies. But CO² emissions path appears complex and perhaps should be rationalised in the AS to reduce Compliance costs (which also produce emissions and should be considered in the overall structure). Should also look at building location relative to user demographics and amenities not provided in the building. For this there should be a project forecast that plugs in to wider objectives such as regional planning. Building user transport contributes 1/2 of energy costs to the overall running of a building (disregarding embodied energy) and this energy use results in even higher CO² emissions because of hydro / wind contribution to the building operating energy. This needs to be part of the equation because it will help developments on sites with poor environmental aspects (shading, wind exposure) that are close to public transport/cycle ways or user populations. This will result in pressure for TA's to put in better public transport and cycle networks as part of regional planning.

The definition of sustainability does not discuss the objectives. We assume that they will be both national and international. Sustainability in the long term must consider both national sustainability and local sustainability and that this may ultimately lead to high levels of self sufficiency, both national and local. With oil running out and global warming it is difficult to predict if global trade will be able to continue as we know it or how capable New Zealand will be at self sufficiency. The Building Code needs to recognize this and engage in what is relevant and what is not. Slightly higher CO² choices may be acceptable when local products are used as there will be more certainty that the measured CO² emission content is accurate and portions of the supply chain have not been missed.

CO² emissions are only one part of achieving sustainability and the Kyoto Protocol itself will not ensure that green house gases are reduced enough to stop climate change. We need a strategy for sustainability with low energy impact options throughout the Building Code. Minimizing energy use is not the same as minimizing CO² emissions. Low carbon energy has its own environmental impacts and tradeoffs may mean that “carbon neutral” energy is merely balance by increasing the carbon content of regular energy, smoke and mirrors. We also need to consider: impacts on ecosystems both direct and indirect, the reduced biodiversity of plantation forest over native forests or regenerated forest, and transport options for particular sites for cost in use.

Fire safety

Question 52: What comments do you have about the matters under consideration to specify fire design scenarios and performance requirements?

Comments

Consider water supply for fire fighting for category 4+ buildings. Consider muiltievent scenarios for critical occupancies. Fire following earthquake for instance. Protected routes need to be free of debris from glazing ceilings and services. Consider disaster planning scenarios. Major quake in downtown Wellington for instance is a greater life risk than fire. Consider that other fire design techniques might still be valid and that the verification method may not fir all designs or user groups. Some of the alternative strategies that have been used to date might result in better design. For instance human behavior is unpredictable within the fire cell but is also unpredictable beyond that fire cell so property protection within an occupancy might also be important. There may be break throughs in fire design or alternative theories that still need testing and innovation in fire design should still be provided for

Question 53: What comments do you have about the fire design process being considered?

Comments

An improvement if we have the risks right. However domestic risk of loss of life is higher than commercial and there is little provision for domestic. Houses are where most deaths in fire occur. Designed escape from up stories in domestic (alternative route and or safe path). Fire appliance access for domestic. Safety is more important than other factors in the Code, it makes more sense to reduce other areas of the Code but keep safety.

Should check fire loss as a contributer to green house emissions from both combustion, demolition and rebuild. CO^2 emissions from property loss mitigation versus emissions from property loss x risk.

Statistically the numbers of deaths in fires and the types of buildings they take place in does not bear any resemblance to the requirements of the Code. Most people are killed in houses and none in office buildings (for some decades) so do we need more regulation for houses and less for office buildings? We need to rethink our approach to fire requirements.

Question 54: What other comments do you have about fire and emergency safety?

Comments

Access for fire fighting and persons authorized by law to enter is a very rare event for the average building. Everyday type of requirements should have a higher priority than rare events. Most people would rate everyday security to keep unwanted people out higher than letting emergency services in. Emergency services may be able to argue they are essential and their job is dangerous but to a particular building the likelihood of that sort of access is very low. So the emotional argument for the emergency services does not stack up practically when the number of events for that building is considered.

Firefighters in some countries will not enter buildings clad with refrigerator panels because of toxic gases and heat. Need to capture furniture risk. Could be done within a compliance document. Easiest where furniture is procured prior to occupation. Refurnishing would need to be consented. This would probably only apply to commercial, civic, health and education buildings. For instance healthcare bedding might be checked for both spread of fire and toxicity of smoke developed. Disaster planning also needs addressing as currently a much greater life risk than fire (for new non domestic buildings due to initial supply of disaster relief resources compared with scale).

Fire fighters will, by the very nature of building fires, always face undue risk, it can not be eradicated altogether. Firefighters access a building by the best means that suits the fire at that point in time, whether it’s the front door, a window or the roof. The statistical likelihood of the building being used by firefighters in one particular preplanned way is very, very low. Undue emphasis is put on fire service requirements for what is a statistically low occurrence for a particular building. we believe the Fire Service should have less impact at building consent stage as the fire parameters should be prestated and universally understood and not left to an inconsistent opinion when it is too late for the design of the building.

Features for wellbeing and physical independence

Question 55: What comments do you have about the requirements under consideration for a ‘design furniture’ standard?

Comments

Good as long as it is not mandatory for all users. Good requirement for developers who are interested in minimising costs (and who might be tempted to cheat when showing furniture on the plans), bad for house designers who use other parameters and methods for ensuring better design. Design for small houses should not be disallowed. Main concern for occupiers is disclosure prior to purchase so that any issues are understood. Coffin test, but coffin should generally be kept horizontal while design furniture can be rotated to the vertical to get through doorways taller than the length of the furniture. Will this result in furniture design standards or furniture coding so that users don't purchase furniture that is larger than the design furniture. Design furniture should only be in the VM/AS so that alternative uses can be considered.

A Japanese Home, for instance, will have different and smaller furniture. Social housing may need bigger furniture. Could require plans to show design furniture including access routes but allow signoff by building endusers if different criteria atre being used.

Question 56: What comments do you have about the requirements being considered for connection to the outdoors?

Comments

Agree but work needs to be done on the table and the minimum values for different housing / building types. Commercial should also have wellbeing aspects as we spend more daylight hours at work. In a factory a long view can be gained interanlly and there may be enough interest because of the size of the space that an external view becomes less important. Other aspects of connection to the outdoors need to be explored: Security from knowing that external spaces are being watched over. Connection to neighbours and neighbourhoods. Outdoor sitting on the street side is even better for this. Reducing eyestrain with a long view. Knowledge of the external climate. These aspects for different user groups need to be explored. Direct sunlight as a germicide in kitchens both bathrooms (both from heating / dessication and UV).

Natural Light – there is a conflict between insulation requirements limiting windows to 30% and natural light requirements which would like them bigger. We believe the insulation requirements are ill considered; the 30% requirement needs to be more graded allowing a larger percentage in some areas and with different amounts of double glazing. This would help achieve good natural lighting.

Generally

Access should take account for people at the height extremes. People who are either short or tall and are disadvantaged by buildings are probably more common than wheelchair users. Door heights for example can be as low as 1965mm this is low by world standards and has been the standard for many years while during the same period the percentage of people over 1950mm tall has increased several fold. Minimum height should be increased by to at least 2100mm.

Introducing changes to the Code and Compliance Documents

Question 57: What comments do you have about the factors that could influence the change process?

Comments

The timeframe for this review has been too short to get all interest groups involved in the process and too short for those interested to fully explore the issues and test them. Our review period for instance has been shorter than required and there is considerable risk that major issues have been missed.

The dividing of the changes into types is a great idea. We assume that the type 2 changes are less developed than type 1 and that further research will result in further primary changes prior to implementation when compared with type 1 changes. We feel that some type 1 schedule 1 changes are better than the type 2 changes scheduled for the same clause.

Question 58: What comments do you have about the support required for successful implementation?

Comments

The whole process is tight and the Building Official training will not be able to adjust. For BCA's to evaluate alternative solutions under VM's they will need manage a peer review process rather than undertake the review themselves. A one type suits all approach to BCA training will not work as expertise is required at a variety of levels. Better to have engineers, architects and building scientists evalute the alternative solutions with general trained building officials assessing the acceptable solution based designs. Alternative solutions will be more interdependent and cover a greater range of design constraints. They will involve complex software in their proofs and may be innovative in that they challenge the understanding of buildings are.

Question 59: What comments do you have about staging changes to the Code and Compliance Documents?

Comments

Agree with the possible implementation process. It is better to republish current code requirements under the new structure at stage 1. We agree with fixed dates for publishing discussion documents but the review time is critical so that if a discussion document date is missed the final document publishing date should automatically be extended.

Question 60: What comments do you have about introducing a regular review cycle for the Code?

Comments

Agree in principle, but some parts of the code might be marked for more regular review where research is ongoing or otherwise incomplete. Need mechanisms for triggering more regular reviews where there are problems identified in practice.

Question 61: What comments do you have about how the building sector and other key interests could feed into a review cycle?

Comments

Industry working groups and review of drafts works well. Need to engage with CIC to ensure their guidelines are updated with new requirements. Need to engage with university research including funding research on metrics to establish types of metrics that will lead to innovation and metrics that may improve wellbeing aspects of building. Need to look at future project delivery including virtual building / BIM and direct analysis of the model. Need to look at specific aspects of performance design where the design will be done by the contractor to performance parameters from the building code, site measurement and consultant team.

Appendices to Auckland Branch report

1) THERMAL COMFORT MODELS

By Dr Regan Potangaroa, Associate Professor of Architecture, Unitec.

Background

Thermal comfort is both a complex and contentious issue. Table 1 below lists the factors that affect thermal comfort. These variables are discussed in detail by Auliciems et al (Auliciems et al, 1997,1).

The impact of these factors is measured by one of the two methods below:

1). Measurement of physiological changes such as sweating, skin wettedness or skin temperature. These are normally carried out in laboratories or climate chambers.
2). Using questionnaires with simultaneous measurement of conditions, used mostly in field studies in the spaces normally occupied by the respondents.

Table 1: Factors Affecting Thermal Comfort

Environmental	Personal	Contributing Factors
Air temperature	Metabolic Rate (Activity)	Food and Drink
Air Movement	Clothing	Acclimatisation
Humidity		Body Shape
Radiation		Subcutaneous Fat
		Age and Gender

Adapted From Thermal Comfort by Auliciems and Szokolay PLEA Note 3 University of Queensland 1997 pp 8

In both situations, respondents are asked to record their comfort rating as conditions change. The response scale used is either the ASHRAE scale or the Bedford scale. These are listed below in table 2.

Table 2: Comparison of Verbal Thermal Comfort Scale Rating

	ASHRAE	Bedford
3	Hot	Much too warm
2	Warm	Too warm
1	Slightly warm	Comfortably warm
0	Neutral	Comfortable
-1	Slightly cool	Comfortably cool
-2	Cool	Too cool
-3	Cold	Much too cool

The two scales appear to be the same but there are subtle and significant differences. The ASHRAE comparative list suggests a reply at a “cognitive” level. It is outside of the respondent. On the other hand, the Bedford scale suggests an answer at an “affective” level, how did the respondent “feel”. It is inside the respondent.

The relationship between the objective measurement and the subjective response is not clear and is at the centre of the thermal comfort debate.

The debate is not resolved. De Dear reporting on new research that showed there were shortcomings in 1992 ASHRAE Standard 55-92 stated that *“…Standard 55-92, in its present form at least, is not relevant to a large part of the building stock across a swathe of global climatic regions. Therefore the Standard needs to have its scope explicitly narrowed down to those situations for which it was originally intended - namely, buildings with large numbers of occupants who have no individual control over their indoor climates. Or even better, a new section dealing with the special requirements of natural and hybrid ventilation needs to be inserted in the next revision of Standard 55".* (ASHRAE, 1992) (de Dear, 1999, 1). He has gone further than this and together with Brager has suggested a thermal comfort model for naturally ventilated buildings (Brager et al, 2000). But it noteworthy that ASHRAE standard 55 (2004) is the "son" of these earlier versions that did not then and still does not address the basic issue of thermal comfort in naturally ventilated buildings.

Humphreys had also come to this conclusion earlier in 1993 stating that thermal comfort modeling was in a *"state of crisis"* (Humphreys, 1993). De Dear's comments above put this crisis into context.

Humphreys' "crisis" was about the relationship between climate chamber studies and field studies. Researchers, using climate chambers studies, developed a thermal comfort model based on a zero balancing of energy inputs and outputs. (Auliciems et al, 1997,2). Such an approach was termed a "heat balance" or "static" model of thermal comfort and was first postulated by Gagge in 1936. Occupants were seen as passive recipients of thermal stimuli. Thus, this approach would specify a set temperature for a given activity and clothing. Fanger went further by categorically stating that thermal preferences were the same regardless of geographical location or climate. (Reported in Auliciems et al,1997, 3).

Methods such as the following were developed from this approach:

- Fanger's comfort model that became the basis for the Predicted Mean Vote (PMV) index and the Predicted Percentage Dissatisfied (PPD) index. (Fanger, 1992)
- The "two node equation" (Gagge et al, 1971)

The PMV and PPD indices became the basis for guides such as ISO 7730 and ASHRAE 1989 (ISO, 1984) (ASHRAE, 1989) and the two node equation is the basis for ASHRAE Standard 55-92 (ASHRAE, 1992) and later versions.

However, the relevance of the heat balance approach (which was based solely on climate chamber studies) to actual working conditions was questioned. In particular, the use of only fit young university students as subjects clearly represented a restricted range of respondents when compared to the variation of demographic backgrounds found in the work force. Moreover, most of those students were based in Universities in the USA consequently further restricting any demographic range. In addition, McIntyre was able to show that using the basic heat balance approach could result in a considerable range of calculated comfort temperatures depending on the accuracy of clothing insulation values (clo) and metabolic rates used (McIntyre, 1983). Clearly there was a problem.

Field studies of free running or naturally ventilated buildings did not support this "static" approach. In spite of the climate chamber testing, these studies supported the conclusion that thermal comfort did have a geographic factor. For example MacFarlane had found earlier that Europeans in Singapore preferred temperatures that were some 2^{O}C warmer than those in Sydney (MacFarlane, 1958).

In addition, Humphreys' study of the available field data showed that there was a strong statistical link between the thermal neutrality temperatures that were reported on verbal scales and the mean air temperature experienced by the respondents (either indoors or outdoors) over a period of approximately a month (Humphrey's, 1975). This is summarised in table 3 below where variance values are listed.

Table 3: Variance of Comfort Temperature Explained by the Adaptive Model

1) Free Running Buildings	Monthly Mean Outdoor Temperature	95%
2) Heating or Cooling plant in use	Monthly Mean Outdoor Temperature	44%
	Plus mean daily Max. of the Hottest Month	59%

From Naturally Ventilated Buildings Ed. Clements-Croome E&FN Spon London pp131

However, many of these field studies were critised for methodological shortcomings such as inadequate instrumentation and omission of key data such as clothing insulation or metabolic rates (de Dear, 1999, 1). This has led to the recent study completed by de Dear (de Dear et al, 2000).

Despite this, the field studies that have been done do suggest that building occupants are "adapting" to their environment. There have been at least 18 thermal comfort studies complete in the tropics with 15 of those being field studies. These studies have been compiled from the following sources:

- Karyono (Karyono, 1996).
- Auliciems et al (Auliciems et al, 1997,4).
- AIRAH publication DA20 "Humid Tropical Air Conditioning" (AIRAH, 1998).

Table 4: Thermal Comfort Studies

In Indonesia Mom and Wiesebron between 1936 and 1940(Climate Chamber) in the city of Bandung (Wiesbron, 1940) Sogiyanto in Jakarta and Bandung in 1981(Sogiyanto, 1981) Karyono in Jakarta in 1993 and in 1996 (Karyono, 1995) (Karyono, 1996)	In Singapore Webb in 1950 (Webb, 1952) Ellis in 1952 and in 1953 (Ellis, 1952) (Ellis, 1953) MacFarlane in 1958 (MacFarlane, 1958) de Dear in 1990 (Climate Chamber) (de Dear, 1991,1) (de Dear, 1991,2)
In Thailand Vechaphutti in Bangkok in 1991 (Vechaphutti, 1992) Busch in Bangkok in 1988, 1990 and 1992 (Busch, 1990) (Busch, 1992).	In PNG Port Morseby by Ballantyne in 1967 and 1979 (Climate Chamber) (Ballantyne, 1967) (Ballantyne, 1979)
In Australia In Townsville by de Dear in 1994 (de Dear et al, 1994) de Dear in Brisbane and Darwin in 1985 (de Dear, 1985)	In Pakistan Nicol and Roaf in 1996 (Nicol et al, 1996)

These are tabulated in table 4 above with those studies done in climate chambers marked accordingly.

There was no general agreement between these studies but the following conclusions appear to be valid (Karyono, 1996):

- Actual comfort temperatures were higher then that predicted by static method. Comfort temperatures were from 1^{O}C to 6^{O}C higher than those recommended by ISO 7730: 1994 and ASHRAE Standard 55-92.
- Building Occupants in naturally ventilated buildings prefer higher comfort temperatures than those in air conditioned buildings.
- On average, Caucasian males (Europeans or Australians in these studies) preferred comfort temperatures slightly lower than those of indigenous tropical males.

Thus, there appears to be foundation for an adaptive approach (rather than a static approach) for free running or naturally ventilated buildings.

This has led various researchers to develop algorithms for adaptive comfort (Humphreys et al, 1995). The adaptive approach recognised that people will use various strategies to achieve thermal comfort. Unlike the static model where building occupants are passive, in an adaptive model the building occupants interact with the environment. Humphreys listed various adaptation strategies that building occupants use (Humphreys, 1997). Clearly, if every avenue of adaptation were available to building occupants it would not be possible to predict what they would do to achieve thermal comfort. Consequently it would not be possible to predict the thermal conditions at which people would be comfortable.

Humphreys addressed this issue by firstly noting that many of these adaptations may not be practicable as there are also constraints such as cost, gender, physiology and construction details such as fixed glazing. He suggested that the building design should be "predictable", the building environment "normal", that people have a level of control over their thermal environment and that there were no sudden or imposed changes of temperature. Given these items then comfort temperatures resulting from an adaptation process are related to the climate, to the society to which the data applied and to whether the building is consuming energy for space heating and cooling. The algorithms for adaptive models presently only account for factors relating to the climate and are listed in table 5 below.

Table 5: Algorithms for Adaptive Thermal Comfort Models

Humphreys 1975	T_n= 2.56 + 0.83 x T_i (r=0.96)
Humphreys 1976	T_n= 11.9 + 0.534 x T_m (r=0.97)
Auliciems 1981	T_n=17.6 + 0.31xT_m (r=0.95 for free Running Buildings)
Griffiths 1990	T_n= 12.1 + 0.534 x T_m
Nicol/Roaf 1996	T_n= 17 + 0.38 x T_m (r=0.975)
T_n= Thermally neutral temperature T_m= Monthly mean temperature	

Adapted From Thermal Comfort by Auliciems and Szokolay PLEA Note 3 University of Queensland 1997 pp 45-46

None of these algorithms allow for the impact of clothing and metabolic activity and it is possibly this is the reason that many practitioners and researchers remain skeptical. Fanger expressed this skepticism in a letter to the CIBSE Journal (Fanger, 1992). *"…Nicol and Humphreys have gathered data from a substantial number of field studies in various parts of the world. For "free running" buildings, i.e. buildings not heated or cooled, they found a remarkable relation between preferred temperature and average monthly temperature. People seem to be reasonably thermal neutral over a large interval of indoor temperatures. Obviously people have altered their clothing and maybe also their activity to maintain reasonable thermal neutrality at even quite high or low temperatures.*

In addition, there may also occur some physiological adaptation which would require that the occupants experience cool or warm discomfort, probably for weeks. Nicol has the intention to develop an "adaptive model" for thermal comfort. The idea is that people gradually should adapt to the temperatures that happen to occur in free running buildings. The application of this idea provides an important energy conservation potential. This idea may well work in dwellings for people who desire to save and also are ready to suffer a certain discomfort during the adaptation process. It may well be interesting to follow the progress of both Nicol's studies but the idea of adaptation is in contradiction to the basic rule in ergonomics; that the machine should adapt to the human. In contrast to this it is Nicol's idea that the human should adapt to the machine (the building). This principle, especially the physiological adaptation is probably less likely to be acceptable in office buildings."

Should the human adapt to the machine? Either way, it is clear that there remains a gap between these two approaches.

Nonetheless, researchers and practitioners appear to have accepted static modes of thermal comfort for air conditioned buildings where people do not have any control over the indoor climate. However, for naturally ventilated and presumably hybrid buildings (having both natural ventilation and some centralised air conditioning system) adaptive modes of thermal comfort should be used (de Dear, 1999, 2).

Adaptive Thermal Comfort Model

The most widely used adaptive model is the Auliciems model (AIRAH, 1998). This is also supported by recent work by de Dear who suggested a similar model (de Dear, 1999,1).

Auliciem's model is as follows:

T_n = 17.6 + 0.31 x T_m

(For free running buildings the correlation coefficient was r=0.95)

T_n = Neutral Temperature

T_m = Mean monthly outdoor temperature.

Aynsley suggests that a thermal comfort range of ±2.5°C above and below this neutral should be included. This comfort range would ensure that 85% of people surveyed are satisfied (Aynsley, 1996).

De dear and Brager have suggested a more recent model that is anticipated to replace the Aucliems model but it is not clear if that is the case as many in the field appear to have remained with thermal comfort models they know. That aside, their model remains the most current and certainly respected. And is as follows:

$T_n = 17.8 + 0.31 \times T_{a(out)}$

T_n = Neutral Temperature

$T_{a(out)}$ = an arithmetic average of the mean monthly minimum and maximum daily air

temperatures for the month in question.

Humidity and Wind Speed.

This lower limit of the thermal neutrality zone also had to be modified to allow for the beneficial cooling effects of wind flow and the increasing of the neutral temperature and the detrimental effects of humidity and the consequent lowering of the neutral temperature. The criteria suggested by MacFarlane were used (MacFarlane, 1958). These criteria were as follows:

For each 10% increase in relative humidity above 60% the thermal comfort zone temperatures should be decreased by 0.8°K.
For each 0.15 m/s increase of air speed the thermal comfort zone temperatures should be increased by 0.55°K for air temperatures up to 37°C

This is the thermal comfort model recommended as being the most appropriate for the tropics by Aynsley and was adopted for this study (Aynsley, 1996).

Recommendation
The recommendation is that the Brager/ de Dear model of adaptive model of thermal comfort together with MacFarlane's modification for humidity be an acceptable means of verification of thermal comfort for building operating in a naturally ventilated or free running situation.

2) Recent Greenhouse Gas Concentrations

T.J. Blasing and Karmen Smith

Updated July 2006

Gases typically measured in parts per million (ppm), parts per billion (ppb) or parts per trillion (ppt) by volume are presented separately to facilitate comparison of numbers. All pre-1750 A.D. concentrations, Global Warming Potentials (GWPs), and atmospheric lifetimes are from Table 4.1 of (Intergovernmental Panel on Climate Change) IPCC 2001 unless otherwise indicated. Additional material on greenhouse gases can be found in CDIAC's Reference Tools. To find out how CFCs, HFCs, HCFCs, and halons are named, see Name that compound: The numbers game for CFCs, HFCs, HCFCs, and Halons.

Sources of the current atmospheric concentrations are given in the footnotes. The concentrations given are frequently derived from data available via the CDIAC Web pages; many corresponding links are given in the footnotes below. These data are contributed to CDIAC by various investigators, and represent considerable effort on their part. We ask as a basic professional courtesy that when you refer to any of these data you acknowledge the sources. Guidelines for proper acknowledgment are found at the end of the page for each link, except for the ALE/GAGE/AGAGE database where acknowledgment guidelines are given in the "readme" files; links to those "readme" files are given in footnote 9, below

GAS	Pre-1750 concentration[1]	Current tropospheric concentration[2]	GWP (100-yr time horizon)[3]	Atmospheric lifetime (years)[4]	Increased radiative forcing (W/m^2)[5]

Concentrations in parts per million (ppm)					
Carbon dioxide (CO_2)	280[6,7,8]	377.3[7]	1	variable[4]	1.66
Concentrations in parts per billion (ppb)					
Methane (CH_4)	730[8]/688[8]	1847[>9]/1730[9]	23	12[4]	0.5
Nitrous oxide (N_2O)	270[8,10]	319[9]/318[9]	296	114[4]	0.16
Tropospheric ozone (O_3)	25	34[4]	n.a.[4]	hours-days	0.35[4,5]
Concentrations in parts per trillion (ppt)					
CFC-11 (trichlorofluoromethane) (CCl_3F)</< td>	zero	253[9]/250[9]	4,600	45	0.34 for all halocarbons collectively, including many not listed here.
CFC-12 (dichlorodifluoromethane) (CCl_2F_2)	zero	545[9]/542[9]	10,600	100	
Carbon tetrachloride (CCl_4)	zero	93[9]/92[9]	1,800	35	
Methyl chloroform (CH_3CCl_3)	zero	23[9]/22[9]	140	4.8	
HCFC-22 (chlorodifluoromethane) ($CHClF_2$)	zero	174[9]/155[9]	1700	11.9	
HFC-23 (fluoroform) (CHF_3)	zero	14[10]	12,000	260	
Perfluoroethane (C_2F_6)	zero	3[10]	11,900	10,000	
Sulfur hexafluoride (SF_6)	zero	5.22[11]	22,200	3,200	0.002[5]
Trifluoromethyl sulfur pentafluoride (SF_5CF_3)	zero	0.12[12]	~ 18,000	~ 3,200 (?)	< 0.0001[5]

Footnotes

1. Following the convention of IPCC (2001), inferred global-scale trace-gas concentrations from prior to 1750 are assumed to be practically uninfluenced by human activities such as increasingly specialized agriculture, land clearing, and combustion of fossil fuels.

2. For most gases, concentrations for year 2004 are given, as indicated more specifically in the footnotes below. Estimates for 1998, from IPCC (2001), are given for CHF_3, C_2F_6, and SF_5CF_3. The current (2004) concentration of SF_5CF_3 is probably around 0.16 parts per trillion (see footnote 12). Atmospheric concentrations of some of these gases are not constant throughout the year. Global annual arithmetic averages are given.

3. The GWP provides a simple measure of the radiative effects of emissions of various greenhouse gases, integrated over a specified time horizon, relative to CO_2 emissions. It is calculated using the formula:

$$GWP = \frac{\int_0^n a_i c_i \, dt}{\int_0^n a_{CO_2} c_{CO_2} \, dt}$$

where a_i is the instantaneous radiative forcing due to a unit increase in the concentration of trace gas, i, c_i is concentration of the trace gas, i, remaining at time, t, after its release and n is the number of years over which the calculation is performed.

Formula taken from page 58 of IPCC 1990: *Climate Change: The IPCC Scientific Assessment*. J. T. Houghton, G. J. Jenkins, and J. J. Ephraums (eds.). Cambridge University Press, Cambridge, UK, 365 pp.

Unless otherwise indicated, GWP's taken from: IPCC 2001. *Climate Change 2001: The Scientific Basis*. J. T. Houghton, L. G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg, and K. Maskell. Cambridge University Press, Cambridge, UK, 944 pp. [see Technical Summary (TS) of the Working Group 1 Report, page 47].

4. The atmospheric lifetime is defined as: "the burden (Tg) divided by the mean global sink (Tg/yr) for a gas in a steady state (i.e., with unchanging burden)" (IPCC 2001, page 247). That is, if the atmospheric burden of gas x is 100 Tg, and the mean global sink is currently 10 Tg/yr, the lifetime is 10 years. The atmospheric lifetime of carbon dioxide is difficult to define because it is exchanged with reservoirs having a wide range of turnover times; IPCC 2001, (page 38) gives a range of 5-200 years. In contrast, most CH_4 is removed from the atmosphere by a single process, oxidation by the hydroxyl radical (OH). The atmospheric lifetime of a gas is relatively easy to define when essentially all of its removal from the atmosphere involves a single process. However, some complications still arise. For example, the effect of an increase in atmospheric concentration of CH_4 is to reduce the OH concentration, which, in turn, reduces destruction of the additional methane, effectively lengthening its atmospheric lifetime. An opposite sort of feedback applies to N_2O: an increase induces chemical reactions leading to an increase in ultraviolet radiation available to photolyze the N_2O, thereby shortening its atmospheric lifetime (IPCC 2001, Section 4.1.4). Such feedbacks are accounted for in the above table. The short atmospheric lifetime of ozone (hours-days) precludes a globally homogeneous distribution; ozone concentrations, and associated radiative effects, are greatest near its sources. The "current" value given is an estimate of the globally averaged value, from IPCC (2001), Table 4.1.

5. Increased radiative forcing is the change in the rate at which additional energy is made available to the earth-atmosphere system over an "average" square meter of the earths surface due to increased concentration of a "greenhouse" gas, or group of gases, since 1750. Energy is measured in Joules; the rate at which it is made available is in Joules/second, or Watts; hence, radiative forcing is measured in Watts per square meter (W/m^2). Numerical values for the radiative fluxes are given in Table 6.11 on page 393 of IPCC (2001); note particularly the discussion of the uncertainty of the radiative forcing for tropospheric ozone (cf. note 4, above). Radiative forcing values for SF_6 and SF_5CF_3 were calculated as the products of the radiative efficiency values given in Table 6.7,and the concentrations given in Table 4.1, of IPCC (2001). This calculation assumes that the radiative efficiency has not changed with time, for these small concentrations (cf. Mitchell 1989). For more details on SF_5CF_3, see also W. T. Sturges et al. (2000). Values for CO_2, CH_4, and N_2O which, collectively, account for almost 90 percent of anthropogenic forcing from greenhouse gases, have been updated through 2005 as per Table 2 of Hofmann (2006)— Radiative Climate Forcing by Long-Lived Greenhouse Gases: The NOAA Annual Greenhouse Gas Index (AGGI), National Oceanic and Atmospheric Administration (NOAA), Earth System Research Laboratory, Boulder CO. Documentation and additional information are available at: http://www.cmdl.noaa.gov/aggi/.

6. The value given by IPCC 2001, page 185, is 280 ± 10 ppm. This is supported by measurements of CO_2 in old, confined, and reasonably well-dated air. Such air is found in bubbles trapped in annual layers of ice in Antarctica>, in sealed brass buttons on old uniforms, airtight bottles of wine of known vintage, etc. Additional support comes from well-dated carbon-isotope signatures, for example, in annual tree rings. Estimates of "pre-industrial" CO_2 can also be obtained by first calculating the ratio of the recent atmospheric $CO_{>2}$ increases to recent fossil-fuel use, and using past records of fossil-fuel use to extrapolate past atmospheric CO_2 concentrations on an annual basis. Estimates of "pre-industrial" CO_2 concentrations obtained in this way are higher than those obtained by more direct measurements; this is believed to be because the effects of widespread land clearing are not accounted for. The record derived from the "DSS" Antarctic ice core, which covers the period from about 1000-1750, indicates an average "natural background" concentration of 280.05 ppm.

7. Recent CO_2 concentration (377.3 ppm) is the average of the 2004 annual values at Barrow, Alaska; Mauna Loa, Hawaii, American Samoa, and the South Pole (one high-latitude and one low-latitude station from each hemisphere). Refer to C. D. Keeling and T. P. Whorf for records back to the late 1950s. Ice-core records provide records of earlier concentrations. For concentrations back to about 1775, see A. Neftel et al.; for concentrations back to about 1000 A.D., see D. M. Etheridge et al.; and for over 400,000 years of ice-core record from Vostok, see J. M. Barnola et al. All these data are available from CDIAC.

8. Pre-industrial concentrations of CH_4 are evident in the "1000-year" ice-core records in CDIAC's *Trends Online* (See D.M. Etheridge et al.) However, those values need to be multiplied by a scaling factor of 1.0119 to make them compatible with the AGAGE measurements of current methane concentrations, which have already been adjusted to the Tohoku University scale. Therefore, pre-industrial values calculated from the ice-core data have been multiplied by 1.0119 before insertion in the above table. Thousand-year records of CH_4, CO_2 and N_2O, from ice-core data, are also presented graphically in IPCC 2001, (page 6).

9. The first value represents Mace Head, Ireland, a mid-latitude Northern-Hemisphere site, and the second value represents Cape Grim, Tasmania, a mid-latitude Southern-Hemisphere site. For CH_4, these values can be compared with the thousand-year ice-core records from Greenland and Antarctica, respectively, discussed in the preceding footnote. "Current" values given for these gases are annual arithmetic averages based on monthly non-pollution concentrations for year 2004. Source: Advanced Global Atmospheric Gases Experiment (AGAGE) data posted on CDIAC web site at: http://cdiac.ornl.gov/ftp/ale_gage_Agage/. For some of the species, available data from January 2004 onward are found at: http://cdiac.esd.ornl.gov/ftp/ale_gage_Agage/AGAGE/gc-ms-medusa/. These data are compiled from data on finer time scales in the ALE/GAGE/AGAGE database (R. Prinn et al.). These data represent the work of several investigators at various institutions; guidelines on citing the various parts of the AGAGE database are found in two README files (http://cdiac.ornl.gov/ftp/ale_gage_Agage/AGAGE/gc-md/readme.agA and http://cdiac.ornl.gov/ftp/ale_gage_Agage/AGAGE/gc-ms/readme.agA) within the ALE/GAGE/AGAGE database, also available via anonymous ftp.

10. Source: IPCC (2001), Table 4.1; The pre-1750 value for $N_{>2}O$ is consistent with ice-core records shown graphically on page 6 of that document. Estimates of "current" (1998) concentrations of CHF_3 and C_2F_6 are based on a variety of sources, including emissions rates and annual growth rates. Data on CHF_3 through 1995 can be found in D. E. Oram et al.

11. For SF_6 data see: http://cdiac.ornl.gov/ftp/ale_gage_Agage/AGAGE/gc-md/monthly/tSF6mon.sum for data from July 2001 onward. For data back ito 1994, see the National Oceanic and Atmospheric Administration (NOAA), Halogenated and other Atmospheric Trace Species (HATS) site at: ftp://ftp.cmdl.noaa.gov/hats/sf6/flasks/sf6global.txt. Concentrations of SF_6 through 1999, obtained from Antarctic firn air samples, can be found in W. T. Sturges et al. See also W. T. Sturges et al. (2000).

12. Taken from Table 4.1 of IPCC (2001); it is an estimate for year 1998. Assuming a ratio of SF_6/SF_5CF_3 of 32; the concentration of SF_5CF_3 in 2004 would still be about 0.16 ppt. Concentrations of SF_5CF_3 through 1999, obtained from Antarctic firn air samples, can be found in W. T. Sturges et al. See also W. T. Sturges et al. (2000)

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