BCE Doc 99/132

FUTURE ISSUES IN PERFORMANCE - BASED DESIGN IN COMMERCIAL BUILDINGS

SUBMISSION TO PRODUCTIVITY COMMISSION ISSUES PAPER "IMPROVING THE FUTURE PERFORMANCE OF BUILDINGS"

by

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July 1999

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1. INTRODUCTION

CSIRO Building Construction and Engineering (CSIRO – BCE) has a major program of research devoted to improving the performance of buildings. This includes the development of performance measures, contributions to the development of performance-based building regulations and Standards and the development of tools and procedures to be used in various stages of the building procurement process. (Many of these outputs are referred to in Section 3 of this submission.)

Some of the CSIRO – BCE research relates to aspects which are specifically highlighted in the Productivity Commission Issues Paper. Other research relates to aspects of building performance which are not addressed by the Issues Paper, but are relevant in the overall context of improving the future performance of buildings.

This submission does not attempt to answer all the questions put in the Issues Paper and it has a particular emphasis on technical issues. The submission consists essentially of two parts, one (Section 2) dealing with generic issues concerning all aspects of the performance of buildings, and the other (Section 3) with specific issues related to particular areas such as energy, durability, safety etc.

A list of key references including CSIRO – BCE outputs relevant to Building Performance is provided in Section 4.

The generic issues covered in the submission relate to the following:

- Measures of performance – distinction is made between in-service performance and performance rating.

- Dimensions of performance – both technical and economic dimensions of performance are considered, leading to different descriptions of performance.

- Regulations – the effects of regulations on building performance are discussed, including problems in utilising a performance-based code.

- Impediments – the various technical and economic factors that prevent better building performance being achieved are discussed.

- Solutions – ways to achieve better building performance are considered, including the exchange of information between building industry computer programs for more efficient building design.

The specific issues covered in the submission relate to the following:

- Energy Utilisation, with particular emphasis on reducing energy consumption and CO_2 emissions using Input Saving Technologies:

- Examination of options for introducing energy efficiency provisions in the Building Code of Australia
- Design tools for assessing the energy performance of buildings and the performance of hybrid ventilation and cooling systems
- Embodied energy, i.e. the energy required to manufacture, transport and assemble building materials
- Life cycle energy, and the environmental and economic impacts from the use of specific designs, materials or whole buildings, considering the full life cycle of a building.

- Waste Management – consideration of issues and technology development relating to the recycling of construction, demolition, commercial and industrial waste stock into quality building products.

- Water Supply – consideration of key performance indicators, the current situation concerning regulations and incentives, impediments to better performance, research on urban water systems.

- Indoor Air Quality – consideration of performance indicators (health aspects, loss of productivity, pollutants), current regulations and impediments to better performance.

- Durability and Service Life – consideration of:
    - the effect on structural, serviceability and aesthetic aspects of building performance caused by the degradation of building materials
    - methods of improving durability performance, including the reduction of maintenance and environmental costs
    - review of progress made in establishing accurate life prediction methods for building components.

- Safety in Building Use – consideration of issues relating to safety on pedestrian surfaces, including cost of fall accidents, current regulations and impediments to improving pedestrian safety performance.

- Fire Safety – suggestions for the use of alternative solutions to the current deemed-to-comply solutions, which could lead to benefits relating to both effectiveness and costs in the provision of fire safety measures.

- Structural Safety – consideration of a more flexible performance-based system for a better balance between economy and risk.

- Building Façade – consideration of the effects that the façade has on other aspects of performance such as energy efficiency, acoustic insulation and natural light transmission.

- Life Cycle Costing of building projects – consideration of alternative methods for life cycle costing, which depend on whether a minimum cost or an optimum return solution is desired.

2. GENERIC ISSUES

2.1 MEASURES OF PERFORMANCE (Refer Issues Paper page 14)

It is useful in the discussion of performance to distinguish between *in-service performance* and *performance rating* [R2.1].

In-service Performance is the measure of performance of a product **in use**. The objective of in-service performance is directly related to **users' needs**. The purpose is to assess whether a building is 'fit for purpose'. The key components are the identification and quantification of **relevant agents** and **parameters used to describe performance.** To evaluate in-service performance it is necessary to consider both the product and the environment within which the product has to perform. Technically, in-service performance can only be measured in terms of probabilities of failure to meet the performance objectives.

A **Performance Rating** is the measure of the performance of a product **under evaluation**. The key component is the **agreed method of evaluation.** The methods of evaluation should use the same parameters as those used to evaluate in-service performance. A performance rating is measured in terms of physical parameters and varies depending on the particular aspect of performance under consideration.

For example, if a building is rated as having an adequate resistance to wind of 30 m/s speed, then that is a performance rating. The question of whether the building is suitable for a specific location (e.g. Sydney or Darwin) is an in-service performance question.

Reference

R2.1 Pham, L. and Leicester, R.H. (1998) Issues in the application of performance concepts. Proc. Australasian Structural Engineering Conference Vol.1, Auckland, Sept.

2.2 DIMENSIONS OF PERFORMANCE (Refer Issues Paper page 12)

2.2.1 Technical Dimensions

There are many ways to group performance measures. Both the International Standards Organisation (ISO) [R2.2] and the Economic Commission for Europe (ECE) [R2.3] have introduced different groupings for different purposes. One possible logical grouping would be based on the users' needs, e.g.:

- Safety (Structural, Fire, Usage)
- Hygiene (Air, Water, Waste)
- Comfort (Acoustical, Visual, Hygrothermal, Serviceability)

- Energy
- Economy
- Durability

The first two aspects (Safety and Hygiene) are generally controlled by regulations. The last two aspects (Economy and Durability) affect practically all other aspects of performance.

CSIRO – BCE has identified the technical issues related to the development and implementation of performance-based codes and Standards. BCE is leading the CIB (International Council for Research and Innovation in Building and Construction) Proactive Program on Performance Based Building Codes and Standards, aimed at facilitating international information exchange and research collaboration in this area [R2.4].

References

R2.2 Performance Standards in Building ISO 6241–1984.

R2.3 ECE Compendium of Model Provisions for Building Regulations – UN New York and Geneva 1996.

R2.4 Foliente, G. C., Leicester, R. H. and Pham, L. Development of the CIB proactive Program on Performance Based Building Codes and Standards. BCE Doc 98/232 November 1998.

2.2.2 Economic Dimensions

Benchmarks for Commercial Buildings

Property Council Metrics	
Strategic	Vacancy rate on portfolio Return on investment Vacancy rate of building Lease expiry profile Internal building management cost ($/m^2) External building management cost ($/m^2) Occupant satisfaction Ratio of net to gross leases as % of total leases Income, capital and total returns Portfolio risk Portfolio yield Property risk Property yield
Operational	Capital value per m^2 Capital expenditure per m^2 Capital expenditure as % of capital value Operating costs per m^2 Energy costs per m^2 Turnover per m^2 by retailing type Maintenance cost per m^2 Ratio of lettable area to total area Fitout costs as % of total capital costs Rental income per m^2 Outgoings recovery per m^2 Rental growth Net income per m^2 Rental arrears as % income Ratio of outgoings to gross income Churn rate Staff density per m^2 Total occupancy costs per employee

Reference

Tucker, S. N., Miller, A. J., and MacSporran, C. (1990). Budget levels for non-residential buildings in Australia - final report. (DBCE DOC 90/62). (CSIRO Australia Division of Building, Construction and Engineering: Highett). (118p.)

2.3 REGULATIONS (Refer Issues Paper page 24)

2.3.1 Shift to Performance Based Regulations

Before the shift to performance-based building regulations, most building regulations contained only prescriptive solutions based on past experience. The trend toward performance-based regulations is growing world-wide. It encourages innovation and flexibility, leading to better efficiency. Australia introduced a performance-based building code in 1996. CSIRO – BCE has been making technical contributions to the Code in various forms as discussed in Section 3 of this submission. The availability of supporting technology, educational programs and supporting infrastructure are the key requirements for successful implementation of performance-based regulations.

Building Regulations can have both positive and negative impacts on Building Performance. The following points are noted:

- While the building regulations prescribe minimum levels of performance, they are in reality the only levels that industries target.

- In all current building regulations, the levels of performance are not quantified. However deemed-to-comply solutions are provided which imply a certain level of performance. If an innovative alternative is proposed in place of the deemed-to-comply solution, then it is the proposer's task to prove that the alternative solution achieves at least the same level of performance.

- The implied level of performance required by regulations is generally derived from past experience and is therefore considered as acceptable by the community.

- Introducing new regulations is the most effective (and probably the only) way to improve specific aspects of performance. This should be done only after comprehensive analysis of the economic benefit of such a measure.

- An aspect of building performance that is currently under consideration for regulation is minimum energy performance requirements. CSIRO – BCE is currently involved in an examination of possible options for achieving this [R2.6].

- Australia now has a performance-based building code [R2.5]. This code provides a framework from which building performance can be improved technically or economically via innovations, increased competitiveness and optimised construction.

- The development and implementation of performance-based building codes is a world-wide trend [R2.7].

- CSIRO – BCE has produced an electronic version of the Building Code of Australia, which contains both the performance requirements and deemed-to-comply solutions for housing. The aim is to facilitate the use of the Building Code using computers [R2.8].

References

R2.5 Australian Building Codes Board (1998) ‘Building Code of Australia’.

R2.6 Scoping Study of Minimum Energy Performance Requirements for Incorporation into the Building Energy Code of Australia, Phase 1: Options and Issues (CSIRO Workshop Draft 6 July 1999).

R2.7 The Inter-Jurisdictional Regulatory Collaboration Committee (1998) ‘Guidelines for the Introduction of Performance Based Building Regulations – Discussion Paper, May.

R2.8 BCAider, Version 4.1 CSIRO 1998 (BCA 1996, Volume 2 – Housing Provisions)

2.3.2 Problems in Utilising Performance Based Regulations

CSIRO – BCE is currently carrying out a study for the Building Control Commission to examine the problems in utilising a performance-based code. Results of a survey of 480 builder respondents indicates that 40% of respondents have never used the performance based part of the Building Code of Australia (BCA); this suggests a need for a program of awareness and education by the Building Control Commission to improve the situation.

The small group (12%) which uses the performance based BCA regularly highlight the reasons for use of performance based solutions as:

- Innovations required by the client
- Cost savings
- Performance based solutions are an easier option.

Over 40% use it to achieve savings, and this is probably the reason that innovations required by the client necessitate the use of the performance based BCA. Other responses given included:

- When solutions to non-compliance issues are required
- To achieve a design solution which is an obvious practical solution.

Perceived problems with performance based solutions are that they are difficult and costly. Other responses given included:

- Others are faced with the problem and we want the solution
- No experience, Don’t know and Time constraints
- Building surveyors sometimes reluctant to use.

Reference

Tucker, S. N., Gipps, P. G., Ambrose, M. D., Lenihan, D., Wadsworth, D., Bhuta, C. J., and Salomonsson, G. D. (1999). Review of building system costs. (BCE DOC 99/106). (CSIRO Building, Construction and Engineering: Melbourne). (132p.)

2.4 IMPEDIMENTS TO BETTER BUILDING PERFORMANCE (Refer Issues Paper, Terms of Reference, page 2)

Impediments to better performance are discussed for each specific aspect of building performance in Section 3. However, the following points apply generally:

- The improvement of the regulated aspects of building performance is constrained by current deemed-to-comply procedures that are based on past experience thus limiting the scope for innovations.

- The use of performance specification in design briefs is limited due to the cost/time and difficulties in assessing alternative proposals. It is also constrained in actual practice by regulations and the lack of verification procedures through current technology.

- Unless there are proven economic benefits for better performance, there is no incentive to improve performance.

- With aspects of safety performance such as structural and fire safety, there are further technical problems associated with the evaluation of very small risk. The proof of performance relies largely on the development of acceptable analytical procedures.

2.5 SOLUTIONS TO BETTER BUILDING PERFORMANCE

2.5.1 General

- Regulate aspects of performance that are considered desirable to have improved performance.

- Improve the education and understanding of building performance, the available tools for performance evaluation, performance-based design and performance-based codes.

- Facilitate the use of performance-based concepts in the development of innovative designs that can subsequently be used as deemed-to-comply solutions.

- Develop methods of establishing quantified performance criteria.

- Further develop tools for use in evaluating performance.

2.5.2 The International Alliance for Interoperability

The International Alliance for Interoperability (IAI) is a group of over 620 companies world-wide who are collaborating on developing standards for the exchange of information between building industry computer programs. There are 50 member companies in Australia and a number of others that are maintaining a watching brief. The work of the IAI has relevance to the Productivity Commission's work in three ways:

- as a measure of the active interest in the use of IT in the building industry;
- as a description of current software capabilities to support building industry processes (on the assumption that software vendors will only develop software to support existing processes);
- in developing process descriptions of existing processes within the industry for several of the areas that are of interest to the Productivity Commission.

The work that is performed by the IAI involves analyses of the processes within the industry for the areas under analysis. Areas that have been completed include:

Energy efficiency of building services
Energy Code checking
Cost estimating
Property management

CSIRO – BCE has also prepared a report for the Queensland Govt. in conjunction with QUT: "Integrating Ecologically Sustainable Development and Information Technology for More Efficient Building Design".
This report analyses the available software to support ESD and reviews how well six of the software packages support information exchange using the IAI definitions.

3. SPECIFIC ISSUES

Sections 3.1 to 3.9 cover specific issues relating to aspects of building performance which are currently under consideration in various CSIRO – BCE research and development projects.

3.1 ENERGY UTILISATION

3.1.1 Input Saving Technologies (Refer Issues Paper page 16)

General

We believe that commercial buildings' energy consumption can be reduced without compromising the facilities provided in most situations.

A recently completed study commissioned by the Australian Greenhouse Office showed the detailed energy consumption and CO_2 emissions by application in the commercial sector in 1990; this is summarised as follows.

Table 1 – Energy consumption and CO_2 emissions by application in Australian commercial buildings sector (Adapted from Commercial Building Baseline Study, EMET 1999 [R3.1]).

Application	Energy		CO_2	
	PJ pa	%	kT pa	%
Ventilation	23.5	16%	7017.00	22%
Cooling	27.4	18%	7854.00	24%
Heating	50.8	34%	4259.00	13%
Lighting	22.4	15%	6694.00	21%
Cooking and hot water	9.8	6%	1319.00	4%
Pumping	4.2	3%	1248.00	4%
Office eqt & Other	13.1	9%	3835.00	12%
Total	151.2	100%	32226.00	100%

The results show that the key areas in reducing energy consumption and CO_2 emissions in commercial buildings are cooling, ventilation, lighting and heating.

The study projects increases in energy consumption and greenhouse gas emissions in commercial buildings of over 90%.

At present there are no mandatory energy efficiency provisions for commercial buildings. However a study undertaken by CSIRO – BCE is under way to examine the options for introducing energy efficiency provisions in the Building Code of Australia for new and refurbished buildings. This study examines residential and non-residential buildings separately. For non-residential buildings, it considers two options for evaluating compliance:

1. Whole-building simulation, where an appropriate simulation tool (such as BUNYIP) is used to calculate the building's annual energy consumption, which is then compared to the code requirement.

2. Systems performance measures, where each building system (e.g. the envelope, lighting, and heating, ventilating and air conditioning systems) must individually meet performance requirements.

There are many available existing technologies that can be used to reduce energy consumption and greenhouse gas emissions from buildings, e.g.

- More efficient lighting systems and controls
- Reducing solar heat gain by using advanced glazing systems, e.g. spectrally-selective glazings
- Improving opaque envelope performance to reduce heat conduction into the building
- Replacing refrigerative cooling with evaporative cooling where appropriate
- Night ventilation to cool the building fabric
- Use of economy cycles where appropriate
- Use of time switches on air conditioning and other systems
- More efficient fans and motors.

Ventilation has been a forgotten area in the consideration of energy performance of buildings. In the mild climates of Australia's population centres, ventilation offers considerable potential for reducing air conditioning energy consumption. CSIRO – BCE is currently working together with experts from 14 other International Energy Agency member countries into developing mixed-mode ventilation systems and design tools for office and school buildings [R3.2].

In a mixed-mode ventilation system, natural ventilation is used wherever possible. A mechanical fan and cooling system is operated in extreme weather conditions. Some purpose-designed natural ventilation systems can be built-in to maximise the period without the need of a mechanical system. For example, filtered window doors – a small vertical door that is built into existing windows, equipped with filters and acoustic control. Such a mixed-mode system will also allow for night cooling by natural ventilation in most commercial buildings.

There is a significant potential for reducing energy consumption and CO_2 emissions by the use of Hybrid Ventilation And Cooling (new HVAC) systems.

CSIRO – BCE has developed a number of design tools for assessing the energy performance of buildings and the performance of hybrid ventilation and cooling systems, such as BUNYIP [R3.3] and CHEMIX [R3.4].

BUNYIP is a windows-based tool for evaluating the energy consumption of non-residential buildings. It can be used at any stage of the design process, from sketch design to final design. It can be used to determine peak air conditioning demand as well as annual energy consumption.
CHEMIX is a research tool that simultaneously calculates temperatures and air flow rates in naturally ventilated buildings.

Example - The new Manly Hydraulics Laboratory

The recently completed Manly Hydraulics Laboratory of the Department of Public Works and Services of New South Wales has adopted a mixed-mode ventilation and cooling system. It was predicted that 80 tonnes less CO_2 will be emitted a year compared to a fully air-conditioned building. There is also a recurrent saving of $A12,000 a year in terms of operating energy. It was also claimed that DPWS saved $A220,000 in upfront capital costs. CSIRO – BCE's program CHEMIX was used for the mixed mode ventilation and cooling system design [R3.4].

References

R3.1 EMET Consultants, Baseline study of greenhouse gas emissions from the commercial buildings sector with projections to year 2010, May, 1999

R3.2 Li, Y., Haghighat, F., Andersen, K.T., Brohus, H., Heiselberg, P. K., Dascalaki, E., Fracastoro, G. V. and Perino, M. Analysis methods for natural and hybrid ventilation - an IEA ECB Annex 35 literature review, To be presented in the 3rd International Symposium on HVAC, Shenzhen, China, 17-19, November, 1999.

R3.3 Moller, S.K. BUNYIP – A Major Upgrade. Proc. ANZSES Solar '96 Conference, Darwin, 22-25 October 1996.

R3.4 Li, Y. and Delsante, A., Analysing natural ventilation of multi-cell enclosures with large openings. CIBSE Virtual Conference, 1997.

3.1.2 Embodied Energy

Embodied energy within the construction industry is the energy required to manufacture, transport and assemble building materials and is a significant contributor to a building's overall energy consumption and resulting greenhouse gas contribution. Current estimates indicate that the ratio of embodied energy to operating energy is approximately 15 for a house and 40 for an office building. Therefore energy and CO_2 performance assessments must include embodied energy as well as operating energy.

CSIRO – BCE has recently completed a comprehensive database of embodied energy and CO_2 values and has developed demonstration-of-principle software for the CAD package APDesign. This calculates the material quantities, embodied energy and greenhouse gas emissions directly from a 3D CAD model of a house. It provides graphing and tabular functions that call upon CAD information to provide a variety of breakdowns of energy and CO_2 resulting from construction of a building by element category, material category, and individual materials. The software is at the leading edge of embodied energy evaluation techniques and has been utilised on several projects within Australia.

References

Tucker, S. N., Ambrose, M. D., and Mackley, C. (1998). A 3D CAD model of embodied energy for assessment of sustainable construction. CIB World Building Congress - Construction and the environment. Gavle, Sweden, 7-12 June. (pp. 1919-1926.)

Tucker, S. N. and Ambrose, M. D. (1997). Embodied energy of dwellings. CSIRO ESD Successful applications Conference. Sydney, 3 September. (7p.)

3.1.3 Life cycle energy (Refer Issues Paper page 14)

Sustainable development and environmental assessment of cities and facilities requires a whole of life approach to avoid the common approach of considering only the initial impacts, whether financial, material or environmental. Constructed facilities such as housing and office buildings have significant impacts on the global environment through their construction and operations, both of which consume energy, produce waste and release greenhouse gases and pollutants into the atmosphere. Reduction in these contributions to the global environmental problems can be achieved once the nature of the fundamental inputs from materials used in construction and operation of a building over its whole life cycle are known.

There is an increasing need for designers of buildings to have measures, procedures and tools which provide guidance and/or quantitative information on environmental and economic impacts (such as the greenhouse effect and the use of non-renewable resources) resulting from the use of specific designs or materials or whole buildings over the life cycle of a building.

A unique prototype system has recently been developed by CSIRO to calculate, direct from 3D CAD drawings, embodied energy, CO_2 emissions and mass for all materials in a building, and provide a wide variety of breakdowns of energy and CO_2 by element category, material category, and for individual materials. Its main application to date has been on single-family dwellings.

The operating energy model CHEETAH forms the basis of the National Home Energy Rating Scheme (NatHERS) energy rating scheme for assessing the energy efficiency of a dwelling. NatHERS is now commercially available as a software package.

These techniques and the computer models to evaluate the embodied energy and operating energy of dwellings have been developed by CSIRO Building, Construction and Engineering but the two aspects of life cycle energy have not yet been brought together to explore the relative life cycle impacts in different climatic zones of Australia.

3.1.4 The Availability of Information (Refer Issues Paper page 18)

Technology transfer is critical in the process of improving the performance of buildings in the commercial sector through adopting effective energy saving technologies

We believe that major research institutions such as CSIRO need to be proactive and play a significant role to make the ISTs information available to industry.

In the past, CSIRO – BCE has organised a number of seminars, workshops, published research brochures and Building Innovation Magazines, developed Web pages to disseminate new research results and energy saving technologies.

Example – HybVent Forum 99

Recognising the significant potential of hybrid ventilation technologies, the CSIRO and University of Sydney are organising the First International One-day Forum on Natural and Hybrid Ventilation to be held in Sydney on 28 September 1999. The sponsors and supporters for this forum include Australian Inst. of Refrigeration Air-conditioning & Heating (AIRAH), Department of Industry, Science and Resources, Master Builders Australia, NSW Sustainable Energy Development Authority and Daikin Australia Pty Ltd.

There are 25 presentations submitted to the forum and more than half of the presentations are from leading overseas experts in the area. Most of them are representatives of their country in the international project Annex 35 on hybrid ventilation. The forum covers a wide range of topics, from the basic thermal comfort design criteria, design tools, operation issues, systems, integration to case studies.

3.2 WASTE MANAGEMENT (Refer Issues Paper page 16)

3.2.1 Reduction in Waste Generation: Recycling and Reuse of Construction Materials

The Need:
Growing public and institutional concerns over the impact of urbanisation and industrialisation on the environment and its implication on the flow and disposal of waste has moved rapidly up the public policy agenda in nearly all countries. This is demonstrated by recent government legislation to establish and promote a unified national waste reduction strategy under the Australian and New Zealand Environment and Conservation Council (ANZECC) initiative. This commitment sets out a national target of a 50% reduction in solid waste going to landfill by the year 2000 against 1990 per capita levels. The current government waste policy frameworks are committed to a solid waste management hierarchy of source prevention, reduction, recycling, treatment and disposal strategies, which create mandatory recycling targets. The lack of flexibility and the great expense of trying to reach these recycling goals severely restrict such initiatives. Furthermore, stringent goals independently set by the different states, for instance the 60% reduction target in NSW, are getting harder to achieve.

The essence of adopting waste minimisation strategies is to slow down the current rapid depletion of non-renewable primary resources for construction whilst contributing to improved efficiency, cleaner production and reduced costs across the construction sector. However enabling technologies for waste minimisation involving high volume waste recycling and sorting technologies are limited. Current practices at best involve downgrading processes, which severely restrict recycling practices to low value adding options, and prevent equitable marketing of recycled construction products. An additional concern is that the environmental implications of manufacturing Portland cement, the key constituent of nearly all binders, are very severe particularly regarding carbon dioxide (CO_2) pollution and energy intensiveness. Currently, one ton of CO_2 is emitted for every ton of cement manufactured.

Desired Situation:
The key is to implement an effective waste reduction strategy that allows equitable competition for recycled building products in the market place based on a closed-loop material recycling principle. This requires technologies to turn recyclable/reusable wastes into resources and, hence, an intensive laboratory and field-based effort to classify, characterise and process a wide variety of generic waste resources including development of novel sorting technologies. Given that cementitious materials dominate current construction practices, efficient and rapid ways of containing waste generated from quarry activity and manufacture of cement-based products remains vital to improved productivity and environmental performance as well as limiting long-term implications on life cycle costing in the construction sector.

How:
It is imperative to develop suitable process technologies for high level recycling of C&D (construction and demolition) and C&I (commercial and industrial) waste stock into competitive and cost effective quality building products which meet current performance and durability requirements. Concurrently, there is a need to develop systems for efficient control of contaminants and the relative influence of different classes of feedstock impurities on recycling potential of different solid waste streams. Initiatives to encourage product development should further demonstrate very strong environmental appeal as well as cost benefits. In addition government should take a lead through mandatory incorporation of recycled materials in public sector contracts. To achieve these goals requires current impediments such as cost differentials, product quality and lack of standards to be first addressed.

Benefits:
The development of enabling sorting and recycling technologies will:
- Stimulate higher-value addition of recycled materials and products. This is the most effective route to achieving national recycling targets, ie a reduction of waste to landfill by 50% by 2000 from 1990 levels.
- Provide a mechanism for better accounting of solid waste management and disposal to facilitate potential for increasing material available for recycling and recycled products.
- Enable direct estimates of the total quantities and the percentages of the various components of all waste streams from all sources and to all disposal routes.
- Improve the administrative framework governing recycling.
- Enable flexible design leading to extension of the building life cycle via rehabilitation and retrofitting.
- Enable design for de-construction.

3.2.2 Recycling of Construction and Demolition Waste

The Need:
Central to the ability to recycle demolition and construction(C&D) waste resources is the acceptability of such products to the construction industry. Product acceptance in turn depends on the ability to meet desired specifications. In contrast to virgin quarried primary materials, the feedstock for recycled materials can change from day to day depending on levels of contamination, source separation and processing operations. The challenges offered by the emerging trends in ESD further emphasises the importance of effective integration of the construction cycle geared towards resource recovery/reuse and cost effectiveness. With currently prevailing unstable markets and price structures for secondary or recycled materials, dealers usually work on fairly low profit margins per unit of material and under conditions of extremely uncertain demand. This current lack of market incentive and the relatively cheaper price tag on natural materials limits growth of the recycling industry**. Thus viability of the industry partly depends on development of appropriate recycling technologies backed by favourable legislative instruments and equitable markets.**

Desired Situation:

Provision of a single performance-based standard for both natural and recycled building materials and products ensures that producers have quality targets and perform regular testing and quality control of products. Ready availability of information on product performance further allows specifiers to be aware of the range of materials and areas of application. Specification on recycled products provides initial incentive required in the market place to stimulate demand whilst enhancing consumer confidence in product quality assurance. Promotion of recycled products has the advantage that it also retards current rapid depletion of non-renewable primary mineral resources consumed during construction whilst contributing to cleaner construction practices.

How:

Significant gains in C&D waste recycling can be achieved through provision of voluntary and mandatory national codes and Standards. The development of Standards is dependent on strategic research on material performance and product development based on either novel or existing technologies. Accordingly, CSIRO – BCE has initiated R&D programs aimed at developing high value-added products from recycled concrete aggregate (RCA) and cement beneficiation technologies of the C&D waste feedstock. Given the embryonic stage of these programs, there is a clear need to accelerate this initiative in order to develop performance criteria of recyclable materials and rapid methodologies of assessing products derived from them. In the interim, the concept of best demonstrated acceptable technologies may be adopted as a balance between achievable standards and cost effectiveness. An integral component of this strategy is the development of rigorous risk assessment methods and models capable of quantifying specifications for acceptable product performance.

Benefits:

The benefits of R&D directed towards performance specifications include:

- promoting the acceptability of recycled resources by developing specifications and technical documentation of product performance
- maximising use of the nation's C&D waste resources involving laboratory and field R&D to develop building products based on recycled resources
- waste avoidance at the end of design life of buildings and structures and delay of arrival of materials to the waste stream
- promotion of recycling operations as commercially viable and desirable business activity to counteract the currently perceived poor image of the industry
- certification of the quality of recycled building products which is conditional to general acceptance and specification of such products.

3.3 WATER SUPPLY (Refer Issues Paper page 16)

Indicators of Performance

There are four key indicators of performance with regard to “generic” buildings (i.e. buildings not designated for use for a particularly water intensive application). These are:

- Risk of supply failure. This would encompass risk of water supply failure as a result of high use leading to unacceptably low levels of pressure or loss of supply.
- Risk of potable water contamination. This would occur, either due to misuse of back flow prevention devices or non-use of these devices. It may increase as a possibility as new low cost water supply systems or in-house treatment becomes more common or more cost competitive.
- Ongoing costs, which include the cost of water itself, cost of system repair and replacement and maintenance costs associated with the necessary infrastructure.
- Costs of installation (i.e. water infrastructure costs, pipes, pumps, storage tanks etc.).

The Current State of Play

Adoption of water system innovations is largely voluntary, although there is a financial incentive for water conservation. Water is now a controllable cost for industry, with charges based on a pay for use arrangement (i.e. cost per kilolitre). In many jurisdictions there is also a cost to private/commercial/industrial operations for sewer discharge. The imposition of such costs provides a financial incentive for industry to adopt more water efficient practices and to manage their liquid waste discharge more effectively.

The exception to the above is the introduction of various trade waste agreements and statutes which limit the volume and concentration of particular substances that may be discharged by commercial premises. These agreements/regulations affect industries' production processes and have encouraged pretreatment prior to discharge. With regard to the former, the approach of some organisations has been to adopt cleaner production practices. With regard to the latter the pretreatment of some wastes means that the liquid fraction is reusable (e.g. as cooling water) reducing water input costs to industry. In order to do this, infrastructure is ideally incorporated in building design from the outset (although it can also be retrofitted).

The impediments to better performance include:

- Lack of knowledge of alternatives on behalf of developers. Information available to this sector regarding water efficiencies that might be made is limited, although State and Federal EPAs provide information on cleaner production processes.
- Cost of infrastructure provision. Water is a cheap commodity. The cost of infrastructure provision and water efficient appliances is often not justified in terms of the rate of return achieved on the investment. Whether water and wastewater treatment is, in fact correctly priced, is a matter of some conjecture. Even when investment in water efficiency is justified financially, lack of information and conservatism on the part of many industries and developers has likely inhibited the uptake of innovative approaches.

- Level of development of water efficient technologies. The water efficiency of appliances has improved significantly over the past decade and the benefits of these are increasingly well understood. There is a lack of such general understanding with regard to innovative approaches to infrastructure development and water and wastewater treatment technologies. Issues of risk and public health also impinge on the uptake of innovation here, as do local regulations.
- Cost of efficient water and wastewater treatment facilities. Technologies for water and wastewater treatment are increasingly becoming more efficient and the cost-effective treatment plant size is rapidly reducing. Developments are currently seeing building treatment facilities as being economically feasible. Innovative use of these technologies could see redesign of current urban water systems.

CSIRO's Contribution

CSIRO – BCE is making a significant contribution to the understanding of urban water systems operation and costs through its Urban Water Program (UWP), being conducted with the support of the Water Services Association of Australia and the High Level Steering Committee on COAG Water Reform. The UWP is a multi-disciplinary approach to understanding urban water systems; its four concurrent tasks (in its feasibility stage) are:

- Development of an understanding of the performance of existing systems through analysis of water and contaminant flows, system costs and the drivers of those costs (eg the need to provide for peak diurnal flows). Externalities and lifecycle costs will be identified through this effort and included in a calculation of total system costs.
- Identification of feasible technical and managerial alternatives and the socio-economic context in which they might be implemented.
- Development of alternative 'scenarios' of the way in which water, wastewater and stormwater services could be provided.
- Construction of a range of models for water supply, water treatment and stormwater allowing a comparison of alternative 'scenarios' with each other and the existing 'base case'. The comparisons will include the impact of alternatives on water and contaminant flows, as well as full life cycle costs. The risks associated with public health impact and public acceptance will also be evaluated.

The Program's feasibility stage, during which results from the above will be available, will conclude in November 1999.

Further detail on the UWP is available at www.dbce.csiro.au/urbanwater .

References

Davis, J. R., Speers, A., Booker, N., and Burn, S. (1998). 'The CSIRO Sustainable Urban Water Program'. *Proceedings of 6th NSW Recycled Water Seminar on Water Recycling and Sustainable Water Cycle Management* - held in conjunction with the 11th IWAS-ASPAC Regional Conference on Integrating the Urban Water Cycle, 1-5 November 1998, Sydney. Keynote Address, pp 14-19 Australian Water & Wastewater Association Incorporated Sydney.

Speers, A. (1999) CSIRO's Urban Water Program – A National Approach to Water System Efficiency and Sustainability *Water*). Journal of the Australian Water and Wastewater Association. (September 1999).

3.4 INDOOR AIR QUALITY

Indicators of Performance

Research studies have shown that indoor air quality is worse than outdoor air quality, whether evaluated according to the pollutant levels in buildings (dwellings, offices, schools) or the subjective responses from occupants. These pollutants arise from the materials and contents that are placed in buildings. While buildings are ventilated to remove occupant odours and to ensure thermal comfort, the levels of ventilation are insufficient to quickly disperse the pollutant from the building and its contents. Increasing ventilation rates is not considered the optimum approach to controlling indoor air pollutants, and would lead to increases in building energy consumption.

Indoor air pollution of the built environment affects the health and comfort of the building occupant, the cost of which tends to be borne by the occupant, and in consequence affects occupant performance and productivity, the cost of which is met by the building owner/manager/lessee. Health effects can vary from non-specific effects such as discomfort, eye/nose/throat irritation, headache and lethargy (from organic compounds, particulates) to severe effects such as allergy and asthma (from microbials, dust mites etc) and cancer (from asbestos, benzene, other organic compounds). The actual cost of these is difficult to assess at present.

The impact on occupant productivity may arise from work absences and from a decrease in daily performance. Again the costs of these are difficult to assess, but are estimated roughly as follows:

(a) Fisk et al. (1997) Indoor Air 7, 158–172 estimated the productivity gains attainable in the US as:
   * $20 billion from reduced respiratory disease
   * $4 billion from reduced allergies and asthma
   * $20 billion from reduced sick building syndrome
   * up to $125 billion from improvements in worker performance

   Assuming similar experience, the total annual gains in Australia can be estimated by proportioning the above relative to the GNPs of each country; the total productivity improvement in Australia is estimated to be $7 billion per year.

(b) Assume that 30% of non-industrial buildings in Australia are affected by poor indoor air quality (conservative), and that 30% of the occupants of these buildings lose 4 to 7% of their performance (realistic). For 4 million non-industrial workers in Australia and an average annual salary of $40,000, the cost of lost performance is $0.6 to 1.0 billion per year.

Current State of Play

There are no regulations to control the levels of pollutants in buildings, other than OH&S requirements that can be applied to offices. However, the OH&S requirements were intended for industrial buildings, and may not be appropriate for office buildings, especially with access by the general public. The Building Code of Australia has ventilation requirements that ensure odours from occupants are removed and thermal comfort conditions are maintained, but do not control pollutant sources in buildings. The National Health & Medical Research Council have recommended advisory performance goals for pollutant levels in dwellings, offices and schools, which can serve as the basis for indoor air control.

Buildings are currently designed with concern only for the thermal comfort and air supply requirements of occupants, and even these may be poorly designed or poorly maintained through the life of buildings. Design for indoor air quality (IAQ) requirements of occupants requires criteria be established and applied for the pollutant emission properties of materials, furniture and appliances used in buildings, especially:

(a) formaldehyde emissions from wood-based panels,

(b) volatile organic compound emissions from paints, adhesives, carpet, furniture and office equipment,

(c) nitrogen dioxide, carbon monoxide and formaldehyde emissions from unflued gas appliances.

Current impediments to development of IAQ criteria for buildings are a lack of Australian Standards and the limited acceptance of manufacturers to adopt pollutant emission criteria for their products. However, these developments are in progress in the USA, Canada, Europe and some Asian countries, and so Australia is falling behind best practice and will limit its future access to these markets.

CSIRO Indoor Air Quality Control Project

CSIRO – BCE has contributed to the development of NHMRC goals [R3.5] and reported on the National State of Environment for indoor air quality in Australia [R3.6]. It provided a benchmark for control of indoor air quality in Australia through production of indoor air guidelines for the Sydney Olympics facilities [R3.7]. It has developed and applied procedures for assessing the indoor air quality of different types of buildings [R3.8, R3.9]. Currently, it is discussing involvement in the Federal Government's Air Toxics program, which will assess and develop management options for air pollutants in outdoor and indoor air.

CSIRO has developed a national facility for the pollutant emission assessment of building materials, with state-of-the-art environmental chambers. This has been used to understand and develop models for pollutant emissions from paints [R3.10], carpet [R3.11], wood-based panels [R3.12], office equipment [R3.13], and gas heaters [R3.14]. These models are used to develop performance specifications for the indoor air impacts caused by the materials, appliances and equipment used in buildings.

References

R3.5 Brown, S.K., Sim, M.R., Abramson, M.J. and Gray, C.N. (1994). Concentrations of volatile organic compounds in indoor air – a review. Indoor Air 4, 123–134.

R3.6 Brown, S.K. (1997). National State of the Environment Report - Indoor Air Quality. SoE Technical Report Series, Dept. Environment, Sports & Territories, Canberra, 88pp.

R3.7 Immig, J., Risch, S. and Brown (1998). Indoor Air Quality Guidelines for Sydney Olympic Facilities. BCE Technical Report 97/3, CSIRO Publishing, East Melbourne, Australia.

R3.8 Brown, S.K. (1996). Assessment and control of exposure to volatile organic compounds and house dust mites in Australian dwellings. Seventh International Conference on Indoor Air Quality and Climate, Nagoya, Vol. 2, 97-102.

R3.9 Brown, S.K. (1998). Case studies of poor indoor air quality in Australian buildings. 14th Int. Clean Air & Environment Conf., 18-22 Oct., Melbourne, 205-210.

R3.10 Brown, S.K. (1998). VOC emissions from interior coatings - measurements and mechanisms. RACI Symposium on Advances in Polymers V "Coatings", Oct 2, CSIRO Molecular Science, Clayton.

R3.11 Brown, S.K. (1996). Controlling sources of indoor air pollution. Annual Conf. Of Aust. Institute of Occupational Hygiene, Perth.

R3.12 Brown, S.K. (1999). Chamber assessment of formaldehyde and VOC emissions from wood-based panels. Indoor Air (in process).

R3.13 Brown, S.K. (1999). Assessment of pollutant emissions from dry-process photocopiers. Indoor Air (in process).

R3.14 Brown, S.K. and Cheng, M. (1999). Pollutant emission properties of unflued gas heaters (in process).

3.5 DURABILITY AND SERVICE LIFE (Refer Issues Paper page 16)

It is well accepted that the performance of a building may be restricted by degradation of the materials used in constructing the building. This appreciation is embedded in the "deemed to comply" provision of a wide range of Australian Standards. With the move from prescriptive to performance based regulation in the BCA, and in the Standards that it calls up, there is a need to develop performance statements requiring the continued performance of a building over its design life. If a building is required to have characteristics of structural integrity, serviceability, aesthetic qualities etc., then provisions such as the following are needed:

The materials or systems in a building shall be such that, over the design life, degradation of these elements will not cause any significant decrease in the "structural integrity" of a building.

In the above performance statement "structural integrity" can be replaced with other criteria, e.g. serviceability (incl. water tightness etc) or aesthetic qualities. Having proposed such criteria, the immediate question raised is – Can performance verification methods be developed for the criteria? There is a considerable level of work internationally and nationally to address this problem. The ISO TC59/SC14 and 15 committees are developing strategies for such performance verification methods, whilst considerable work is being carried out on a national level in Australia, New Zealand, Canada and the Scandinavian countries [R3.15].

In essence what is required is

(a) a method to connect material degradation with the decrease in a performance aspect (e.g. Structural Integrity);
(b) a method to estimate the extent of degradation of a building component over its design life, given a knowledge of the microclimate in which it is located;
(c) a method to estimate and characterize the microclimate in buildings across Australia.

Over the past five years there has been considerable progress in each of the above areas. In particular, in (b) the extent of degradation could be defined from experience, performance tests or analytical methods. Experience could include full scale test programs, surveys of in-situ components or field exposures. Over the past five years there has been development of a new range of performance tests [R3.15 - R3.17] in which the actual service environments are simulated, and which are to a greater level of accuracy than prior tests. Further analytical methods including modelling [R3.18 - R3.20] are reaching such a level that the performance of simple components can be reasonably predicted. Recent work has established new classification procedures for environments [R3.21] and developed methods to characterize environments in buildings throughout Australia [R3.22].

Knowledge has reached such a level that performance statements governing not only the initial but also the lifetime performance of buildings can be written, and technologies exist that could be used to verify these performance standards. However although the components of such a system are available there is considerable work required to develop the regulatory framework and to incorporate in it the technology to provide the verification system.

Advantages of Accurate Life Prediction Methods.

If accurate life prediction methods were derived and integrated into the design process it would allow selection of materials to give the optimum combination of initial cost, maintenance cost, risk of failure, replacement cost and environmental impact. Such a system could be constructed using the technology outlined above. Such a tool would be a very valuable Input Saving Technology in reducing, in particular, maintenance and environmental costs. The impact of climate change compounds this problem, as present design and materials selection practice is based on the historic climate. As the climate changes over the design life of the current generation of buildings, the extent of material degradation, and thus maintenance and environmental costs, as well as risk of failure, may decrease dramatically. An integrated life prediction tool has the capacity to incorporate the effect of climate change and thus provide guidance on adaptive strategies to minimize costs associated with such change.

References

R3.15 Cole, I.S, "The Development of International Standards and of Verification Techniques for Performance Evaluation in Tropical Countries", Key note Lecturer at First Asia/Pacific Conference on Harmonization of Durability Standards and Performance Tests for Components in Building and Infrastructure, Bangkok 8th-10th September 1999.

R3.16 Cole, I.S., Linardakis, A. and Ganther, W. "Controlled humidity/salt dose tests for the estimation of the durability of masonry ties", Masonry International. 9, no.1 , p11-15 1995.

R3.17 Cole, I.S., Neufeld, A.K., Kao, P., Ganther, W.D., Chotimongkol, L., Bharmornsut, C., Hue N.V. and Bernardo, S. "Corrosion Mechanisms and Performance Tests for Tropical Environments", To be presented at 14th ICC Cape Town 27 September - 1 October 1999.

R3.18 Cole, I.S, King, G.A., Trinidad, W.Y., Chan, W.Y., Paterson, D.A. "An Australia-wide map of corrosivity: A GIS Approach"-8th Int. Conf. on Durability of Building Materials and Components, Vancouver, 30 May-3 June 1999.

R3.19 Cole, I.S., Trinidad, W.Y., Chan, W.Y., D.A. "Prediction of the Impact of the Environment on Timber Components: A GIS-Based approach."-8th Int. Conf. on

Durability of Building Materials and Components, Vancouver, 30 May-3 June 1999.

R3.20 Cole, I.S., Patterson, D.A., Furman, S.A., Neufeld, A.K. and Ganther, W.D. “A Holistic approach to modelling atmospheric corrosion”, To be presented at 14th ICC Cape Town 27 September - 1 October 1999.

R3.21 Burn, L.S., Cole, I.S. and Tucker, S.N.. “Information technologies and data formatting for the design life of buildings”, 7th International conference on durability of building materials components”-May 30-June3, 1998.

R3.22 Cole, I.S. “An analysis of the microclimate of Australian wall cavities”, Construction and Building Materials, Vol. 8, No. 4, p 1–9, 1994.

3.6 SAFETY IN USE

Safety on pedestrian surfaces

A 1990 study of all public liability claims found that 65% related to preventable slip and fall accidents. Many commercial buildings are still not 'fit for purpose' because the selected floor surface either offers too little slip resistance, or pedestrian safety is jeopardised by some other design input. Furthermore, the performance of many floors is often compromised by unsuitable cleaning practices, given the lack of routine slip resistance assessment in most buildings. Although the largest settlement for a single slip and fall accident is believed to be $2.75 million, pedestrian safety has not been considered as a component in life cycle costing studies. Given that the $3 billion annual cost of fall accidents exceeds that of motor vehicle accidents, there is ample incentive to improve the design aspects of product selection and to develop relevant performance indicators, preventative measures and interventional remedial actions. While the BCA now requires all accessible paths of travel to have a slip-resistant surface, there is no specified means of demonstrating compliance. Since there is a growing demand for safer pedestrian surfaces, particularly among the elderly and the disabled, the ABCB will soon need to evaluate the economic impact of mandating minimum levels of slip resistance. A major impediment to improving the pedestrian safety performance of commercial buildings is the lack of integrated performance indicators and a general inability to assess slip resistance in situ. While several new test devices continue to be developed overseas, they need to be purchased independently appraised against rigorous criteria before they can be considered for general or specialised adoption in standards. Government funding is required for this vital 'public good' research.

Although pedestrian slip resistance is an extremely complex area, CSIRO – BCE is familiar with the multifactorial issues and has been commissioned by Standards Australia to write its Slip Resistance Handbook. BCE has a well-equipped slip resistance laboratory that includes Australia's only ramp test facility, where humans are used to subjectively evaluate the slip resistance of floors under various conditions of contamination and footwear. BCE is purchasing a sophisticated laboratory tester that measures the slip resistance of any combination of footwear, contaminant and flooring under the biomechanical conditions when slip is most likely to occur. BCE is thus well equipped to evaluate the performance of slip resistance devices and the effect of remedial floor treatments. BCE is also well placed to conduct a preliminary assessment of the economic impact of mandating slip resistance requirements in commercial buildings in terms of the socio-economic benefits and the financial costs.

CSIRO has Australia's only slip resistance website <www.dbce.csiro.au/pubs/slip>. This contains most of the relevant CSIRO publications on slip resistance. It will soon include the outcomes of the Workshop on the Evolution of Sustainable Pedestrian Safety, that CSIRO held in late June 1999.

References

Bowman, R. (1998) 'Assessing the Relative Contribution of Ceramic Tiles to Slip and Fall Accidents', 5th World Congress on Ceramic Tile Quality, Castellon, Spain, Vol. 2, 161-73.

Bowman, R. (1999) 'What must we do to prevent pedestrian slips and falls?', paper presented at 3rd National Conference on Injury Prevention and Control, Brisbane, 9-12 May.

3.7 FIRE SAFETY

The safety of people in buildings in the event of fire is currently controlled by the Building Code of Australia (BCA). Therefore in order to implement change it is necessary to restructure the BCA. In recent years the Fire Code Reform Centre (FCRC) has been formed by a consortium of industry, government and research organisations to recommend changes to the BCA, which has recently become performance-based. CSIRO has been a major contributor to research conducted by the FCRC [R3.23].

There is currently no overall objective for fire safety in the BCA. Instead compliance with a series of separate performance requirement is mandatory. While the innovative designer can interpret the performance requirements to include "trade-offs" between various fire-safety sub-systems, a global objective or objectives would provide more flexibility.

Global objectives for building fire safety systems in the current BCA can be expressed:

- to keep loss of life in building fires to a very low level;
- to limit property damage by introducing measures to control fire size and to prevent fire spread between buildings;
- to provide protection to fire fighters in the execution of their duty.

Quantification of the primary global objective, ultimately in the form of an acceptable level of risk to life, would allow for more versatility in building design.

Fire engineering is often used to provide solutions that meet the client's need for building functionality and show compliance with the performance requirements. Developments in fire-safe engineering can ultimately reduce building costs by 5%-7% by providing a credible method for estimating fire growth and fire spread and designing new fire suppression systems. . The fire safety engineering market which depends on the knowledge produced by CSIRO is a $25million industry in Australia and is growing at 20% annually.

CSIRO is well placed to move fire engineering knowledge into the 21st century and maintain an independence which is demanded by the Australian fire protection agencies and the Australian community. CSIRO – BCE Fire Science and Technology Laboratory is at the forefront of development of methods for fire engineering, and can further develop tools to support fire engineers.

Buildings now and into 2010 are changing from those of predictable size and shape to a wide range of possible designs. We now regularly see building such as the Sydney and Melbourne casinos which defy the size and shape of conventional buildings. These dramatic changes impose enormous demands on our knowledge of the performance of materials in relation to one another and in performance in building design where they face fire. Improved knowledge will allow significant innovation in building design and reduced construction costs whilst maintaining Australia's excellent life safety record [R3.24] in an increasingly complex built environment.

References

R3.23 Dowling, V. P. and Blackmore, J. M. 1998, *Fire Performance of Wall and Ceiling Linings*, Final Report, Project 2 Stage A, Fire Code Reform Centre Ltd, Sydney

R3.24 Dowling, V. P. and Ramsay, G. C. 1997 Building fire scenarios - Some fire incident statistics. In *Fire Safety Science, Proceedings of the Fifth International Symposium, Melbourne*, International Association for Safety Science, Boston, Massachusetts, pp 643–654

3.8 STRUCTURAL SAFETY

Structural Safety is another regulated aspect of performance. To make any significant improvement it will be necessary to revise the Structural Design Standards. CSIRO – BCE has taken a leading role in the revision of these Standards in the last 20 years. These include the loading Standards (e.g. wind, snow, earthquake) and the material design Standards (e.g. steel, concrete, timber).

In-service structural safety performance can be measured in terms of the probability of failure. CSIRO – BCE developed a program called ‘Safety Index’ [R3.25] to evaluate the probability of failure of structural components. The program was used extensively in the conversion of the design process from Allowable Stress to Limit States to ensure the consistency of the safety performance of current design Standards. This program has been used more recently Australia-wide to evaluate the performance of new innovative products.

Current work at CSIRO – BCE is aimed at creating a more flexible structural design system that takes into account the life of the building, its importance and risk of injuries to people in the event of failure. This will produce a better balance between economy and risk in building design. The result of this work is a new draft standard currently out for public comment [R3.26] which will form the basis for the next generation of design standards.

CSIRO – BCE is also taking a leading role in drafting International (ISO) Standards for Housing Performance. This work is aimed at facilitating international trade in housing and building products [R3.27]. CSIRO – BCE is also taking a leading and coordinating role in the harmonisation of standards internationally with the aim of reducing technical trade barriers in this area [R3.28].

References

R3.25 Macindoe, L., Pham, L. and Leicester, R.H.(1993) ‘Safety Index Manual’ DBCE Doc.93/41(M) May.

R3.26 Standards Australia (1999) ‘General Structural Design Requirements’ AS1170.0 (Draft for Public Comment).

R3.27 Pham, L. and Stark, G. (1998) ‘ISO Performance Standard for Housing’ Proc. Australian Structural Engineering Conference (Vol.1) Auckland October.

R3.28 Pham, L. (1999) ‘Alignment of Structual Loading Standards for Building Design & Construction in APEC Economies BCE Doc.99/078 June.

3.9 BUILDING FAÇADE (Refer Issues Paper page 16)

The building façade industry in Australasia and South East Asia alone is worth in excess of 10Billion dollars/year. A recent study conducted in the Northern hemisphere has indicated that water seepage in high-rise buildings is a major problem which affects 30% of buildings within the first 18 months of life. Further, it was noted that 80% of the surveyed buildings suffered significant water tightness problems within 15 years of construction. Unlike other aspects of performance, the water tightness performance of building façades can only be evaluated by testing. CSIRO – BCE is highly active in this area nationally and internationally. The CSIRO Wall Evaluation Test Method (SIROWET), was developed by CSIRO. It has been in operation for some 20 years and is now regarded as a standard structural and weather performance test for all curtain wall and façade systems. It is particularly useful for curtain wall and component manufacturers in verifying the performance of prototype test specimens at the design stage. The current Australian / New Zealand Standard AS/NZS 4284 "Testing of Building Facades" was developed on the basis of SIROWET. CSIRO – BCE has recently proposed a new method to improve the effectiveness of the water tightness testing and further modifications of this procedure are under progress.

The performance of the façade also has an effect on energy efficiency, acoustic insulation and natural light transmission. CSIRO – BCE is also active in researching these areas. In particular, use of interactive façade using "Blue Building Technology" promises to cut the energy consumption of buildings by up to 30-50% as well as giving significant savings in maintenance costs.

References

Brown, N.G. and Ballantyne, E.R. (1975) 'The Sirowet Rig for Testing Weather-proofness of Building Facades. CSIRO Division of Building Research.

Standards Australia (1995) 'Testing of Building Facades' AS/NZS 4284:1995.

Sankaran, R., Roberts, G. F. and Mayo, A. P. (1996) 'SIROWET II – An Advanced Technique for Weather Testing Facades', 3rd International Sysposium on Applications of the Performance Concept in Building, Tel-Aviv, Israel, Dec. 9-12.

Sankaran, R. and Roberts, G. F. (1999) 'Use of Weather Data in Water Resistant Design of Buildings', Proc. of the 10th International Conference on Wind Engineering, Vol. 2, p 1165-1170, Copenhagen, Denmark, June 21-24.

Brescianini, C. and Sankaran, R. (1999) 'A Study of Pressure Equalised Rain-screens Using Numerical Models Buildings', Proc. of the 10th International Conference on Wind Engineering, Vol. 2, p 1221-1227, Copenhagen, Denmark, June 21-24.

3.10 LIFE CYCLE COSTING (Refer Issues Paper page 15)

Life cycle costing is one of the most widely used methods of economic evaluation of buildings and their components. Yet it is one of the least understood by those who use it. The definition of life cycle costing in the Glossary of Australian Building Terms (Milton 1994) is *the total cost of an item throughout its life including planning, design, acquisition and support costs and any other costs directly attributable to owning or using an item*. Annual support costs for buildings include maintenance, rehabilitation, energy, cleaning, statutory charges and fixed charges, while initial capital costs include purchase of land, design fees and other progress payments made during design and construction.

With buildings having lifetimes measured in decades or even centuries, decisions made during the design and construction of buildings have impacts on operational efficiency throughout the long productive use of a building. It is essential to include the ongoing costs of such a facility, along with the initial capital costs in assessing the total costs of a building over its entire lifetime. But how do we do this simply, consistently and effectively?

There are two distinct and different applications of discounted cash flow techniques, both of which are called life cycle costing:

- estimation of the total cost of a particular building or component, after the quality and function has been specified in order to investigate the minimum total cost solution, and
- estimation of the return on a project where quality, function, size, level of service and revenue or benefit may be varied to obtain an optimum return.

The first approach usually requires a single decision on capital outlay versus operating expenses over the lifetime of the asset. Any income or other financial benefits resulting from the use of the asset are assumed to the same for all options. When reduced to examining a particular item in some equipment, the technique is often called value analysis. This approach is most likely to be used when evaluating institutional buildings or government buildings where a particular standard has been predetermined.

In the second approach, the ultimate aim is to obtain the best return on the investment subject only to some minimum acceptable standards. The possible options are much more extensive. A minimum life cycle cost as required in the first form of appraisal may produce a lower return. There are often opportunities to raise the quality and hence the cost of a building by adding extra facilities to increase the revenue from its use. This kind of analysis is often termed an economic feasibility. With commercial buildings, the second form is often used during the planning stages to determine the best overall project but once the project is implemented and the parameters for performance set, the first approach is more applicable to the long term management of the existing asset.

In either case, the basic requirement of life cycle costing is to obtain a time dependent cash flow over the entire life of the asset being investigated, whether the asset is a light bulb or a 100-storey building. The cash flows may be monthly or annual, depending on the expected lifetime of the item. Success with life cycle costing analysis is achieved by creating a realistic and accurate representation of all the relevant cash flow contributions without excessive complications.

References

Tucker, S. N. and Rahilly, M. (1990). Life cycle costing of housing assets. In Quah, Lee Kiang (Ed.), Building Maintenance Management and Modernisation Worldwide. Singapore, 7 - 9 March. (Vol. 1, pp. 161-172.) (Longman: Singapore).

Bennett, A. F., Page, I. C., Bourke, K., Tucker, S. N., and Nireki, T. (1999). Life cycle costing for a design standard. Proceedings of 8th International Conference on Durability of Building Materials and Components. Vancouver, 30 May - 3 June 1999. (National Research Council of Canada: Ottawa). (12p.)

Tucker, S. N. (1996). Economic and environmental assessment conflicts for long lived facilities. In Katavic, M. (Ed.), Economic management of innovation, productivity and quality in construction. Zagreb, 4-7 September. (Vol. 2, pp. 917-925.) (Faculty of Civil Engineering, University of Zagreb: Zagreb).

4. KEY REFERENCES

General

- Pham, L. and Leicester, R.H. (1988) 'Issues in the application of performance concepts' Proc. Australasian Structural Engineering Conference Vol.1, Auckland, Sept.

- Performance Standards in Building ISO 6241-1984.

- ECE Compendium of Model Provisions for Building Regulations – UN New York and Geneva 1996.

- Foliente, G. C., Leicester, R. H. and Pham, L. Development of the CIB proactive Program on Performance Based Building Codes and Standards. BCE Doc 98/232 November 1998.

- Tucker, S. N., Miller, A. J., and MacSporran, C. (1990). Budget levels for non-residential buildings in Australia - final report. (DBCE DOC 90/62). (CSIRO Australia Division of Building, Construction and Engineering: Highett). (118p.)

- Australian Building Codes Board (1998) 'Building Code of Australia'

- The Inter-jurisdictional Regulatory Collaboration Committee (1998) 'Guidelines for the Introduction of Performance Based Building Regulations – Discussion Paper, May.

- Scoping Study of Minimum Energy Performance Requirements for Incorporation into the Building Energy Code of Australia, Phase 1: Options and Issues (CSIRO Workshop Draft 6 July 1999).

- BCAider, Version 4.1 CSIRO 1998 (BCA 1996, Volume 2 – Housing Provisions)

- Tucker, S. N., Gipps, P. G., Ambrose, M. D., Lenihan, D., Wadsworth, D., Bhuta, C. J., and Salomonsson, G. D. (1999). Review of building system costs. (BCE DOC 99/106). (CSIRO Building, Construction and Engineering: Melbourne). (132p.)

Energy Utilisation

- EMET Consultants, Baseline study of greenhouse gas emissions from the commercial buildings sector with projections to year 2010, May, 1999

- Li, Y., Haghighat, F., Andersen, K.T., Brohus, H., Heiselberg, P. K., Dascalaki, E., Fracastoro, G. V. and Perino, M. Analysis methods for natural and hybrid ventilation

- an IEA ECB Annex 35 literature review, To be presented in the 3rd International Symposium on HVAC, Shenzhen, China, 17-19, November, 1999.

- Moller, S.K. BUNYIP – A Major Upgrade. Proc. ANZSES Solar ’96 Conference, Darwin, 22-25 October 1996.
- Li, Y. and Delsante, A., Analysing natural ventilation of multi-cell enclosures with large openings. CIBSE Virtual Conference, 1997.
- Tucker, S. N., Ambrose, M. D., and Mackley, C. (1998). A 3D CAD model of embodied energy for assessment of sustainable construction. CIB World Building Congress - Construction and the environment. Gavle, Sweden, 7-12 June. (pp. 1919-1926
- Tucker, S. N. and Ambrose, M. D. (1997). Embodied energy of dwellings. CSIRO ESD Successful applications Conference. Sydney, 3 September. (7p.)

Water Supply

- Davis, J. R., Speers, A., Booker, N., and Burn, S. (1998). 'The CSIRO Sustainable Urban Water Program'. *Proceedings of 6th NSW Recycled Water Seminar on Water Recycling and Sustainable Water Cycle Management* - held in conjunction with the 11th IWAS-ASPAC Regional Conference on Integrating the Urban Water Cycle, 1-5 November 1998, Sydney. Keynote Address, pp 14-19 Australian Water & Wastewater Association Incorporated Sydney.
- Speers, A. (1999) CSIRO's Urban Water Program – A National Approach to Water System Efficiency and Sustainability *Water*). Journal of the Australian Water and Wastewater Association. (September 1999).

Indoor Air Quality

- Brown, S.K., Sim, M.R., Abramson, M.J. and Gray, C.N. (1994). Concentrations of volatile organic compounds in indoor air – a review. Indoor Air 4, 123–134.
- Brown, S.K. (1997). National State of the Environment Report - Indoor Air Quality. SoE Technical Report Series, Dept. Environment, Sports & Territories, Canberra, 88pp.
- Immig, J., Risch, S. and Brown (1998). Indoor Air Quality Guidelines for Sydney Olympic Facilities. BCE Technical Report 97/3, CSIRO Publishing, East Melbourne, Australia.

- Brown, S.K. (1996). Assessment and control of exposure to volatile organic compounds and house dust mites in Australian dwellings. Seventh International Conference on Indoor Air Quality and Climate, Nagoya, Vol. 2, 97-102.

- Brown, S.K. (1998). Case studies of poor indoor air quality in Australian buildings. 14th Int. Clean Air & Environment Conf., 18-22 Oct., Melbourne, 205-210.

- Brown, S.K. (1998). VOC emissions from interior coatings - measurements and mechanisms. RACI Symposium on Advances in Polymers V "Coatings", Oct 2, CSIRO Molecular Science, Clayton.

- Brown, S.K. (1996). Controlling sources of indoor air pollution. Annual Conf. Of Aust. Institute of Occupational Hygiene, Perth.

- Brown, S.K. (1999). Chamber assessment of formaldehyde and VOC emissions from wood-based panels. Indoor Air (in process).

- Brown, S.K. (1999). Assessment of pollutant emissions from dry-process photocopiers. Indoor Air (in process).

- Brown, S.K. and Cheng, M. (1999). Pollutant emission properties of unflued gas heaters (in process).

Durability and Service Life

- Cole, I.S, "The Development of International Standards and of Verification Techniques for Performance Evaluation in Tropical Countries", Key note Lecturer at First Asia/Pacific Conference on Harmonization of Durability Standards and Performance Tests for Components in Building and Infrastructure, Bangkok 8th-10th September 1999.

- Cole, I.S., Linardakis, A. and Ganther, W. "Controlled humidity/salt dose tests for the estimation of the durability of masonry ties", Masonry International. 9, no.1 , p11-15 1995

- I.S. Cole, A.K. Neufeld, P. Kao, W.D. Ganther, L. Chotimongkol, C. Bharmornsut, N.V. Hue and S. Bernardo, "Corrosion Mechanisms and Performance Tests for Tropical Environments", To be presented at 14th ICC Cape Town 27 September - 1 October 1999

- Cole, I.S, King, G.A., Trinidad, W.Y., Chan, W.Y., Paterson, D.A. "An Australia-wide map of corrosivity: A GIS Approach"-8th Int. Conf. on Durability of Building Materials and Components, Vancouver, 30 May-3 June 1999.

- Cole, I.S, Trinidad, W.Y., Chan, W.Y., D.A. "Prediction of the Impact of the Environment on Timber Components: A GIS-Based approach."-8th Int. Conf. on Durability of Building Materials and Components, Vancouver, 30 May-3 June 1999.

- Cole, I.S., Patterson, D.A., Furman, S.A., Neufeld, A.K. and Ganther, W.D. "A Holistic approach to modelling atmospheric corrosion", To be presented at 14th ICC Cape Town 27 September - 1 October 1999.

- Burn, L.S., Cole, I.S. and Tucker, S.N.. "Information technologies and data formatting for the design life of buildings", 7th International conference on durability of building materials components"-May 30-June3, 1998.

- Cole, I.S. "An analysis of the microclimate of Australian wall cavities", Construction and Building Materials, Vol. 8, No. 4, p 1–9, 1994.

Safety In Use (Slip Resistance Publications)

- Bowman, R. (1998) 'Assessing the Relative Contribution of Ceramic Tiles to Slip and Fall Accidents', 5th World Congress on Ceramic Tile Quality, Castellon, Spain, Vol. 2, 161-73.

- Bowman, R. (1999) 'What must we do to prevent pedestrian slips and falls?', paper presented at 3rd National Conference on Injury Prevention and Control, Brisbane, 9-12 May.

Fire Safety

- Dowling, V. P. and Blackmore, J. M. 1998, *Fire Performance of Wall and Ceiling Linings*, Final Report, Project 2 Stage A, Fire Code Reform Centre Ltd, Sydney.

- Dowling, V. P. and Ramsay, G. C. 1997 Building fire scenarios - Some fire incident statistics. In *Fire Safety Science, Proceedings of the Fifth International Symposium, Melbourne*, International Association for Safety Science, Boston, Massachusetts, pp 643–654.

Structural Safety

- Macindoe, L., Pham, L. and Leicester, R.H.(1993) 'Safety Index Manual' DBCE Doc.93/41(M) May.

- Standards Australia (1999) 'General Structural Design Requirements' AS1170.0 (Draft for Public Comment).

- Pham, L. and Stark, G. (1998) ‘ISO Performance Standard for Housing’ Proc. Australian Structural Engineering Conference (Vol.1) Auckland October.

- Pham, L. (1999) ‘Alignment of Structual Loading Standards for Building Design & Construction in APEC Economies BCE Doc.99/078 June.

Building Façade

- Brown, N.G. and Ballantyne, E.R. (1975) ‘The Sirowet Rig for Testing Weather-proofness of Building Facades. CSIRO Division of Building Research.

- Standards Australia (1995) ‘Testing of Building Facades’ AS/NZS 4284:1995.

- Sankaran, R., Roberts, G. F. and Mayo, A. P. (1996) ‘SIROWET II – An Advanced Technique for Weather Testing Facades’, 3rd International Sysposium on Applications of the Performance Concept in Building, Tel-Aviv, Israel, Dec. 9-12.

- Sankaran, R. and Roberts, G. F. (1999) ‘Use of Weather Data in Water Resistant Design of Buildings’, Proc. of the 10th International Conference on Wind Engineering, Vol. 2, p 1165-1170, Copenhagen, Denmark, June 21-24.

- Brescianini, C. and Sankaran, R. (1999) ‘A Study of Pressure Equalised Rain-screens Using Numerical Models Buildings’, Proc. of the 10th International Conference on Wind Engineering, Vol. 2, p 1221-1227, Copenhagen, Denmark, June 21-24.

Life Cycle Costing

- Tucker, S. N. and Rahilly, M. (1990). Life cycle costing of housing assets. In Quah, Lee Kiang (Ed.), Building Maintenance Management and Modernisation Worldwide. Singapore, 7 - 9 March. (Vol. 1, pp. 161-172.) (Longman: Singapore).

- Bennett, A. F., Page, I. C., Bourke, K., Tucker, S. N., and Nireki, T. (1999). Life cycle costing for a design standard. Proceedings of 8th International Conference on Durability of Building Materials and Components. Vancouver, 30 May - 3 June 1999. (National Research Council of Canada: Ottawa). (12p.)

- Tucker, S. N. (1996). Economic and environmental assessment conflicts for long lived facilities. In Katavic, M. (Ed.), Economic management of innovation, productivity and quality in construction. Zagreb, 4-7 September. (Vol. 2, pp. 917-925.) (Faculty of Civil Engineering, University of Zagreb: Zagreb).