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International Developments in Planning Design Life of Buildings

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INTERNATIONAL DEVELOPMENTS IN PLANNING DESIGN LIFE OF BUILDINGS

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ABSTRACT

Performance-based building codes are becoming popular in many countries around the world. As a result many organisations are focussing on developing standards and guides to assist those involved in the building industry show compliance with such codes. The documents produced are not prescriptive but define methodologies which the user can follow to provide suitable evidence of compliance with the code. The International Standards Organisation (ISO) has constituted a new subcommittee SC14 'Design Life' under the Committee which covers building construction (ISO TC59). The sub-committee includes members from a number of CIB Working Commissions who have been working on building related issues for a number of years. This brings to the sub-committee a great deal of expertise in issues such as prediction of service life, building maintenance, performance concepts in buildings and building pathology.

In the past, researchers working in the area of 'prediction of service life' have been accused of being focussed too much on making materials last as long as possible. The current approach in the ISO sub-committee recognises that design life is intimately connected to client and societal (as expressed in building codes and planning regulations) requirements. The documents being developed at the present time include not only general introductory material and a guide on service life prediction, but documents which look at economic life cycle costing (LCC) techniques, ways of representing building design data in computer models and environmental sustainability. This paper looks at the general concepts involved in the LCC document and presents some brief examples of the use of this technique in practice. The likely future links between design life/LCC and environmental life cycle assessment are also briefly covered with some views on what this may mean to the way we go about designing buildings.

INTRODUCTION

Traditionally, disciplines involved in designing buildings have tended to work in a linear fashion. The architect/designer produced a plan from the client brief which was passed to an engineer for any engineering input required. Sub-trades may have been required to complete the specification of items such as glazing and weather-sealing. Project teams which incorporate all these disciplines from project conception to completion have been the exception rather than the norm. Researchers in construction related activities have also tended to be focussed on their individual topic areas. A review of the research publicity material put out by leading research institutes and universities worldwide, shows many groups with excellence in individual areas such as engineering, moisture, energy, materials etc, but much less focus on integrated teams which address more holistic building problems. It is not surprising therefore, that Standards development at both the national and international level has tended to follow the same individualistic style.

In recent years there have been signs of changes to this approach. Joint Australian/New Zealand Standards committees producing standards which are intended to be used as Acceptable Solutions or Deemed to Satisfy solutions for the respective national building codes, often have to consider how provisions in one standard may impinge on other building code requirements. There are a number of ISO committees and subcommittees active in construction related areas. Recent developments in two of these groups, demonstrate that a wider view of the activities involved in construction is being seen as important if Standards are to have influence and improve buildings as they are intended.

ISO CONSTRUCTION ACTIVITIES

There are a surprisingly large number of ISO Technical Committees (TC) involved either directly in building related matters or in materials used in buildings. Some of these are listed below:

- TC 59 Building construction
- TC 71 Concrete, reinforced concrete and pre-stressed concrete
- TC 92 Fire safety
- TC 98 Basis for design of structures
- TC 160 Glass in building
- TC 165 Timber structures
- TC 167 Steel and aluminium structures
- TC 179 Masonry
- TC 205 Building environment design.

The main focus of this paper is the activities of Subcommittee 14 (SC14) ‘Design life’ of TC 59. This subcommittee was formed about 18 months ago although many members were previously active in a working group. The original interest area of many early members of the working group was service life prediction and the activities of CIB W80 in this area provided a solid basis for the programme of work. Attention has in recent times become directed at the concept of ‘design life’ where materials performance is ideally matched to the intended function and life of the building. Service life is still an important aspect of design life, but is now part of a broader process which is intended to deliver the optimal building solution to the building owner and users, taking into account all relevant regulatory requirements.

SC14 is working on six documents which will eventually be published as ISO 15686 at the present time, all related to design life. These are:

- general principles
- service life prediction
- auditing
- data formatting
- life cycle costing
- environmental sustainability.

The first three parts under development cover the concepts and methods of service life prediction and methods for checking that the results of these processes are realistic and appropriate for the specific building in question. As such, these three parts bring together in a standardised form, guidance on techniques which are already in use in varying degrees within the construction industry although in widely differing degrees of sophistication.

The last three parts address aspects of design which are much less widely used at the present time, but are likely to have an important role in the future. Part 4 ‘data formatting’ looks at the way in which a building (as a sum of its components) can be described or represented in a common format which is suitable for use in computer software or models. While this may sound esoteric, the successful development of a common data format has far reaching implications. There are a wide range of applications where the quantities and properties of various building components are used to calculate or model properties of buildings. Some examples are:

- quantity surveying
- CAD design
- structural engineering calculations (eg. bracing)
- fire engineering
- LCC
- environmental life cycle assessment (LCA).

All of these applications use as an input some form of description of a building element and have various properties associated with them (eg. cost, stiffness, strength, combustibility etc). The cost of having to re-enter all this data into these different applications could be avoided if a standardised way of representing the data can be agreed on.

The inclusion of life cycle costing (LCC) as Part 5 of the SC14 working brief recognises that costs over the design life are often as important as form and functionality to the building owner. Applying LCC to buildings at the design stage is not a new concept but is seldom used to its full potential. Two of the reasons for this are; the complexity of undertaking calculations manually, and the scarcity of reliable data on costs other than those which can be easily quantified during design, procurement and operation. The trend towards design/build speculation, where the building is on-sold shortly after or even before completion, encourages a lowest initial cost mentality rather than a lowest whole life cost view. The development to-date of the draft LCC Standard and some practical aspects are discussed later in this paper.

Part 6 'Environmental sustainability' is a very recent addition to SC14's work plan and reflects the growing awareness and interest in this area by legislators, industry and the public. The burdens placed on the environment by construction activities can theoretically be calculated over the life of the building in a similar manner to economic life cycle costing. Many of the tools necessary to do this accurately are still under development and ISO TC207 "Environmental Management" is producing a series of environmental standards. The challenge for TC 59 SC14 is to integrate environmental issues into the building design process rather than have them off to one side with fringe interest groups.

The activities of ISO TC59 SC14 have largely been driven by researchers with a materials interest. It is worth noting that ISO TC98, which looks at the engineering basis for the design of structures, has also recognised the importance of an integrated design process for construction. An international symposium planned for 2000 in Finland, which includes as a co-organiser ISO TC98, has the following themes:

- framework and process of integrated life cycle design
- procedures, methods and guides of life cycle design
- life cycle accounting
- life cycle assessment
- service life design and optimisation
- durability design and prediction models for life cycle assessment
- design for recycling and reuse
- computer applications and software for life cycle design
- examples of life cycle design.

The similarities between the themes above and the activities of TC59 SC14 are obvious and show a convergence of thought which should provide a strong driving force for continued progress for an integrated design model for construction.

LCC IN ISO TC 59 SC14

The approach of the ISO TC59 SC14 sub-committee is to look at LCC as it affects the design process for buildings. The Standard is intended to cover construction works, which includes buildings, infrastructure items such as civil engineering works and building services. It is not intended to be a comprehensive financial investment tool which would look at returns on investment, compare different forms of investment and minimise taxation. A sub-committee draft has been produced which draws on established documents such as ASTM E917 (1994) and ASTM E833 (1997). An Australian/New Zealand Standard on life cycle costing is also being developed by committee OB/11 and their draft work also provided valuable input.

The overall concept of LCC is simple; all the costs associated with the design, construction, use, maintenance and disposal of the building are estimated or calculated over a defined period. The costs are then adjusted to take into account interest rates and, in some cases, inflation, to bring the whole life cost over the defined period into today's currency. This then allows a comparison to be made between different design options. The scope of the LCC exercise is set by the client's requirements (such as appearance, size, cost, expected life etc), taking into consideration planning and regulatory requirements. The output is used to assist in the final design decisions. Some of the concepts covered in the draft standard are detailed below.

Phases of LCC

The phases of the life cycle are as follows:

- acquisition (including land, planning and design, construction and fit out)
- use and maintenance
- renewal and adaptation (such as major refurbishments or redevelopments)
- disposal.

The renewal and adaptation phase may not exist but when it does, the use and maintenance phase commences again so that there are cyclic restoration and use steps which may repeat a number of times before the disposal phase occurs. The acquisition phase is where most opportunity to influence whole life costs exists. Different alternatives can be compared and the cost of changing a design is much less than attempting to alter a completed or partially completed building. While the ideal time to conduct an LCC is at the beginning of a building's life, LCC can have significant uses for existing buildings. LCC techniques can be used to evaluate the costs associated with various maintenance options for the whole or parts of a structure. This could include a review of the original maintenance schedule in light of the performance to-date or to evaluate alternative maintenance solutions resulting from unexpected failures.

Scope of LCC exercises

Life cycle costing can be carried out over the design life of a building, or over a finite period of the design life. It can be applied to a complete building, or to a specific assembly, component or system, such as plant or a roofing assembly. The latter are derived automatically in a complete LCC because the life cycle cost for a complete building or structure is built up from the sum of the independent parts plus the interaction between them and the consequential costs, if any.

Repercussions or consequences of selecting between alternative options in an LCC exercise must be considered and accounted for. For example, changing a cladding option may alter the thermal resistance properties of the building envelope resulting in changes to heating and cooling costs. Changing from a paint to an oil-based stain will result in a different recoating regime. In particular, some options may have different external or intangible costs, such as disruption to building activities or access, or increased costs borne by others than the client (e.g. retail tenants to a shopping centre during building maintenance).

Inputs to LCC analysis

The following details of the proposed building is required for LCC analysis:

- acquisition costs
- operating costs
- maintenance costs
- service life data
- period of analysis
- external costs and savings data

The information can be sourced from actual costs or estimates gathered from quantity surveyors or vendors, estimates based on past projects, performance models and best guesses at future trends. Each cost must be associated with a duration or date at which the cost occurs.

LCC decision variables

The mathematics of LCC are now well standardised (ASTM, 1994) and are not reproduced in this paper. A key concept is that costs incurred at a future point are less than the equivalent cost incurred now. This is because money can be set aside to earn interest over the period that the expenditure is deferred for. The value assigned to the interest rate (usually referred to as the discount rate) has a large influence on the outcome of an LCC exercise.

Costs in a life cycle costing analysis can be in real, nominal or discounted terms. A value in real cost is the monetary amount to be paid if the cost occurred at the base date, regardless of which point in time it occurs. The need to refer to a year when using real costs is because of general price inflation and also the fact that future prices may not necessarily change at the same rate for all items being covered by the LCC. The main benefit in using real costs is that it allows for more accurate estimates of costs since current values are used. Real costs are not generally appropriate for preparing financial budgets where the actual monetary amounts in today's currency are required to ensure actual amounts in future currency are available at the time when they are to be spent.

Nominal costs are ascertained from projected economic, technological and efficiency factors. The nominal cost is related to the real cost by the expected general price inflation.

Discounted costs are calculated by taking costs that occur in future years and reducing them by a discount factor derived from the discount rate. Different discount rates apply depending on whether nominal costs or real costs are being discounted. With nominal cost, the discount rate should include an inflation component. If real costs are used, the discount rate should not include an inflation component. Different discount rates also apply to different organisations and individuals. The discount rate reflects the preference for money now rather than later. The discount rate is the interest rate that would make it just worthwhile for the decision-maker to spend money in a year's time rather than now. It is also the rate by which future income would need to be discounted each year so that the decision-maker would prefer to have it now rather than in a year's time.

When evaluating life cycle costs, two different terms may be used to enable comparison of different options. Present value is the cost found by discounting future cash flows to the base date. It is used for comparing alternatives with the same period of analysis. Where options have a different period of analysis, the annual equivalent cost is used.

Risk and uncertainty

Many of the parameters used as input into an LCC are estimates of costs, materials performance, maintenance regimes etc. and can be subject to considerable uncertainty. This will naturally be carried through the LCC calculations into the results of the analysis. It is important to recognise this risk and take steps to guard against gross errors resulting. A common way to do this is by carrying out a sensitivity analysis. This involves estimating the degree of error in the input data, and re-running the LCC using credible upper and lower limits. If the results of the LCC are little affected, then the variability of that particular input is not a major concern. Inputs that should be subjected to sensitivity analysis include:

- discount rates
- the period of analysis
- maintenance regime frequencies
- incomplete or unreliable service life data based on assumptions.

The use of very long periods of analysis should be avoided since the use of times in excess of about 30 years tends to result in costs beyond this becoming negligible in today's dollars in many cases.

Reporting

Any LCC report must ensure that users can clearly understand both the outcomes and the implications of the analysis, including limitations and uncertainties. The report should include:

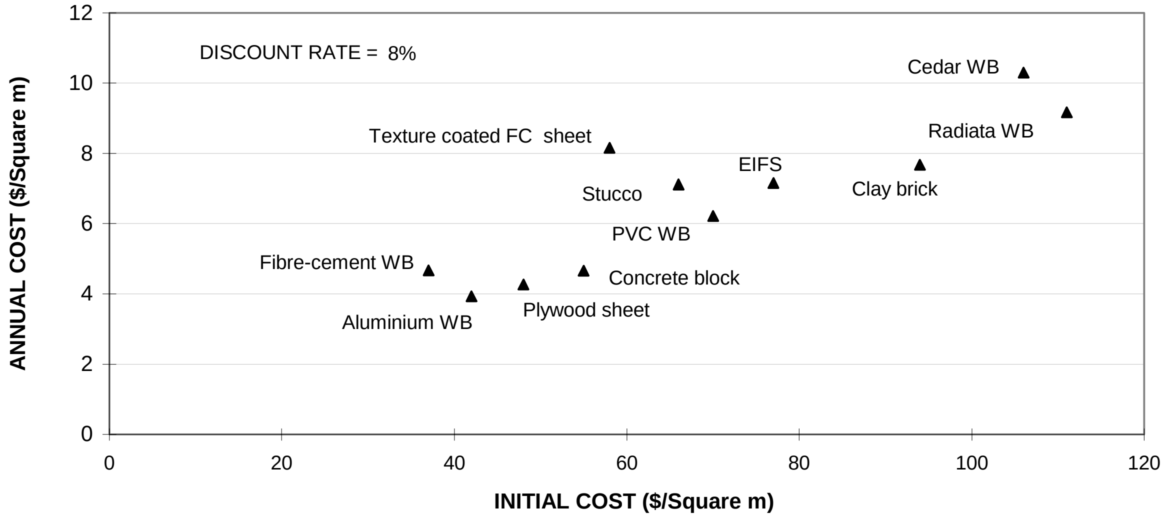
- a statement of objective, materials under consideration, assumptions, constraints, and alternatives
- impacts likely to affect costs either directly or indirectly but which can not be quantified
- a presentation of the results, including sensitivity analysis, cost structure and method of accounting for the time value of money
- a thorough discussion of the interpretation of the results
- conclusions and recommendations.

PRACTICAL APPLICATIONS OF LCC

Applications of LCC to complete building projects from acquisition to disposal are rare. Examples of partial LCCs on existing and new structures are simpler and more common. Work at BRANZ has in recent times (Page, 1997) looked at producing comparative LCC data on cladding options for domestic and commercial buildings. The aim of this is to provide data in a useable form and the final output is likely to be a software model. One of the interesting results of this work was the lower whole life costs associated with some cheaper initial priced, but higher maintenance, claddings (see Figure 1). An important aspect of this finding is that the results were strongly influenced by the price structure and interest rates applicable in New Zealand at the time of the analysis. In Australia, the different price structure and lower interest rates could well result in significant differences between material choices.

A second exercise was carried out for a commercial property owner with a large number of houses with concrete tile roofs. The tiles were typically 30-45 years of age and many were refurbished by painting with an acrylic finish. The finish came with a 10 year pro-rata warranty and a requirement to fungal wash every 4 years. The question was whether the cost of the wash versus possible adverse performance caused by not washing had the most impact on the costs over a 20-30 year period. After a detailed investigation into coating performance, including field inspections, a series of different coating/wash/performance scenarios were analysed. The lowest cost option was found to be to not wash. However, as part of the sensitivity analysis, an option not considered by the client was included. The effect of the unattractive lichen clad coating was assumed to increase the gap between tenants to four weeks after eight years. This resulted in the highest whole life cost of any of the options illustrating the dangers associated with overly simplistic LCC models.

Figure 1. Wall Claddings - Life Cycle Costs (Page, 1997)
(MODERATE ENVIRONMENT)



FUTURE DIRECTIONS IN DESIGN LIFE

There is no doubt that environmental aspects will feature heavily in future deliberations on design life. There remains a considerable amount of data to be collected on the environmental impacts of buildings and on ways in which different environmental impacts can be compared with each other (eg. green house gas emissions versus depletion of natural resources) and costed in a common framework. There are however, some practical issues which are becoming more widely debated. Potential changes in demographics, town planning, technology or legislation make it difficult to guarantee how long a building will be used for its original intended function. How can designers and building owners make decisions at the design stage to reduce the risks and impacts of a building becoming obsolescent before it has reached the end of its design life? Options include a more flexible approach to design, where the floor area readily accommodates different space arrangements, services are flexible and the interior fittings and partitions are re-useable. Recycling of building materials does occur, but often only a relatively small part of a building is salvaged undamaged during demolition. The use of factory assembled components using adhesives reduces initial costs and allows for innovative engineering solutions. Such components are however, difficult to take apart and unless they can be re-used as a complete assembly, they may not readily be re-used or recycled.

A increasing trend in the future will be the use of design teams to provide ‘useable space’ not simply to design a building. A new building may be the ultimate result, but the team will look at all options including the client’s existing buildings, other existing buildings and possibly even how the client’s processes can be improved to allow better space utilization. The option which gives the best economic and environmental return while still meeting the client’s operational requirements would be chosen.

CONCLUSION

International Standards development is seeing a convergence of interest among those involved in the design life of buildings. Increasingly, the design process is being viewed as an integrated one rather than a linear series of inputs from different professions who may act in relative isolation. The inclusion of economic life cycle costs and environmental sustainability into the thinking of materials and engineering based standards committees is evidence of this.

The challenge will be for those involved in building acquisition, maintenance, use and disposal, to work with building regulators to ensure that the construction plays its part in their role in maintaining the sustainable future demanded by society.

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