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Advances in Methods for Service Life Prediction of Building Materials and Components – Final Report – Activities of the CIB W80

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ABSTRACT

The development of service life product standards and standardization of service life design and planning of buildings and constructed facilities are key elements for achieving "Sustainable Construction". The technical committee CIB W80 has focused over the past decade, on the development of knowledge in support of such standards and design methods and it has been the prime purveyor of fundamental information on the service life prediction of building materials and components. A final report is provided of work completed in the most recent work programme covering the period between 2002-2005. Advances in three areas of estimating the service life of building products components or systems are outlined. These include the factorial method, an engineering design approach and reliability-based methods. As well, a summary is given of work carried out in related areas, including environmental factors. Additional information is provided on failure mode effects analysis and its use in the building industry. Insights are provided into the collaborative efforts and related activities within ISO TC 59 SC14 – "Design life" and the Performance based building (PeBBu) thematic network initiative focused on "Construction materials" of the fifth EC framework on Competitive and Sustainable Growth

KEYWORDS

Building materials, building components, service life, sustainable construction

INTRODUCTION

Considerable work has been carried out in the area of service life prediction as requisite tools for helping assess long-term environmental effects, for maintenance management of infrastructure systems, such as roads, bridges, waterways, water distribution and waste-water removal systems, or indeed for maintenance of building envelope systems, envelope components and related materials. Increasingly, building material and component manufacturers are seeking systematic methods to assess the likely risk to premature deterioration of existing products given specific climatic effects, or the most vulnerable exposure conditions of new products in specified systems.

The CIB working commission (CIB W080), focused on reviewing methods of service life prediction of building materials and components, was created in September 1996. Prior to this, the joint CIB W080 / RILEM Committees (RILEM 71-PSL, 100-TSL, 140-TSL and 175-SLM) have been responsible for a preparing a series of useful working documents [e.g. Sneck 1982; Masters and Brandt 1989; Sjöström and Brandt 1991; Sjöström 1996; Lacasse and Vanier 1999; Vanier et al. 1999; Burn 2002; Daniotti 2003] as well as co-ordinating the efforts required to bring about nine international conferences related to durability and service life issues and the tenth taking place in Lyon, France. As has been stated previously [Lacasse and Sjöström 2003; Lacasse and Sjöström 2004], a substantial depth of knowledge to this field has been offered through this series of conferences and related symposia. However much of this information is not readily accessible to manufacturers of building materials and components, nor others who would likely benefit such as designers, specifiers, constructors, as well as asset and property managers. To enhance the knowledge derived from these collective efforts, the overriding task of the CIB W080 has been to, collate, review summarise and integrate information related to durability and service life from which guides and related types of information had been produced. The outgrowth of these efforts has culminated in contributions that enable practitioners to select the appropriate tools to predict service life.

This on-going exercise has in part been achieved through the committees' on-going support in developing the ISO standard 15686 prepared by the ISO TC59 SC14 on Design Life. The development of this standard has brought about broad recognition of the need to assess durability of components in all construction standards and this is being address in the EU and other national standards bodies. Additionally, collaborative efforts with the Performance based building initiative (PeBBu), currently in progress, are likewise increasing the outreach of work being carried out within the CIB W80 working commission (WC). This brief report provides an overview of activities completed in the period between 2002 and 2005, including a description of collaborative efforts and outreach activities.

ACTIVITIES OF THE CIB W80

Activities of CIB W80 extend back to 1978 and it has since seen different designations as it had been associated with the RILEM TC 71-PSL (Prediction of Service Life), 100- and 140-TSL and more recently the 175-SLM (Service Life Methodologies). The current work term will be completed as of the annual meeting in 2005 and the membership last met following the CIB World Building Congress – "Building for the Future" held in June 2004 in Toronto, Canada.

Collaborative efforts and outreach

The CIB W080 committee has always maintained links with related CIB committees such as the W060 on performance-based standards, W094 on Design for durability and W086 on Building pathology. However, since 1993 its outreach has been extended in large part due to its close collaboration with both the ISO technical activities, in particular the ISO TC 59 SC 14 (Design Life), the ISO TC 59 SC 17 (Sustainability in Building Construction), and the Performance based building (PeBBu) initiative undertaken within the context of the fifth EC framework for collaborative thematic research on

Competitive and Sustainable Growth. Brief overviews describing the nature of each collaborative effort are provided below.

Collaboration with ISO
The collaboration with ISO has been described in some detail in previous contributions [Lacasse and Sjöström 2003; Lacasse and Sjöström 2004], and the efforts regarding support on this standard within the WC are expected to continue for the foreseeable future. To date, the first three and the sixth part of the standard (ISO 15686 Buildings and Constructed Assets – Service Life Planning) have been published in successive years starting in 2000. A brief overview of the different parts is given below.

Summary of standard and current progress
Part 1 - General principles [ISO 2000] - describes the principles and procedures that apply to design, when planning the service life of buildings and constructed assets. It is important that the design stage includes systematic consideration of local conditions to ensure, with a high degree of probability, that the service life will be no less than the design life. The standard is applicable to both new constructions and the refurbishment of existing structures.

Part 2 - Service life prediction procedures [ISO 2001a] - of the standard is mainly based on the Service Life Methodology developed by Masters and Brandt [1989]. It describes a procedure that facilitates service life predictions of building components. The general framework, principles, and requirements for conducting and reporting such studies are given.

Part 3 - Performance audits and reviews [ISO 2002] - is concerned with ensuring the effective implementation of service life planning. It describes the approach and procedures to be applied to pre-briefing, briefing, design, and construction and, where required, the life care management and disposal of buildings and constructed assets to provide a reasonable assurance that measures necessary to achieve a satisfactory performance over time will be implemented.

Part 6 - Procedures for considering environmental impacts [ISO 2004] - describes how to assess, at the design stage, the potential environmental impacts of alternative designs of a constructed asset. It provides information on the interface between environmental life cycle assessment and service life planning (SLP).

A more detailed overview of the ISO 15686 series of standards and information on other parts of the standard are described in Sjöström et al. [2002]. Work undertaken within the CIB W080 directly supports development of the standard.

Activities related to the PeBBu
The EU thematic network PeBBu (Performance Based Building) was initiated in 2001 as part of the broader fifth EC framework for collaborative thematic research on Competitive and Sustainable Growth [Sjöström and Lair 2003]. The specific domain within the PeBBu on Construction Materials and Components (Domain 1) addresses issues related to the implementation and adoption of the performance-based standard on service life planning developed as ISO 15686. The motivation for this specific initiative emerged from the European Construction Products Directive (CPD) [Council of the European Communities 1988]. This directive specifies the "Essential (Performance) Requirements" that should be met of constructed works during their intended working life. This necessarily resulted in the need for establishing performance requirements on all building products from which the "life performance" (i.e. service life) of materials and products likewise has now to be assessed and declared.

A compendium of information regarding the project specifically related to the activities of CIB W080 focus on Domain 1 (Life Performance of Construction Materials and Components) can be obtianed from the PeBBu Web site (http://www.pebbu.nl/maincomponents/scientificdomains/domain1). These include for example:

- Specific Workplan: Objectives, scope activities, deliverables and milestones) of all tasks in the PeBBu programme.

- Domain members – list of participants, organisation, country, function
- Meetings and documents – Minutes to past meetings and other documents such as;
    - First Domain 1 report - provides information related to the first PeBBu Domain 1 Workshop (September 20, 2002, Gävle, Sweden) in which is presented the Work Programme, State-of-the-art on performance based building that summarises reports from a number of countries, and information on the need to develop service life data on building materials and components. Additionally, the applicability and development needs of the Factor Method and the Reference Service Life concept are presented, as are the domain research and research priorities. A comprehensive research overview is, however, not provided.
- Domain resources – source of documentation in which can be found, for example:
    - Domain 1: Synthesis Report Construction Materials and Components.
    - Performance Based Building – Some Implications on Construction Materials and Components [Sjöström and Lair 2003].
    - Operational Methods for Implementing Durability in Service Life Planning Frameworks [Lair et al. 2001].

The CIB W080 WC continues support of PeBBu network Domain 1 activities in that the WC's work programme has focused to further develop the Factor Method and the Reference Service Life concept as well as reporting on recent developments on the use of failure modes effects analysis (FMEA) for assessment of service life data for building materials and components [Lacasse and Sjöström 2003; Lacasse and Sjöström 2004]. Additional information related to the FMEA is offered in the subsequent section.

Recent work carried out in CIB W80

Publication of the results from the CIB W080 work programme that concluded in early spring 2002 have been summarised in two sets of documents:

(i.) Guide and Bibliography to Service Life and Durability Research [Jernberg et al. 2004]

(ii.) Performance Based Methods for Service Life Prediction [Hovde and Moser 2004]

Information on the service life and long-term performance of materials, components and system is a vital link in attaining sustainable and economically viable construction. Hence, it is hoped that in regard to the "Guide and Bibliography", this initial contribution will spur others working in this domain, in particular in the construction material manufacturing industry, to provide additional information on the durability of components, insights into their comportment in an assembly or system and related information on their performance and long-term performance.

Performance based methods for service life prediction focuses on two approaches to estimating service life: (i) the factor method and, (ii) the engineering method.

A brief overview of each document is offered below.

Guide and Bibliography to Service Life and Durability Research for Buildings and Components
This publication [Jernberg et al. 2004] covers work undertaken within the CIB Working Commission W080/RILEM Technical Committee 140-TSL on the prediction of service life of building materials and components during the period between 1991 and 1996, and as well, additional information subsequently provided in the period between 1997 and 2002. It was intended that this publication offer researchers and knowledgeable practitioners a useful guide to service life prediction. Essentially a primer that provides fundamental information related to methods of service life prediction, on environmental characterisation, and relevant to the performance and durability of construction materials.

The introduction offers background to the work, a general overview of the document and the terminology used in the text. Following which, the document is divided into four parts, the first of which provides an overview of service life and durability issues; it is an introduction to the topic. The second part represents a significant contribution on environmental characterisation, previously published by the Norwegian Institute for Air Research in 1996. The third part encompasses various contributions specifically related to materials. Originally, it was thought that this part would provide basic information on material properties and the performance and durability of a broad range of construction materials including, cement-based materials and concrete, different metals including, steel, iron, aluminium, and polymer based materials and so on. Although this part does provide some extremely useful information on copper, natural stone, brick masonry, clay and wood construction materials, the broad list of materials originally intended has yet to be completed. Given the broad scope of the task, the work of providing an all-encompassing compendium of relevant information on all construction materials must be considered on going. The final part of the document provides an annotated bibliography that includes abstracts or summaries of works related to service life and durability, case studies as well as experimental work on materials, components and systems, based on the original document prepared by Grondin at the National Research Council Canada [Grondin 1993].

Performance Based Methods for Service Life Prediction
The report [Hovde and Moser 2004] is divided in two parts (A and B) the first of which focuses on the Factor method whereas the second describes the Engineering approach to service life estimation.

Part A — This report contains a state-of-the-art regarding development, evaluation and use of factor methods for service life prediction, in particular the factor method presented in ISO 15686 Part 1 [ISO 2000]. The initial two chapters provide a short introduction and background to the topic, respectively. In Chapter 2, some important activities that have taken place during the last decade are described and highlight the increased focus on sustainable development and the need for service life prediction tools. These activities are evident both internationally and on a national level. Chapter 3 contains some examples in which the need for service life prediction is explained. Four different tables expressing design lives for different categories of buildings are provided. In Chapter 4, general requirements for service life prediction methods are delineated. It is evident that the need for estimating service life may be dependant the purpose for carrying out an estimate and thus would require different levels of sophistication to achieve meaningful values. As well, it is shown that service life prediction is encumbered with considerable uncertainties in estimating factors affecting the service life of materials and components, and as such, it is not an exact science. Chapter 5 contains a description and explanation of different factor methods whereas Chapter 6 contains an evaluation of factor methods. Illustrative examples of application of the ISO factor method are given in Chapter 7 – the examples show how factor methods can be incorporated in design for durability and development of sustainable buildings. Specific application of the factor method for service life prediction of facades and windows is provided. Finally, Chapter 8 contains important aspects regarding further development of factor methods.

Part B — Provides a literature review and appraisal of the state of the art of the factor method. A basic “engineering” approach is described that can be applied to the factorial method for standard cases as well as to other service life prediction methods that employ mathematical relations for service life. As opposed to using simple numerical factors, as is done in the original factor method, this approach incorporates the use of probability density functions for factors as well as for estimating the service life of individual components to arrive at an overall estimate of a building system's service life. The density distributions are established using reliable and understandable engineering techniques applied in a systematic and straightforward manner. Three examples are shown to illustrate the proposed procedure for different basic equations and different quality of input data.

Review of recent Work program (2003-2005)

Following discussion within the group on a notional program developed in 2002 [Lacasse and Sjöström 2003] it was decided that emphasis would be placed on: (i) the use of FMEA (failure modes

effects analysis), and; (ii) further development of information related to obtaining Reference Service Life data for building components (products). No new information has been provided in regard to Reference service life that was not previously reported [Lacasse and Sjöström 2004]. Hence the following will concern providing information on recent work related to FMEA.

Failure mode effects analysis
The method of failure modes and effects analysis (FMEA) was developed and used in the aircraft industry as early as the 1960's [Lair 2003] as a means to help ensure adequate levels of systems reliability and maintainability during the production phase given the many different components that potentially could cause failure in modern aircraft. For building construction, it was suggested as a useful tool for the curtain wall industry to help mitigate risk of premature failure arising from problems that might be encountered not only over the course of fabrication, but also during installation [Layzell 1997, Layzell and Ledbetter 1998].

The applicability of FMEA to help assess the durability of building materials and components was first suggested by Lair and Le Teno [1999] and thereafter further refined by Lair [2000]. FMEA is used to understand the functionality and hierarchy of building elements including the interrelation among the different systems (building envelope, structure) sub-systems (cladding, windows, doors, roofing membrane) and other components of the building.

The use of a multifaceted operational approach has been suggested as a means of implementing the ISO standard on service life planning, ISO 15686, in practice [Lair et al. 2001, Sjöström et al. 2002]. The method is proposed for estimating the reference service life of a building component (RSLC) on the basis of service life data using the basic three items in the approach: (i) FMEA; (ii) data gathering and (iii) data analysis. Further refinement of the approach was provided by Lair and Chevalier [2002] in which the durability assessment methodology is described. The method is extended from design and implementation to an in-use assessment tool for maintenance management. Additional work by Talon et al. [2003] is reported on developing a simplified tool for decision making in both the design and in-use stages of building.

SUMMARY

The current work program was intended to develop additional information to promote the use of the ISO standard on design life, further refinement of methods of data gathering and analysis, in particular the use of the FMEA. The examples provided in the literature on the use of FMEA suggest that the method is readily adaptable to many building systems. Indeed, it has been demonstrated for certain roofing systems, insulated glass units, and for window and IG unit systems. Given that the method has been applied to many other building systems a comprehensive guide is being prepared on the use of FMEA for the building industry that would provide useful to other organizations seeking to undertake service life studies in a systemic fashion.

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