SERVICE LIFE PLANNING OF BUILDING COMPONENTS

Service life planning of building components

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Abstract

Service life planning of building components was studied for a whole building in an R&D project, carried out at the Centre of Built Environment, Gävle, Sweden. The study was connected to a demonstration construction scheme and was integrated in the design and construction of a building. The study was performed in accordance with the draft standard ISO/DIS 15686.1 Buildings: Service life planning, and one aim was to test, evaluate and give input to further development of the standard. To make an estimation of a component's service life, the requirements, degradation environment and performance have to be considered. This paper will discuss this approach and discuss how available service life data can be collected and evaluated. Examples of service-life predictions are also shown.

Keywords: Service life planning, service life predictions, degradation environment, degradation agents, degradation mechanisms.

1 Introduction

This paper describes the use of a methodology for service life planning of building components and materials. The work was carried out on an actual building project, a four-storey apartment house in Gävle, Sweden. The service life planning is carried out in accordance with the draft standard ISO/DIS 15686.1 Buildings: Service Life Planning, part 1: General Principles (ISO 1998). The standard defines how to find out whether an estimated service life (ESLC) meets or exceeds a desired service life (DLC, design life of component). This paper is a continuation of (Hed 1998) where the early stage of the service life planning is described. Background and preparatory work of the ISO standard are presented by (Caluwerts 1996) and (Soronis 1998).

To perform the service life planning the following aspects of a component should be considered:

- requirements of the component and its design life
- type and intensity of degradation agents
- performance – the reaction of materials to degradation agents.

An ideal situation is that data are available on all of the three aspects and that the data are accurate and well defined. But that is not always the situation today; very few service-life data are available. Data that are at hand will be used in the estimations although they may not be as accurate as desired. This is accepted in the project and this shortage will be used to point out further research. Results of estimations are shown as examples.

2 Method of service life design

2.1 Performance requirements

It is essential to describe the function and the requirements of every component since the service life of a component is reached when these requirements are not met. The same approach applies for all parts of the building such as structure, building envelope, services, complements etc. When establishing the requirements of a component it is essential to define the level of the component on which the function of the component should be described (see Table 1).

Table 1: Level of component

Level	*Example*
Building Assembly	Facade including rendering, windows, ventilation openings, fixings, flashing etc.
Component	Facade rendering
Material	Top coating
Molecule	Chemical composition of top coating

The next step is to describe the performance requirements. The requirements can be of the type either/or such as a non-acceptance of a water leakage or a degradation such as a maximum reduction of a paint-thickness due to weathering agents (see Table 4). At this stage the design life of the components (DLC) are set. As governing user requirements, the six essential requirements in the European Union Construction Product Directive, CPD are employed (Caluwerts1996).

2.2 Degradation agents – degradation environment

Degradation agent is defined in ISO/DIS 15686-1 as: “Whatever acts on a building or its parts to adversely affect its performance, e.g., person, water, load, heat.” This means that wear for a flooring material and use such as opening and shutting of a window are also degrading agents. Degradation environment is the combined action of different agents that act on a material. The degradation agents originating from the atmosphere can be classified in four levels, see table 2 (Haagenrud 1997).

Table 2: Levels of degradation agent originating from the atmosphere

Level	*Example*
Macro	Global: Sweden, Northern Europe
Meso	City, community: Gävle
Local	Location in city: Kvarteret Diligensen (block in actual building project).
Micro	Actual location of a component on the building.

At the meso-level, climate data can be obtained: wind speed, predominant wind-direction, driving rain, temperature characteristics, relative humidity etc. In Table 3, air pollution characteristics are described for the site of the building on a meso/local level. Subsequently these data will be interpreted to a micro-level, which is dependent on the component location on the building and also the building material itself.

Table 3: Air pollution characteristics for Gävle, Sweden, (Meso)

UN ECE ICP *Agent*			ISO 9223-9226 Category		
TOW	3300	hours/year	T_4	2500-5500	hours/year
SO_2	5-10	$\mu g/m^3$	P_0	≤ 10	$\mu g/m^3$
NO_x	30-65	$\mu g/m^3$			
Cl^-			S_0	≤ 3	$mg/m^3/day$

2.3 Performance over time data

To estimate the service life at last, it is necessary to describe how materials or components react to different agents. Different ways of attaining this are discussed in this section.

- Degradation mechanisms
- Dose response functions
- Evaluation of test results
- Systematic observations on the built environment
- Observations on the built environment

The service life can be obtained by performing calculations based the *degradation mechanism* of a material, where the mechanism can be described on a molecule or a micro level. A typical example of this is when colour changes are explained on an atomic level. Another example is the theory of frost heave to explain degradation of rendering. In this case the requirements either have to be formulated in terms of the theory or the results have to be interpreted into other (visible) terms.

Another approach uses *dose-response* functions where (typically) loss of material is measured and the environment monitored, often for a number of years at different exposure sites. The observations are subsequently correlated into formulas, which can be used to calculate the loss of material for other degrading environments. A dose response function can be of the type $M=A_1*A_2*b^t$, where M is loss of material, A_1, A_2 and b are dependent on material properties or the environment and t is time. If $M= M_0$, where M_0 is a specific value, the time corresponding to this loss of material is the service life.

Conclusions might also be drawn from *tests carried out by component manufacturers*. Examples are flooring abrasion tests, mechanical function tests of doors, tests of frost resistance, acid resistance, fungi resistance etc. Performed *systematic inspections* on the built environment can also be used for estimations, (Tolstoy 1989) and (Sjöström 1990). Information is also available from some insurance companies; one example might be the HAPM Component Life Manual (HAPM 1992).

A considerable amount of service life data are available where the requirements, the degradation environment or the performance are poorly described. These data are often based on observations on the built environment, but are not systematic.

To obtain performance over time data seems to be the most difficult part of the process. It is easier to formulate requirements and describe degradation agents than to calculate the effect or formulate a theory, which also has to be tested for validation.

A general methodology for service life predictions is described in ISO/DIS 15686-2 (ISO 1999). A test program carried out according to that procedure will produce a quality assured predicted service life based on specific conditions. To date few values are available, which are gained with the method in its entirety. However, the knowledge will increase as the methodology is further used in R&D projects and programmes.

2.4 Factor method

A predicted service life as obtained according to the methodology [ISO 1999] or from other sources of information should be used in the design as a reference value in order to estimate the service life of a component. If the design conditions are the same or substantially similar to the reference conditions, the reference value can be used directly as estimation. But what to do if the conditions deviate from the reference conditions? ISO/DIS 15686-1 suggest a factor method (discussion see Hovde 1998). The service life of a component is estimated by using the formula

$$ESLC = RSLC \times A \times B \times C \times D \times E \times F \times G \quad \textbf{(1)}$$

ESLS = Estimated service life of component
RSLC = Reference service life of a component.

The modifying Factors A to G reflects the deviations from the conditions from which the RSLC derives.

- A Quality of components
- B Design level
- C Work execution level
- D Indoor environment
- E Outdoor environment
- F In-use conditions
- G Maintenance level.

3 Results

Worked examples of service life estimations are shown in Table 4. Of significance is the facade rendering seems to have a longer service life than the flashing. This leads to the conclusion that either a maintenance program or a material change needs to be done for the flashing.

Table 4: Examples of results of service life estimations

Component	*Performance*	*Performance criterion*	*DLC*	*Degrading agent*	*Estimation of service life*	*Comment*
Exterior door, SWEDOOR						
Hinges, lock	Mechanical function. Open, shut and locking of door.	Non-acceptance of malfunction	60	Open shut 10 times a day (200 000 times)	Life expectancy 60 years with maintenance	Tests performed by manufacturer Feedback from experience
Draught stripping	Air-tightness	Non-acceptance of malfunction	30	Weathering, use	Maintenance interval 30 years	See above
Paint	Protection of substrate	Protection ability (reduction of thickness, cracking adhesion etc.)	10	Weathering	Maintenance interval 10 years	See above
Paint	Aesthetic, colour changes	According to standards (reference pictures)	10	Weathering	Maintenance interval 10 years	See above
Flashing, (Figure 1,2) coil coated steel	Weather protection, covering of joints	Non-acceptance of malfunction	60	Weathering		
Front coating (Plastisol)	Protection of substrate	Protection ability (blistering, cracking adhesion loss)	30	Weathering	10 years, maintenance interval	(Sjöström 1990)
Front coating	Aesthetic, colour changes	According to standards (reference pictures)	30	Weathering	10 years, maintenance interval	(Sjöström 1990)
Zink	Loss of material	20 μm	30	Weathering (air pollution)	Service life 25 years (no coating)	Dose/response calculation (Haagenrud 1997) UN ECE ICP

Continued.

Component	*Performance*	*Performance criterion*	*DLC*	*Degrading agent*	*Estimation of service life*	*Comment*
Concrete Outdoor exposed	Carbonation	Carbonation depth 20 mm	60	Outdoor exposed	Service life more than 100 years	Calculation from (Sarja 1996) Concrete K40
Rendering on facade – STO Vario (figure 4)	Weather protection	Non acceptance of malfunction	60			
Finishing coat Type: Water repellent, organic plaster	Aesthetic, colour changes	Some acceptance of colour changes.	20	Weathering (air pollution, UV-radiation etc.) growth of algae	Washing every 15 to 20 years	Feedback from experience Observations on maintenance intervals
Finishing coat	Protection of render and heat insulation	Non acceptance	30	Weathering	Service life 60 years	Feedback from experience Observations on maintenance intervals Laboratory testing
Rendering	Frost damage	Total degradation in spots	60	Critical moisture contents, freezing temperature.	At least 60 years, dependent of coating	See above
Rendering	Cracking, general	Non visible w=0.2 mm	60	Shrink of underlying material	At least 60 years	See above
Rendering	Cracking in structural joints	Non visible w=0.2 mm	60	Movements of structure	At least 60 years	See above
Fibre-cement board TEPRO Minerit facade board	Aesthetic	Non acceptance of ageing, (cracking, flaking etc.)	30	Weathering (in nordic conditions)	Life expectancy more than 30 years.	Feedback from experience, observations on maintenance intervals, Accelerated ageing tests
Roofing concrete slates (Benders) (figure 3)	Weather protection	Non acceptance of malfunction	60	Weathering (rain, freezing, UV-radiation etc.)	At least 60 years	Feedback from experience Observations on maintenance intervals Laboratory testing

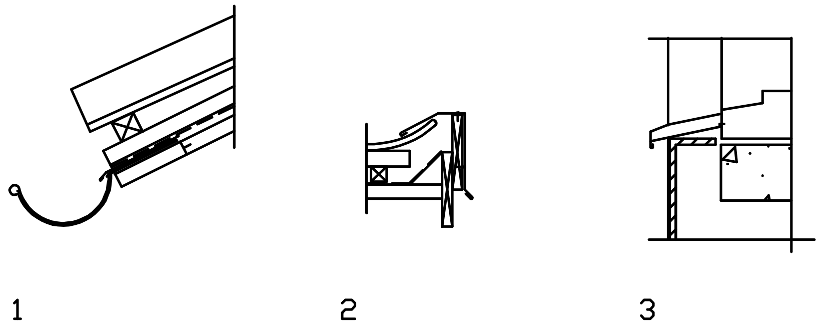


Figure 1. Flashing, coil coated steel, *1: gutters, 2: barge boards, 3: window edge flashing*

Figure 2. The basic build-up of coil-coated sheet metal.

1. Front coating
2. Primer
3. Pre-treatment
4. Zn or Al/Zn (typical 0,6 mm)
5. Steel or aluminium
6. Zn or Al/Zn
7. Pre-treatment
8. Back coating

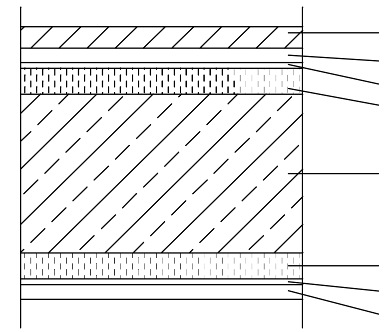


Figure 3.
Roof concrete slates

1 Concrete slate
2 Wood battens
3 Roofing underlay, roofing felt
3 Tongued and grooved board

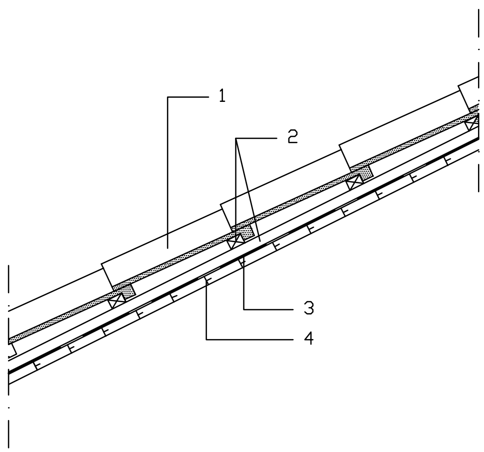
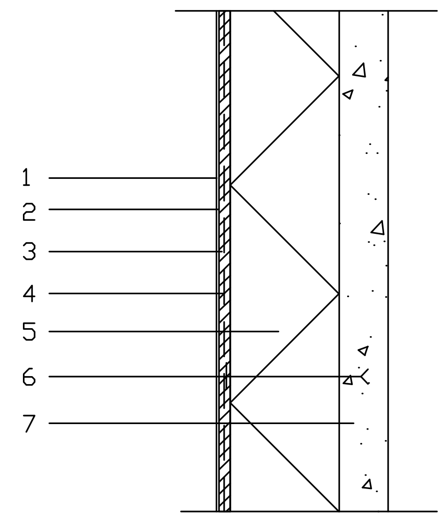


Figure 4.
Exterior wall

1 Finishing coat
2 Primer
3 Rendering
4 Reinforcement
5 EPS heat insulation
6 Mechanical fixing
7 Concrete structure



4 Discussion of service life planning

4.1 Customers demands

In a discussions with representatives of designers, house owners and building management they claim that active service life planning is preferable to today's maintenance programs, which are applied to the building after it has been built.

4.2 Reference service life

A problem is that there are still few tests performed of material and component service life, comprising all the aspects required of the building component when it is in operation in the building, i.e. following the service life prediction methodology [ISO 1999]. A lot of tests are done to explore the degree of frost-resistance, acid-resistance, water repellence, fungi repellence etc. In this work though, the results of such tests have to be considered, as they might be the only available.

The accuracy of the estimated service life is of course suffering from this fact, so one has to discuss if it is worth the effort of doing the estimations or not. If the goal is to find a precise value it is clear that the goal not is reached. But if the goal is to improve the general situation in service life planning the answer is yes.

4.3 Factor method

The factor method in ISO/DIS 15686-1 is meant to be a tool to improve the estimation of the service life. It was found in the project that this method did not improve service life estimations. This opinion is summarised in the following.

Uncertainty of RSLC and values of Factors — The factorial formula (1) comprises in the right side of a reference value (RSLC) and the adjusting Factors, A to G. If the reference value can not be determined accurately it is not appropriate to adjust these values with a set of uncertain Factors.

Uncertainty of the effect by combination of Factors — The method does not support the thoughts that one needs knowledge of cause and effect to estimate the service life. The estimation will be based on uncontrollable occurrences, which can act independently of each other.

5 Conclusions

Service life planning for building components was performed for a whole building. Estimations of service life were based on available data, which have been arranged and evaluated for this purpose. Data were gathered from test-results, interviews, research reports, handbooks. The standard ISO/DIS 15686-1, Buildings: Service Life Planning serves its purpose well by giving a methodology in the work and giving definitions to different items. One observation though is that the Factor method in the standard did not improve the estimations of the service life of a component.

Service life planning is a tool to improve the quality of a building and can be used both in a specific case, as here, and in general estimations of the building stock. All service life estimations should be based on the requirements, degradation environment and performance of a component.

To improve the possibilities to perform an adequate service life planning the following areas of research are suggested:

- Test methods with the aim to predict service life need to be developed.
- In general, computer calculation methods based on the degradation mechanisms need to be developed.
- Service life data need to be collected and be made available to customers through databases, which also should be coupled to design software.

6 Acknowledgements

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