INTERNATIONAL STANDARD

ISO 15686-2

Second edition
2012-06-01

Buildings and constructed assets — Service life planning —

Part 2:
Service life prediction procedures

Bâtiments et biens immobiliers construits — Conception prenant en compte la durée de vie —

Partie 2: Procédures pour la prévision de la durée de vie

Reference number
ISO 15686-2:2012(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15686-2 was prepared by Technical Committee ISO/TC 59, *Buildings and civil engineering works*, Subcommittee SC 14, *Design life*.

This second edition cancels and replaces the first edition (ISO 15686-2:2001), which has been technically revised.

ISO 15686 consists of the following parts, under the general title *Buildings and constructed assets — Service life planning*:

— *Part 1: General principles and framework*

— *Part 2: Service life prediction procedures*

— *Part 3: Performance audits and reviews*

— *Part 5: Life-cycle costing*

— *Part 6: Procedures for considering environmental impacts*

— *Part 7: Performance evaluation for feedback of service life data from practice*

— *Part 8: Reference service life and service-life estimation*

— *Part 9: Guidance on assessment of service-life data* [Technical Specifiation]

— *Part 10: When to assess functional performance*

The following parts are under preparation:

— *Part 4: Service Life Planning using IFC based Building Information Modelling* [Technical Report]

— *Part 11: Terminology*

Introduction

The ISO 15686 series on buildings and constructed assets, including service life planning, is an essential contribution to the development of a policy for design life. A major impetus for the preparation of the ISO 15686 series is the current concern over the industry's inability to predict costs of ownership and maintenance of buildings. A secondary objective of service life planning is to reduce the likelihood of obsolescence and/or to maximize the re-use value of the obsolete building components.

The purpose of this part of ISO 15686 is to describe the principles of service life prediction (SLP) of building components and their behaviour when incorporated into a building or construction works considering various service environments. The SLP methodology is developed to be generic, i.e. applicable to all types of building components, and is meant to serve as a guide to all kinds of prediction processes. The methodology may be used in the planning of SLP studies regarding new and innovative components, whose performance is little known, or may be the guiding document in the assessment of already performed investigations in order to appraise their value as knowledge bases for SLP and reveal where complementary studies are necessary.

This part of ISO 15686 is intended primarily for

— manufacturers who wish to provide data on in-use performance of their products,

— test houses, technical approval organizations, etc.,

— those who develop or draft product standards, and

— users who may not be directly involved in making service life predictions, but who use them as inputs to reference service lives, within audits or reviews of service life planning, as information in environmental product declarations (EPDs), as inputs to service life prediction of assets and facilities in life-cycle costing, etc.

NOTE For this part of ISO 15686 to be used for service life evaluation at the scale of complex products or at the scale of construction works, a guidance document could be necessary.

For an improved understanding of the context of this part of ISO 15686, it is useful to read the other parts, in particular ISO 15686-1, which is the umbrella document of the ISO 15686 series.

Data obtained in accordance with the methodology described in this part of ISO 15686 can be used in any context where appropriate, and specifically to obtain reference or estimated service life data as described in ISO 15686-8.

Predictions can be based on evidence from previous use, on comparisons with the known service life of similar components, on tests of degradation in specific conditions or on a combination of these. Ideally, a prediction will be given in terms of the service life as a function of the in-use condition. In any case, the dependence of the service life on the in-use condition will be quantified in a suitable way. The reliability of the predicted service life of a component (PSLC) will depend on the evidence it is based on.

The methods described in the ISO 15686 series are based on work carried out in many countries. In general terms, they are a development of the current standards on durability published by the Architectural Institute of Japan, the British Standards Institution (BSI), the Canadian Standards Association (CSA), and the Italian Organization for Standardization (UNI). Specifically, this part of ISO 15686 is an extension and modification of the RILEM recommendation 64, "Systematic Methodology for Service Life Prediction", developed by RILEM1) TC 71-PSL and TC 100-TSL. It also results from the work carried out in the CIB2) W080.

---

1) The International Union of Testing and Research Laboratories for Materials and Structures.

2) International Council for Building Research, Studies and Documentation.

Buildings and constructed assets — Service life planning —

Part 2:
Service life prediction procedures

1 Scope

This part of ISO 15686 describes procedures that facilitate service life predictions of building components, based on technical and functional performance. It provides a general framework, principles and requirements for conducting and reporting such studies.

It does not cover limitation of service life due to obsolescence or other non-measurable or unpredictable performance states.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6241:1984, *Performance standards in building — Principles for their preparation and factors to be considered*

ISO 6707-1, *Building and civil engineering — Vocabulary — Part 1: General terms*

ISO 15686-1, *Buildings and constructed assets — Service life planning — Part 1: General principles and framework*

ISO 15686-7, *Buildings and constructed assets — Service life planning — Part 7: Performance evaluation for feedback of service life data from practice*

ISO 15686-8, *Buildings and constructed assets — Service-life planning — Part 8: Reference service life and service-life estimation*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6707-1, ISO 15686-1 and the following apply.

3.1.1
accelerated short-term exposure
short-term exposure (3.1.19) in which the **agent intensity** (3.1.5) is raised above the levels expected in service

3.1.2
ageing
degradation due to long-term influence of **agents** (3.1.4) related to use

3.1.3
ageing exposure
procedure in which a product is exposed to **agents** (3.1.4) believed or known to cause ageing for the purpose of undertaking/initiating a **service life prediction** (3.1.18) or comparison of relative performance

3.1.4
agent
whatever acts on a building or its parts to adversely affect its performance

EXAMPLE Person, water, load, heat.

3.1.5
agent intensity
measure of the extent to or level at which an **agent** (3.1.4) is present

NOTE In this part of ISO 15686, the term “agent intensity” refers figuratively to any quantity that conforms to the requirements for a measure, i.e. not only to UV radiation and rain intensity, etc., but also to relative humidity, SO_2 concentration, freeze–thaw rate and mechanical pressure, etc.

3.1.6
component
product manufactured as a distinct unit to serve a specific function or functions

[ISO 6707-1:2004, definition 6.1.3]

3.1.7
degradation
process whereby an action on an item causes a deterioration of one or more properties

NOTE Properties affected can be, for example, physical, mechanical or electrical.

[ISO 15686-8:2008, definition 3.4]

3.1.8
degradation indicator
deficiency which shows when a **performance characteristic** (3.1.14) fails to conform to a requirement

EXAMPLE When gloss is a performance characteristic, gloss loss is the corresponding degradation indicator. When mass (or thickness) is a performance characteristic, mass loss is the corresponding degradation indicator.

3.1.9
dose-response function
function that relates the dose(s) of a **degradation** (3.1.7) **agent** (3.1.4) to a **degradation indicator** (3.1.8)

3.1.10
inspection of buildings
performance evaluation or assessment of residual service life of building parts in existing buildings

3.1.11
in-use condition
any circumstance that can impact the performance of a building or other constructed asset, or a part thereof under normal use

3.1.12
long-term exposure
ageing exposure (3.1.3) under **in-use conditions** (3.1.11) and with a duration of the same order as the service life anticipated

3.1.13
mechanism
process causing change over time in the composition or microstructure of a component or material that can cause degradation

3.1.14
performance characteristic
physical quantity that is a measure of a critical property

EXAMPLE A performance characteristic can be the same as the critical property, for instance reflectance. On the other hand, if the critical property is strength, then thickness or mass can in certain cases be utilized as a performance characteristic.

3.1.15
performance requirement
performance criterion
minimum acceptable level of a critical property

3.1.16
predicted service life
service life predicted from recorded performance over time

EXAMPLE As found in service life models or ageing tests.

3.1.17
predicted service life distribution
probability distribution function of the **predicted service life** (3.1.16)

3.1.18
service life prediction
SLP
generic methodology which, for a particular or any appropriate performance requirement, facilitates a prediction of the service life distribution of a building or its parts for the use in a particular or in any appropriate environment

3.1.19
short-term exposure
ageing exposure (3.1.3) with a duration considerably shorter than the service life anticipated

NOTE A term sometimes used and related to this type of exposure programme is “predictive service life test”. A predictive service life test is a combination of a specifically designed short-term exposure and a performance evaluation procedure.

3.1.20
terminal critical property
‹in an established set of critical properties for a building or a part› critical property that first fails to maintain the corresponding performance requirement when subjected to exposure in a particular service environment

3.1.21
time acceleration factor
number or function used to transform the results of ageing of a component(s) derived from accelerated short-term exposure testing to a predicted service life or predicted service life distribution

3.2 Abbreviated terms

ESLC	estimated service life of a component
PSLDC	predicted service life distribution of a component
PSLC	predicted service life of a component
RSLC	reference service life of a component
SLP	service life prediction

4 Methodology

4.1 Brief description of service life prediction (SLP)

The methodology described is intended to be generic and aims, for a particular or any appropriate set of performance requirements, to facilitate a service life prediction (SLP) of any kind of building component for use in a particular, or range of, in-service environment(s).

NOTE In practice, an SLP is usually restricted to covering a few typical service environments or a single reference environment complemented by an analysis on the sensitivity of intensity variations of degradation agents.

The term “prediction” of an SLP study refers to one of four ways, or any combination of these, to assess the service life, as follows:

- speeding-up of the time dimension (at accelerated short-term exposures);
- interpolation/extrapolation using data of similar components;
- interpolation/extrapolation using data from similar service environments;
- extrapolation in the time dimension (at short-term in-use exposures).

The systematic approach or methodology for the SLP of building components described includes the identification of necessary information, the selection or development of test procedures (exposure programmes and evaluation methods), testing, interpretation of data, and reporting of results. The essential steps in an SLP process are outlined in Figure 1. The methodology employs an iterative research or decision-making process which enables improved predictions to be made as the base of knowledge grows, as illustrated by the outermost loop in Figure 1. It is often not necessary to perform every step, for instance the pre-testing procedure can often be excluded or shortened due to already available knowledge of the component under study. While not illustrated, sub-loops between steps within a cycle may be necessary. Normally, the service life for a particular set of performance requirements is not predicted as a single value, a predicted service life of a component (PSLC). Instead, a predicted service life distribution of a component (PSLDC) is determined. The PSLDC is described by at least two parameters, the expectation value and the standard deviation. For very costly tests, however, the aim may be limited to finding a PSLC only.

The choice of the single-value reference service life of the component (RSLC) from the distribution established depends on the safety margin expected for the component. For replaceable, non-structural components, in most cases, the expectation value (i.e. the mean) PSLC of the distribution could be employed as the RSLC. However, scheduled maintenance plans, interlocking with other replaceable components or other circumstances, may suggest a more conservative choice. For non-replaceable and/or structural components, for which a safety margin is requested, a more, and frequently a significantly more, conservative choice has to be made. In such cases, though, normally the safety margin is directly or indirectly regulated by standards or codes specifically applicable to the component.

See also A.1.1.

4.2 Connection to ISO 15686-1 and ISO 15686-8

This part of ISO 15686 refers to ISO 15686-1 and ISO 15686-8 and aims, in this context, to describe a tool to achieve a reference service life of the component (RSLC) as accurately as possible (or, alternatively, to achieve a forecast service life directly). An RSLC is necessary when an estimated service life of the component (ESLC) for a particular design object is to be assessed in accordance with the factor method as described in ISO 15686-8. Thus, the RSLC can be obtained from the PSLDC as established in accordance with this part of ISO 15686. The condition at which the PSLDC has been established then becomes the reference condition, which is compared to the particular condition prevailing at the design object in order to estimate the factors of the factor method.

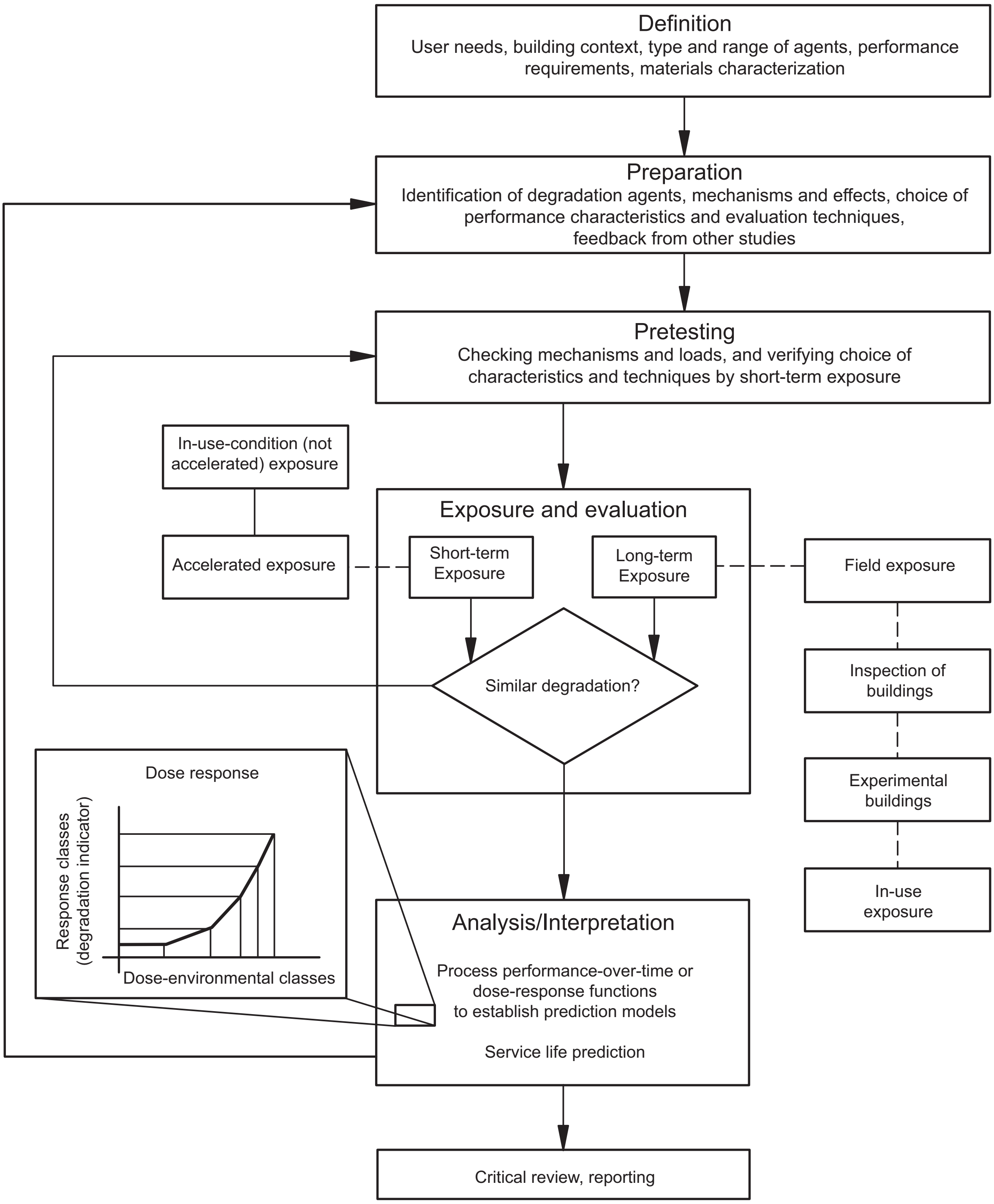


Figure 1 — Systematic methodology for SLP of building components

When the SLP utilized to obtain the RSLC for the particular design object has been carried out under various conditions, the PSLDC obtained under the condition that deviates the least from the particular condition is used for that purpose. An SLP carried out under various conditions also implies a means to estimate factors of the factor method, in most cases particularly the factor taking into account the difference between the specific and the reference outdoor environment. This can be accomplished by interpolation/extrapolation techniques.

5 Methodological framework

5.1 Range of SLP and problem description

5.1.1 General

Initially, the problem to be solved shall be defined and the range of the study established, including identification or specification of essential data.

NOTE These issues can vary from case to case depending on the aim and ambition of the SLP and on the level of existing knowledge of the component.

Two extreme ranges are as follows.

a) **Specific study:** this is intended to focus on a rather specific application of the component tested in terms of service environment and usage with a specified set of performance requirements. The aim is to establish the PSLDC (or PSLC) and determine the sensitivity of the PSLDC (or PSLC) on moderate variations from these presumptions.

b) **General study:** this is intended to cover a broad application of the component tested in terms of service environment and usage with an unspecified or a loosely specified set of performance requirements. The aim is to establish performance-over-time functions for the performance characteristics chosen in the whole range of applications.

5.1.2 Definition of a specific study

5.1.2.1 Specification of the service life environment

When presenting service life predictions for products or components, a specific or generic set of in-use conditions shall be identified for documenting the specific study. This shall account for the specific use of the component, covering the design consequences, and shall comprise a description of the environment, including static and dynamic mechanical stress, at the site where a building is planned. A description of the effects of occupancy (such as water vapour, heat or abrasion) and the principles on which the building is operated (e.g. high or low thermal inertia) shall also be included if appropriate.

5.1.2.2 Quantification of the set of performance requirements

The set of performance characteristics shall be identified and the corresponding requirements quantified in accordance with critical properties specified.

NOTE This can take the form, for example, of a failure mode and effect analysis (FMEA). See 5.6.

The set of performance requirements shall conform to the information obtained in accordance with 5.1.2.1.

5.1.3 Definition of a general study

5.1.3.1 Specification of ranges of service life environments

All types of environments where the component is intended to be used, or being within the range of the study, shall be described, including static and dynamic mechanical stress.

The various types of environments may be grouped into a discrete number of classes, each class being representative for certain ranges of agent intensities.

Care shall be taken regarding the effect of various usages and positions of the component, as this can strongly govern the in-use conditions and possible synergistic effects of the degradation agents. See 5.2.3.

NOTE The actual in-use condition relevant to materials degradation is the micro-environment, i.e. the prevailing environmental condition in a layer adjacent to or at a component's surface (e.g. pollutant concentration and driving rain), and within the component (e.g. mechanical stress).

5.1.3.2 Quantification of the set of performance requirements

First, a set of performance characteristics shall be identified from critical properties specified. Next, in order to limit the performance range to be covered by the service life analysis, the set of the lowest appropriate performance requirements for the component shall be expressed.

NOTE The set of performance requirements can include specifications on, for example, strength, optical transmission, acoustical insulation and aesthetic qualities.

The performance requirements shall be in accordance with 5.1.3.1.

5.1.4 Characterization of the component

The component to be evaluated shall be characterized thoroughly in terms of structure, physical properties and chemical composition.

5.1.5 Critical review considerations

Critical review is a technique to verify whether or not an SLP study conforms to the requirements for methodology and reporting given in this part of ISO 15686. Whether, how and by whom the critical review is to be conducted shall be planned and confirmed when defining the study.

A critical review of an SLP shall be conducted where the results are to be disclosed to the public.

For other applications, for example for company-internal product development, critical review may be omitted.

The process of critical reviewing is described in Clause 6.

5.2 Preparation

5.2.1 General

After the range of the study has been defined, in accordance with 5.1, degradation agents, possible degradation mechanisms and how degradation can be accelerated or induced within ageing exposure programmes shall be identified and postulated.

5.2.2 Identification of degradation agents and their intensities

The type and intensity distribution of the expected degradation agents, based on the knowledge as compiled in accordance with 5.1.2.1 or 5.1.3.1, shall be identified.

NOTE It can be difficult to quantify the in-use intensity of biological agents and agents originating from the occupancy, but upper limits within the normal range can usually be established by professional judgement.

One or several reference environments shall be considered, the number depending on the range of the study. A list of relevant degradation agents is presented in Table 1.

The agents are classified in accordance with their nature. In general, external to the building, the origin of the agents is either the atmosphere or the ground, whereas internal to the building, the origin is related to occupancy or design and installations. However, although not stated in ISO 6241, an agent acting externally while originating as a design consequence can also occur, for instance from an incompatible neighbouring component. Furthermore, the influence of agents originating from the atmosphere on internal degradation should not be disregarded.

Table 1 — Degradation agents affecting the service life of building components[a]

Nature	Class
Mechanical agents	Gravitation Forces and imposed or restrained deformations Kinetic energy Vibrations and noises
Electromagnetic agents	Radiation Electricity Magnetism
Thermal agents	Extreme levels or fast alterations of temperature
Chemical agents	Water and solvents Oxidizing agents Reducing agents Acids Bases Salts Chemically neutral
Biological agents	Vegetable and microbial Animal

[a] Condensed from ISO 6241:1984, Table 4.

See also A.2.1.1 to A.2.1.3.

5.2.3 Agents related to occupancy and significance of installation and maintenance practices

Although agents related to occupancy are not often included in ageing exposure programmes, as they can affect the service life of building components, they should be evaluated if deemed critical. Such a measure shall be carried out either by means of inspection of buildings or in-use exposure, or both; see 5.4.3.3 and 5.4.3.5, respectively.

NOTE However, abuse is usually considered beyond the scope of these test methods.

Normally, installation and possible maintenance undertaken for samples of the ageing exposure programme should follow practices recommended by the manufacturer or good practice if such are not given.

Evaluation of effects imposed by variations in installation and maintenance procedures may be included as part of the study.

It is of crucial importance not to exaggerate any maintenance procedure, which may lead to erroneous PSLC compared to real use.

5.2.4 Identification of possible degradation mechanisms

All possible mechanisms by which the identified degradation agents are known, or believed, to induce changes in the properties of the component shall be identified; this is a necessary step of the preparation.

The mechanisms can be identified at various levels. If, for instance, the chemistry of the component is well documented, it may be possible to identify mechanisms based upon specific chemical reactions, such as hydrolysis and photo-oxidation. If less is known about the chemical, mechanical, physical and biological reactions of the component, mechanisms may be defined in more general terms as, for example, thermal decomposition, volatilization of constituents, constituent diffusion, corrosion, fatigue, wear, shrinking/swelling and rotting. See also A.2.1.4.

5.2.5 Identification of possible effects of degradation

Possible effects of degradation on performance characteristics of the component shall be identified on the basis of data obtained in accordance with 5.2.2 and 5.2.4.

5.2.6 Choice of performance characteristics and performance evaluation techniques

The critical properties corresponding to the set of performance requirements quantified in accordance with 5.1.2.2 or 5.1.3.2 shall be interpreted in terms of any of the performance characteristics found to be afflicted with degradation in accordance with 5.2.5.

For each of the performance characteristics selected, appropriate measurement and/or inspection techniques shall be chosen. To be able to perform an SLP in accordance with this part of ISO 15686, quantitative data shall be obtained. The initial values of the performance characteristics selected shall be determined before the ageing exposure programme starts. See also A.2.1.4.

5.2.7 Feedback from other studies

Information from other studies, concluded or running, should always be sought.

NOTE Useful information can come from general knowledge of similar components, measurement techniques and exposure programme design to detailed data on performance-over-time functions of cases closely related to the case to be studied. In the latter case, in favourable circumstances, this can reduce the necessary test volume and range required and/or reduce the test period considerably.

5.2.8 Establishing ageing exposure programmes

The information obtained in accordance with 5.2.2 to 5.2.7 will help in establishing procedures for inducing the identified mechanisms of degradation using the degradation agents identified.

When accelerated short-term exposure is used, care shall be taken to ensure that extreme intensity levels of degradation agents do not result in degradation mechanisms that would not be experienced in service.

NOTE The postulations that are made in this step lay the groundwork for selecting or designing preliminary exposure programmes.

5.3 Pre-testing

5.3.1 General

Pre-testing shall be as a consequence of 5.2.8. A pre-test shall provide for the selected performance characteristics to be evaluated before and after exposure to the degradation agents to which the component will be exposed in service, or at least to all degradation agents suspected to be of any significance. This shall, when properly performed,

- establish the primary degradation agents and their order of importance,
- support or rule out the previously identified mechanisms by which property changes occur,
- establish the agent intensity levels necessary to induce property changes and demonstrate how rapid changes in the selected performance characteristics can be induced by exposure to extreme intensities,
- contribute to a better understanding of the nature of the primary degradation agents leading to property changes and indicate additional or substitutional property changes that are likely to be relevant and useful as performance characteristics, and
- verify the adaptability of the measurement and inspection techniques chosen for the performance evaluation.

See also A.2.2

5.3.2 Intensities of degradation agents employed in pre-tests

Intensities shall be levelled in relation to the quantitative in-use distributions or ranges identified in accordance with 5.2.2.

EXAMPLE Weather and climatological data for the most extreme climates in which the component will be used can form the basis for the choice of intensities of these agents in the pre-tests.

5.4 Ageing exposure programmes

5.4.1 General

The full exposure programme shall be carefully designed so as to provide necessary data in accordance with the range and aim of the study, considering the information and data obtained by the procedures described above.

Although evident from the definitions of agent (see 3.1.4) and ageing exposure (see 3.1.3), it should be emphasized that ageing exposure in this context should be regarded in a broad sense, i.e. ageing exposure refers to any kind of set-up in which samples are subjected to degradation agents in accordance with Table 1. For instance, when applying mechanical loads, samples are exposed to mechanical agents.

5.4.2 Design and performance of exposure programmes

As component properties and environmental characteristics are stochastic variables, i.e. they are represented by statistical distributions, the exposure programme, irrespective of the type, shall be designed, if possible, to comprise a multiplicity of specimens or test objects, enabling a statistical treatment of test data.

This may be difficult to follow in some cases when dealing with experimental building and in-use-exposure, see 5.4.3.4 and 5.4.3.5, respectively, or when tests are very costly. In such cases distribution widths or ranges should, if possible, be estimated from other sources of information.

For all exposure programmes, the conditions shall be recorded continuously or at sufficiently short intervals, for the following reasons (partially depending on the type of exposure programme):

- to enable establishment of performance-over-time or dose-response functions, see A.2.4.2 and A.2.4.3;
- to provide a relationship between different exposure periods and sites, and especially to compare results with data from the field, and exposure programmes with uncontrolled conditions; see 5.4.3.2;
- to check that the actual environmental conditions are representative of the environmental reference conditions (for exposure programmes with uncontrolled conditions);
- to verify that the intended degradation agent intensities are achieved (for exposure programmes with controlled conditions).

NOTE 1 The sources of recording can vary from official environmental databases to detailed measurements of degradation agent intensities at or in the vicinity of the test samples.

NOTE 2 In the field of environmental characterization a strong development occurs, e.g. towards standardized measurement techniques and improved dispersion models, hosted in GIS (Geographical Information Systems) software environments, facilitating mapping of environmental data from meso/local levels to micro levels.

5.4.3 Long-term exposures

5.4.3.1 Range and type

The exposure programme shall either consist of an actual in-use exposure of a complete system, in which feedback information on the performance of the components included is obtained over time, or involve exposure of selected components. An exposure programme shall be designed so that all agents of importance are taken into account.

Even for a specific study, the exposure should preferably take place in more than one type of service environment.

The different ways of generating data from long-term exposures are described in the following four categories:

- field exposure, see 5.4.3.2;
- inspection of buildings, see 5.4.3.3;
- exposure in experimental buildings, see 5.4.3.4;
- in-use exposure, see 5.4.3.5.

5.4.3.2 Field exposure

Standardized ways of performing atmospheric field exposures have been in operation for some time, see A.2.3.1.1.

It is essential to note that

- the results of a field exposure relate to the specific exposure site and that the transformation of data to relate to another geographic location necessitates knowledge of performance-over-time or dose-response and environmental characteristics,
- care should be taken when drawing conclusions from one exposure period to another, especially if the time of exposure is short,
- exposing component samples to the environment may be regarded as an accelerated exposure (for instance at exposure racks with inclination 45° and directed towards the sun) with the degree of acceleration varying with the type of component under exposure, and
- environmental condition during field exposure should be monitored on site to compare degradations and losses in performance achieved in the field and in laboratory (for obtaining the re-scaling); weather station data next to the field exposure site may also be used.

5.4.3.3 Inspection of buildings

The service life of building components may be evaluated through inspection of buildings. As many buildings as necessary should be included in the study by means of statistical sampling methods.

See also A.2.3.1.2, and ISO 15686-7.

5.4.3.4 Exposure in experimental buildings

Durability evaluations of building components may be carried out by exposing the component in dedicated experimental test buildings.

Similar difficulties may apply as outlined under field exposure, see 5.4.3.2.

See also A.2.3.1.3.

5.4.3.5 In-use exposure

In-use exposure is an intentional use of a component in a full-scale building or structure under normal use, in order to evaluate the service life of the component.

See also A.2.3.1.4.

5.4.4 Short-term exposures

5.4.4.1 Accelerated short-term exposures

Accelerated short-term exposures should normally be designed from information obtained in pre-tests and/or from long-term exposure of the same or similar components. In general, the intensity of agents in these exposure programmes should be less than in pre-tests to reduce the likelihood of causing degradation by mechanisms that are not encountered in service. Those properties that have been identified as most useful or most important for indicating degradation should be measured before and after ageing. The possibility of synergistic effects between degradation agents should be taken into account.

It should be confirmed that degradation mechanisms and the relative reaction rates induced by accelerated short-term exposures are the same or at least similar to those observed in service.

See also A.2.3.2.

5.4.4.2 Short-term in-use exposures

Short-term exposures are usually, but not always, based upon accelerated ageing. In cases when property changes leading to degradation can be detected at early stages (typically by means of highly-sensitive surface analysis instruments), an exposure set-up employing in-use conditions, i.e. designs similar to those for long-term exposures, can be utilized.

5.4.5 Performance evaluation

5.4.5.1 Evaluation scheme

During exposure, the performance shall be evaluated in terms of the selected performance characteristics by means of the measurement and inspection techniques chosen, see 5.2.6. The evaluation shall take place at sufficiently narrow intervals, in accordance with the range and aim of the study. To verify that the degradation mechanisms do not change with time of exposure, the exposure programme shall enable the most important degradation mechanisms to be identified in a relatively short period of time.

The exposure shall, except for a short-term in-use exposure, be run such that at least one of the performance characteristics, i.e. the one corresponding to the terminal critical property, retained at the end of exposure has declined to a level equal to or below the corresponding performance requirement for a statistically satisfactory number of samples.

See also A.2.3.3.

5.4.5.2 Comparison of types of degradation

The types and range of degradation obtained from accelerated short-term exposures shall be checked against those from in-use conditions.

If the categorization of these degradations demonstrates a good agreement, a time acceleration factor shall be evaluated to calculate the service life using the results of short-term exposure tests.

If mechanisms are induced, not being representative of those obtained under the in-use conditions, the ageing exposure programmes shall be altered after reassessing the information obtained in accordance with 5.1 to 5.3.

5.5 Analysis and interpretation

Degradation models in terms of the PSLDC (or PSLC) shall be established by processing the results of the performance evaluations carried out at various ageing exposure programmes (long-term exposures, short-term exposures or combinations thereof) in two or three steps.

a) From performance evaluation data, performance-over-time functions or dose-response functions for the exposure conditions employed are established.

b) If the exposure conditions employed do not cover all exposure conditions in which the component is to be assessed, by synthesizing, modelling and/or interpolating/extrapolating the performance-over-time or dose-response functions established in step a), a performance-over-time or dose-response function for a hypothetical condition may be established.

c) A PSLDC (or PSLC) is resolved from performance-over-time or dose-response functions established in step a) or b) by inserting the set of performances to be fulfilled by the component tested, expressed in terms of the performance characteristics or degradation indicators employed in the exposure programmes. The PSLDC is determined by the performance-over-time function or dose-response function of the critical property found to be the terminal critical property. (When dealing with proper dose-response functions the dose variable(s) is separated into time and intensity variables in order to obtain the time dimension and, finally, the service life in an explicit form.)

Extra caution should be taken with all extrapolations (see A.2.4.1); support from mechanism-based models is strongly recommended.

In addition to interpolation/extrapolation in exposure conditions, interpolation/extrapolation in time and material properties (for similar components) may be utilized.

In a specific study (see 5.1.2), the analysis may be limited to the PSLDC (or PSLC) at the specified conditions and its sensitivity to moderate variations in the service environment and the set of performance requirements, typically expressed as partial derivatives.

See also A.2.4.

5.6 A complementary approach: the failure mode and effect analysis (FMEA)

5.6.1 General

The failure mode and effect analysis (FMEA) is a method used to identify all possible degradation phenomena of a given building component in a specified environment. It enables the behaviour of a product to be inferred from knowledge about its structure.

5.6.2 Methodology

It is based on a two-level systemic view of the product:

— a structural view, which is a description of each of the sub-components of the product, such as described in 5.1.4, how they are physically connected, and also a description of the environment in which the product is to be used.

NOTE 1 A list of degradation agents such as provided by ISO 6241:1984 can be used to describe the environment.

— a functional view, obtained though functional analysis, where the different functions of each sub-component are defined in accordance with the end user’s needs.

The procedure is based on an iterative principle. Possible failure modes of each sub-component have to be identified, as well as their causes and effects. As each effect is potentially the cause of another failure, a second set of failure modes is determined from the first one, and so on until full failure scenarios are determined. The result of the failure modes and effects analysis is a list of failure scenarios usually summed-up in a table.

NOTE 2 Most of the information necessary to lead FMEA is relative to performance and properties of sub-component materials, rather than the product itself. Thus, FMEA is particularly relevant for assessment of innovative products for which in-use behaviour is unknown.

5.6.3 Use of FMEA results in service life prediction procedures

Information obtained through FMEA might be useful at different stages of the service life prediction procedure.

Possible uses of FMEA in SLP procedure are for help in

— identifying relevant degradation agents (see 5.2.2) as well as agents related to occupancy of installation and maintenance practices (see 5.2.3), and

— identifying possible degradation mechanisms (see 5.2.4) as well as their possible effects (see 5.2.5) for complex products.

NOTE Structural and functional analysis as mentioned above bring a comprehensive answer to 5.1.4.

6 Critical review

6.1 General description of critical review

The critical review process shall ensure that

- the methods used to perform the SLP are consistent with this part of ISO 15686,
- the methods used to perform the SLP are scientifically and technically valid,
- any external data used are appropriate and reasonable,
- the interpretations reflect the limitations identified and the goal of the study, and
- the reporting is transparent and consistent, and suitable to inform the intended audience (e.g. the public or the client experts).

6.2 Needs and requirements for critical review

The use of SLP results to support planning of buildings raises special concerns, since this application will affect interested parties external to the SLP study, in which case a critical review shall be conducted. In some applications, divergent critical review recommendations may be imposed from other parties, e.g. from certification and technical approval bodies. Such compulsory measures can increase the stringency compared to, but shall not be used to circumvent the recommendations of, the critical review process as described in this part of ISO 15686.

6.3 Process of critical review

The scope of the critical review shall be defined when defining the study or when deciding to perform a critical review of an existing study. The scope shall identify why the critical review is being undertaken, what will be covered and to what level of detail, and who needs to be involved in the process.

A critical review should be carried out by an internal or, preferably, an external expert, in any circumstances independent of the study. The expert shall be familiar with the requirements of this part of ISO 15686 and have scientific and technical expertise. A review statement shall be prepared, either by the person conducting the SLP study and then reviewed by the expert, or by the expert in its entirety. The review statement, comments by the commissioned specialist and any response to recommendations made by the reviewer shall be included in the report.

7 Reporting

The results of the study shall be reported to all interested parties. The findings of all analyses, data, methods, assumptions and limitations should be transparent and presented in sufficient detail to enable the reader to assess the quality of the information. The report shall also allow the results and interpretation to be used in a manner consistent with the goals of the study.

The report shall include measured, calculated or estimated statistical distributions.

NOTE 1 Distributions can, for example, be expressed in terms of distribution functions, standard deviations or levels of confidence.

As short-term exposures typically involve a significant degree of uncertainty, the results shall be considered with care.

A report on an SLP shall, wherever applicable, include the following information.

a) General aspects:
   1) details of the commissioning client of the SLP;
   2) details of the commissioned specialist of the SLP;
   3) date and identification number of the report;
   4) statement that the study has been conducted in accordance with all the requirements of this part of ISO 15686.

b) Goal and range definition

c) Component description:
   1) main or other identification marks of the components;
   2) designation of the components in accordance with recommendations or prescriptions expressed in official standards or regulations;
   3) description of the components;
   4) properties of the components such as performance data and model descriptions;
   5) name and address of manufacturer or supplier of the components;
   6) date of supply of the components.

When actual tests have been performed, include the following.

d) Exposure programme description, including exposure at pre-tests:
   1) general exposure situation, i.e. at outdoor exposure data as latitude, longitude, altitude, distance from coast, special factors like high wind, climate type, etc.;
   2) design of the exposure programme, including possible maintenance undertaken for samples, and any accidental deviations thereof;
   3) environmental data (including any neighbouring dissimilar components), degradation agent intensities and cycling data;
   4) exposure period.

e) Performance evaluation description, including evaluation at pre-tests:
   1) methods of measurements or inspections;
   2) component data, results of measurements or inspections.

f) Interpretation of data:
   1) account for external data sources utilized;
   2) specific models or algorithms;
   3) results of interpretation;
   4) limitations of the interpretation, related to methodology as well as to data;
   5) data quality assessment.

g) Critical review:
   1) details of reviewers;

2) critical review reports;

3) responses to recommendations.

When the results of the SLP are to be communicated to a third party (i.e. an interested party other than the commissioning client and the commissioned specialist of the study), a third-party report should be prepared, containing all information indicated above, except what is agreed between the commissioning client and the commissioned specialist to be closed information. This report constitutes a reference document and should be made available to any third party to whom the communication is made.

NOTE 2 ISO 15686-4 provides more detailed guidance on methods of presenting and formatting data on SLP.

Annex A
(informative)

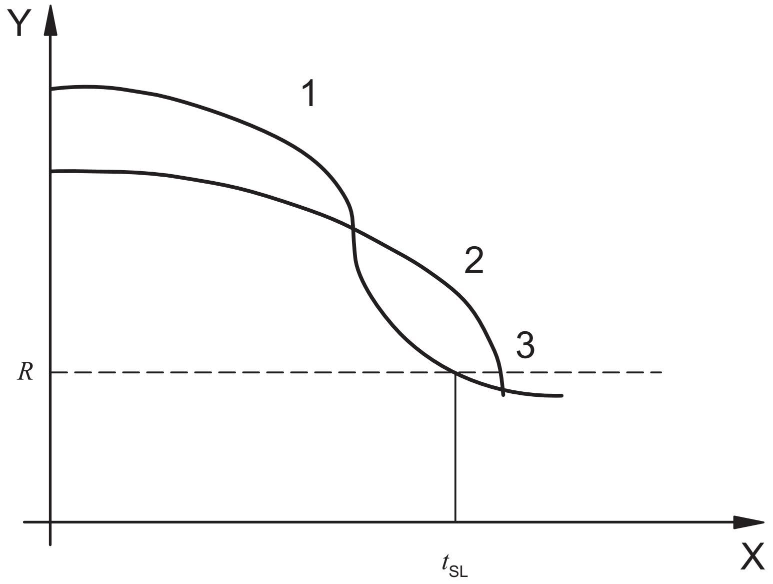
Guidance on process of SLP

A.1 General

A.1.1 Brief description of SLP (see 4.1)

Figure A.1 indicates possible variable patterns of performance over time (so-called performance-over-time functions) for particular performance characteristics of a component in a particular service environment. Performance characteristics are measurable, physical quantities for each of the critical properties identified for the tested component.

When only one critical property is identified, once the performance-over-time function and the corresponding performance requirement have been determined, the PSLC is given as the point in time when the performance-over-time function and the performance requirement intersect. If several critical properties are identified, and thus several performance-over-time functions and corresponding performance requirements are determined, the PSLC is given by the intersection predicted to take place first.



Key

X time, t

Y performance characteristics, $C(t)$ (arbitrary scale)

1 critical property 1: terminating critical property

2 critical property 2

3 performance requirement

Figure A.1 — Hypothetical performance-over-time functions

Thus, the critical property quantified by the performance characteristics that will first fall below its performance requirement is decisive for the service life and this property, therefore, is designated the terminal critical property. The terminal critical property can vary from case to case, depending on the actual environment and the actual set of performance requirements.

However, in reality, performance over time describes a statistical distribution of the decline in the performance characteristic (see A.2.4.2). In practice, most quantities involved in an SLP process are statistically distributed and should therefore be treated by appropriate statistical methods. This is also true of, for example, component properties, degradation agent intensities and, consequently, service lives.

Rather than performance characteristics, related degradation indicators may be measured over time, as for instance when so-called dose-response functions are employed. Such functions relate the doses of the most important degradation agents to one or a few degradation indicators. See A.2.4.3.

A.2 Methodological framework

A.2.1 Preparation

A.2.1.1 Identification of degradation agents (see 5.2.2)

The most relevant agents within ageing exposure programmes on building components usually originate from the atmosphere, such as the following:

- freeze–thaw and wind (mechanical);
- solar radiation (electromagnetic);
- temperature: elevated, depressed and pulsed (thermal);
- precipitation: solid, liquid, vapour (chemical);
- normal air constituents (chemical);
- air contaminants: gases, aerosols, particulates (chemical).

Some quantitative information on agents originating from the atmosphere is available from published weather and climatological data and from data published on air pollution. The environment is classified in terms of its corrosivity on a number of standard materials, mainly metals, and is also carried out for wide areas. Normally this work uses a series of International Standards specifying how to classify atmospheric corrosivity, i.e. ISO 9223, ISO 9224, ISO 9225 and ISO 9226.

Dose-response functions (see A.2.4.3) relating the dose of agents, mainly of a chemical nature, to the degradation of materials, are available from this work for certain classes of materials.

In the IEC 60721 series, intensities of agents affecting the performance of electric components are classified. Where appropriate, these standards may also be applied to the environmental agents affecting building components.

A.2.1.2 Combined agents and combination of agents

Some agents are combined by more than one co-existing factor (e.g. an imposed force such as freeze–thaw stress is due to cycling temperature and to the presence of water). At the same time, water is solely a chemical agent. Temperature itself is the thermal agent, while for many chemical reactions the temperature is decisive for the reaction rate. Other agents of the same or different nature can give rise to significant synergistic effects [e.g. sulfur dioxide together with nitric oxides, and UV radiation together with oxygen (photo oxidation)]. Effects of combined agents and combinations of agents have to be considered as significant parameters in all steps in an SLP.

A.2.1.3 Chemical and physical incompatibility between dissimilar components

Incompatibility between components is considered as an agent related to the design, and normally only occurs under particular conditions. By considering each component separately, incompatibility between a particular component and a neighbouring component can be treated analogously to, for instance, the case when the component is subjected to an agent originating from the atmosphere. That is, in general terms, both the neighbouring component and the agent originating from the atmosphere are parts of the environment of the component, in accordance with ISO 6241:1984, 6.4.1. Incompatibility includes, for example, corrosion caused by contact between dissimilar metals when moisture is present, or stress caused by different thermal expansion coefficients of rigidly connected dissimilar components at extreme temperature conditions.

A.2.1.4 Identification of possible degradation mechanisms (see 5.2.4)

Limitations on the knowledge available will always exist. However, it is important to identify as many conceivable degradation mechanisms as possible. This reduces the possibility for error and improves the basis for establishing that mechanisms induced at exposure programmes, in particular at accelerated short-term exposures, are representative of those that occur in service.

NOTE Choice of performance characteristics and performance evaluation techniques (see 5.2.6): Numerous inspection techniques exist with various degrees of sophistication. Standardized techniques are usually recommended just because they are standardized. However, apart from generally being phenomenological and very simple (too simple in certain cases), many of the standardized inspection techniques suffer from the fact that they rely upon subjective judgements of the practitioners. This makes comparisons between studies from different practitioners less reliable, which in fact counteract the purpose of standardization. Accordingly, there is a need for further development in this field and the standardization of existing, more sophisticated techniques.

A.2.2 Pre-testing

A.2.2.1 Biological and incompatibility agents (see 5.3)

Biological and incompatibility agents may not be important unless combined with the extreme values of other agents. For example, fungi and bacteria are most active in warm, moist locations; chemical incompatibility may only be important as long as liquid water is present between joined components; physical incompatibility may not be important unless there are large temperature changes. Accordingly, the effects of biological and incompatibility agents can usually be estimated along with pre-tests intended to determine the effect of the relevant main agents.

A.2.3 Ageing exposure programmes

A.2.3.1 Long-term exposures

A.2.3.1.1 Field exposure (see 5.4.3.2)

National and international atmospheric field exposure programmes have been performed on a vast number of materials; many are still ongoing. Evaluations of these programmes have resulted in the establishment of performance-over-time and dose-response functions (see A.2.4.2 and A.2.4.3), which are sources of information for SLP.

The most extensive exposure programme is the UN ECE ICP programme, aimed at classifying the effect of airborne acidifying pollutants on the corrosion of materials. The programme involves field exposure at 39 sites in 12 European countries and in the United States and Canada.

Several International Standards are available specifying how to expose specific materials outdoors, for example ISO 8565, ISO 877 (all parts), ISO 2810 and ISO 4665-2. In addition, ISO 9226, which mainly specifies how to classify atmospheric corrosivity, also specifies exposure set-up.

A.2.3.1.2 Inspection of buildings (see 5.4.3.3)

Evaluating the service life of building components through the inspection of buildings involves several obstacles:

— it may be difficult to obtain data of the history of the inspected components, i.e. data on the original performance values, information on installation and performed maintenance, etc.;

— normally, the service environment cannot be controlled and may be difficult to monitor or measure and describe.

Feedback from practice of durability data by inspection of buildings has the advantage, when the investigations are properly designed, to give direct correlation between the state of components, the exposure environment and the building use.

A.2.3.1.3 Exposure in experimental buildings (see 5.4.3.4)

If the exposure programme and the test building are properly designed, this approach has several advantages. The most important advantage is that the building component can be tested in full scale (for example to measure the effective sound insulation performance).

A.2.3.1.4 In-use exposure (see 5.4.3.5)

The aim of this approach is to create an experimental situation as well observed as possible, where the component tested is under the influence of the full range of degradation agents of the in-use situation. There are several similarities between the use of experimental buildings and the in-use exposure approach.

The limitations of the in-use exposure approach are basically the same as for experimental buildings. The in-use environment affecting the component tested is normally more difficult or not at all possible to control, and may also be difficult to measure and describe.

In-use exposure is a necessary experimental approach in many cases when building components are to be subjected to degradation agents directly related to user action and behaviour.

A.2.3.2 Accelerated short-term exposures (see 5.4.4.1)

The aim of accelerated short-term exposures is to provide relatively rapid means of measuring the rate of property changes, typical of those that occur in long-term exposures under in-use conditions.

Accelerated short-term exposures may be structured into three major groups.

a) **Reference components/comparative exposures:** in the simplest form, such exposure programmes can be used to rank and classify new components in reference to existing components. However, when the degradation mechanisms are understood, by designing an exposure programme carefully and combining results from detailed long-term exposures on the same type of or similar (reference) components, an SLP is achievable.

b) **Simulated and accelerated environmental exposures:** such exposure programmes attempt to simulate and accelerate the entire service environment, or at least the intensity of the agents to which the component is expected to be susceptible. The level of acceleration is normally estimated from relative intensities of the degradation agents and some degradation model.

c) **Acceptance exposures:** usually such accelerated exposures are designed with a pass or fail performance requirement, relying on experience of the performance of similar components in specific environments. This type can at best give a crude quantitative indication of the service life and is discouraged.

In order to confirm that degradation mechanisms and the relative reaction rates induced by accelerated short-term exposures are the same or at least similar as those observed in service, accelerated short-term exposures are often combined with in-use condition short-term exposures (see 5.4.4.2). By measuring degradation at early stages under both exposure situations, a quick comparison can be made.

Accelerated short-term exposure, in combination with modelling, is particularly well suited to assessing the effects of mechanical and thermal agents, static as well as cyclic.

Many International Standards are available that specify how to expose specific materials to artificial weathering, for example, ISO 4611, ISO 877 (all parts), ISO 4892-2, ISO 4892-3, ISO 4892-4, ISO 291, ISO 9370, ISO 4582, ISO 4892-1, ISO 3668, ISO 11341, ISO 11507, ISO 4665-1, ISO 4665-2, ISO 4665-3, ISO 30013, ISO 11431, ISO 13638, ISO 14615, ISO 2135 and ISO/TR 11728.

A large number of International Standards for exposure of electric components is available in the IEC 60068-2 series, where mechanical agents are also considered. Several of these standards may be applicable to certain building components.

A.2.3.3 Performance evaluation (see 5.4.5)

For certain agents, empirical and semi-empirical models have been developed which enable for simulation of exposure. In such cases the evaluation can be based mainly on computing with moderate exposure and measurements efforts only. This is particularly the case for agents of mechanical and thermal nature. However, models on the effects of chemical agents exist and should be used whenever possible.

A.2.4 Analysis and interpretation

A.2.4.1 General (see 5.5)

An essential part of data interpretation is always a judgement by experts. Despite efforts to quantify results and to base decisions upon scientific information, judgement is required.

NOTE An alternative to actually predicting service life, but which does not conform to this part of ISO 15686, is to compare the relative performance of several components that have been tested in a similar manner. Such comparisons are often made to rank components. For this purpose, parts of the principles of this part of ISO 15686 can be used.

Already established relationships between performance-over-time functions obtained from long-term and short-term exposures may, if conducted with care, be used to predict service lives of related components by means of additional short-term exposures exclusively.

To illustrate the difficulty of extended extrapolation, Figure A.2 outlines results using three different extrapolation functions to fit four measured values of an arbitrary quantity over time. As can be seen, quite different baseline interception can be obtained depending on the choice of function. Using an established model as a basis, the proper choice of extrapolation function will improve the reliability. However, as minor changes to the measured values can give rise to a significantly altered baseline interception (see Figure A.3), there is still a need to be very cautious since, in practice, measured values are afflicted with uncertainties.

A.2.4.2 Performance-over-time functions

In general a performance-over-time function, possibly expressed in terms of a degradation indicator, is a complicated, nonlinear function of time as well as of agent intensities or combinations of such agent intensities. Moreover, such a function is not single-valued but describes a statistical distribution of a performance characteristic.

In the variable range of interest, however, it is normally possible to approximate the function by a considerably simplified expression, often linear in some or all variables (see A.2.4.3). A performance-over-time function is evaluated, for instance by means of regression analysis, from quantitative data, possibly by the aid of physical-mathematical models, established semi-empirically or from first principles.

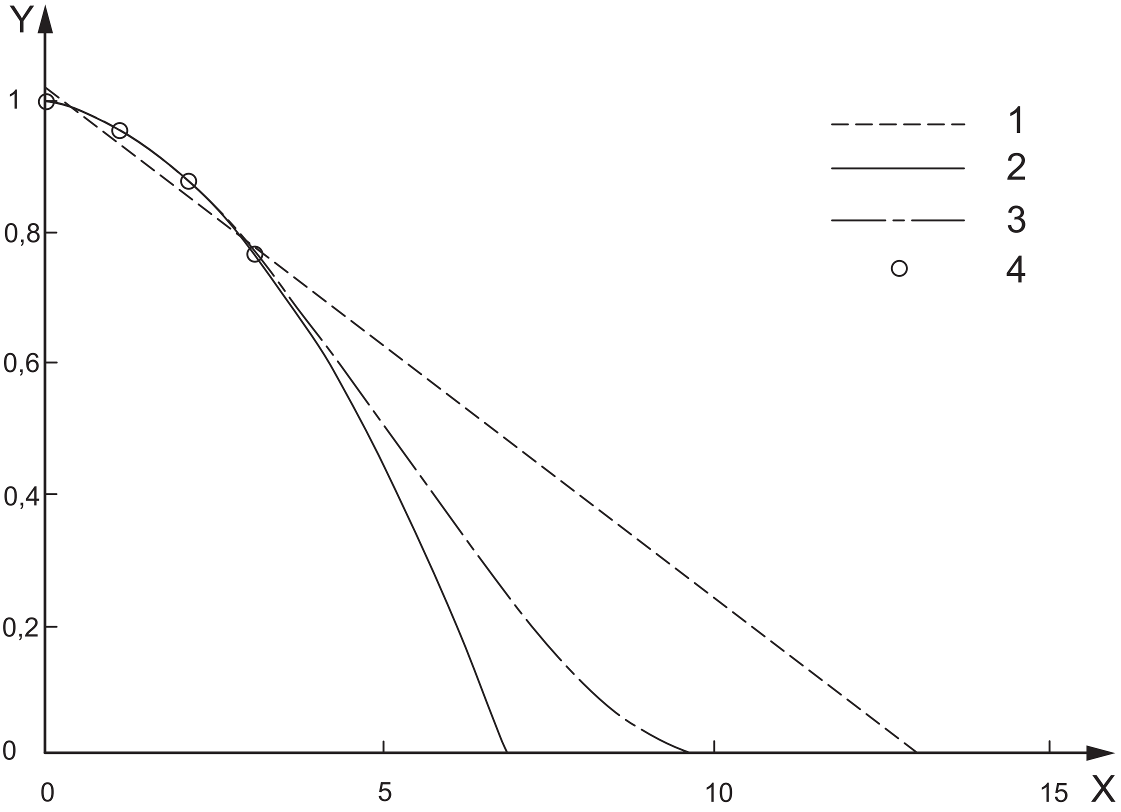
A.2.4.3 Dose-response functions

For many classes of components it has been possible, based on field exposures, to establish approximate, descriptive dose-response functions, each of them valid for an entire class of component. These functions, which relate the doses of the most important degradation agents to one or a few degradation indicators of the components, are by necessity simplified relationships, frequently of linear, but sometimes of nonlinear, character. The degradation indicator is characterized in a summarized and simplified way, often as weight-loss or weight-gain. Essentially, dose-response functions describe the same courses of events as do performance over-time functions, however simple in form and character and with the time and intensity variables merged into variables of doses, at least formally3).

NOTE Based on studies in the medical field, the use of dose-response functions has been adopted and developed within the field of atmospheric corrosion of components and the environmental research area.

---

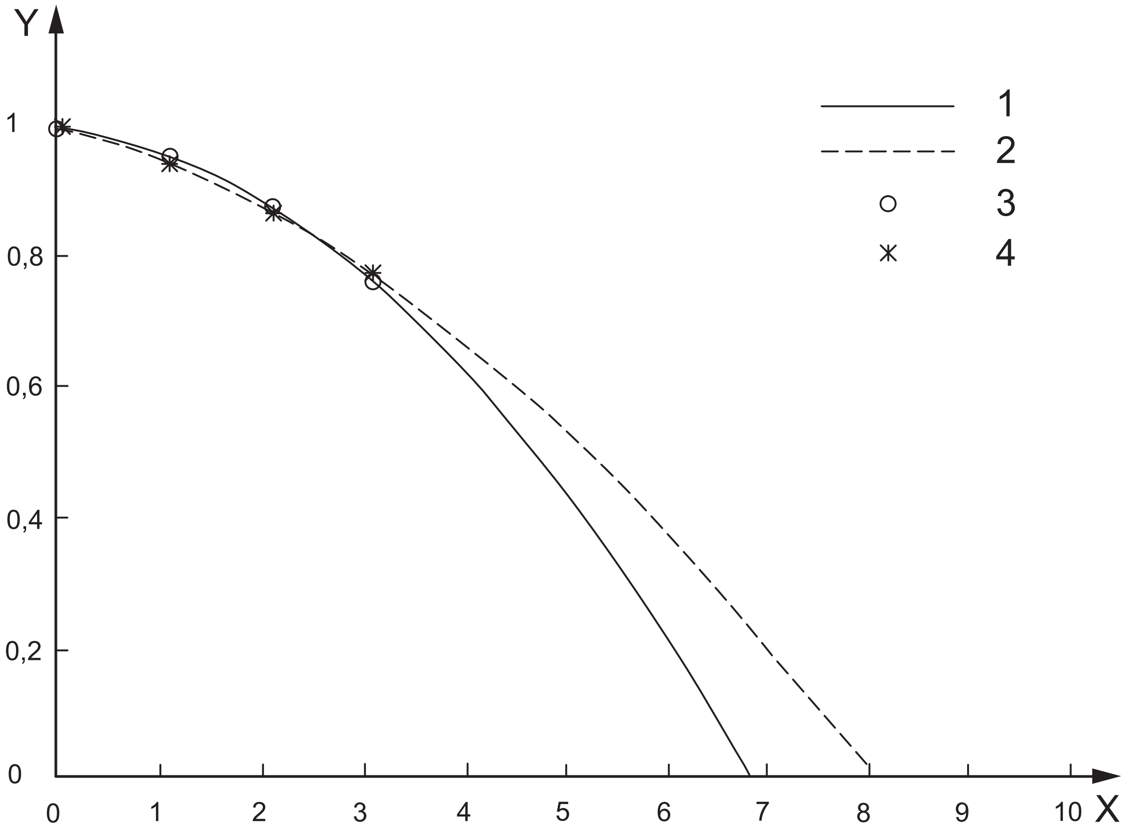
3) Functions referred to as dose-response functions, where time and intensities (or related quantities) are explicit variables, can be found in the literature. Although this is not in accordance with a strict definition, it has become an established designation, especially within the environmental research area.



Key

1 polynomial of 1st order
2 polynomial of 2nd order
3 polynomial of 3rd order
4 measured values

Figure A.2 — Example of extrapolation based on various functions



Key

1 polynomial “a” of 2nd order
2 polynomial “b” of 2nd order
3 measured values “a”
4 measured values “b”

Figure A.3 — Example of extrapolation from two closely related sets of measured values

Bibliography

[1] ISO 291, *Plastics — Standard atmospheres for conditioning and testing*

[2] ISO 877 (all parts), *Plastics — Methods of exposure to solar radiation*

[3] ISO 2135, *Anodizing of aluminium and its alloys — Accelerated test of light fastness of coloured anodic oxidation coatings using artificial light*

[4] ISO 2809, *Paints and varnishes — Determination of light fastness of paints for interior use*

[5] ISO 2810, *Paints and varnishes — Natural weathering of coatings — Exposure and assessment*

[6] ISO 3668, *Paints and varnishes — Visual comparison of the colour of paints*

[7] ISO 4582, *Plastics — Determination of changes in colour and variations in properties after exposure to daylight under glass, natural weathering or laboratory light sources*

[8] ISO 4607, *Plastics — Methods of exposure to natural weathering*

[9] ISO 4611, *Plastics — Determination of the effects of exposure to damp heat, water spray and salt mist*

[10] ISO 4665-1:1985, *Rubber, vulcanized — Resistance to weathering — Part 1: Assessment of changes in properties after exposure to natural weathering or artificial light*

[11] ISO 4665-2:1985, *Rubber, vulcanized — Resistance to weathering — Part 2: Methods of exposure to natural weathering*

[12] ISO 4665-3:1987, *Rubber, vulcanized — Resistance to weathering — Part 3: Methods of exposure to artificial light*

[13] ISO 4892-1, *Plastics — Methods of exposure to laboratory light sources — Part 1: General guidance*

[14] ISO 4892-2, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc sources*

[15] ISO 4892-3, *Plastics — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps*

[16] ISO 4892-4, *Plastics — Methods of exposure to laboratory light sources — Part 4: Open-flame carbon-arc lamps*

[17] ISO 8565, *Metals and alloys — Atmospheric corrosion testing — General requirements*

[18] ISO 9223, *Corrosion of metals and alloys — Corrosivity of atmospheres — Classification, determination and estimation*

[19] ISO 9224, *Corrosion of metals and alloys — Corrosivity of atmospheres — Guiding values for the corrosivity categories*

[20] ISO 9225, *Corrosion of metals and alloys — Corrosivity of atmospheres — Measurement of environmental parameters affecting corrosivity of atmospheres*

[21] ISO 9226, *Corrosion of metals and alloys — Corrosivity of atmospheres — Determination of corrosion rate of standard specimens for the evaluation of corrosivity*

[22] ISO 9370, *Plastics — Instrumental determination of radiant exposure in weathering tests — General guidance and basic test method*

[23] ISO 11341, *Paints and varnishes — Artificial weathering and exposure to artificial radiation — Exposure to filtered xenon-arc radiation*

[24] ISO 11431, *Building construction — Jointing products — Determination of adhesion/cohesion properties of sealants after exposure to heat, water and artificial light through glass*

[25] ISO 11507, *Paints and varnishes — Exposure of coatings to artificial weathering — Exposure to fluorescent UV lamps and water*

[26] ISO/TR 11728, *Anodized aluminium and aluminium alloys — Accelerated test of weather fastness of coloured anodic oxide coatings using cyclic artificial light and pollution gas*

[27] ISO 13638, *Building construction — Sealants — Determination of resistance to prolonged exposure to water*

[28] ISO 14615, *Adhesives — Durability of structural adhesive joints — Exposure to humidity and temperature under load*

[29] ISO 30013, *Rubber and plastics hoses — Methods of exposure to laboratory light sources — Determination of changes in colour, appearance and other physical properties*

[30] IEC 60068-2, *Environmental testing*

[31] IEC 60721, *Classification of environmental conditions*

[32] RILEM *Technical Recommendation 64, Systematic Methodology for Service Life Prediction of Building Materials and Components*4)

[33] HAAGENRUD, S.E. (1997) *Environmental Characterisation including Equipment for Monitoring. CIB W80/RILEM 140-PSL, SubGroup 2 Report*, NILU, Kjeller, NILU OR 27/97

[34] HOVDE, P.J., MOSER, K. (2004) *Performance Based Methods for Service Life Prediction: Part A - Factor Methods for Service Life Prediction; Part B - Engineering Design Methods for Service Life Prediction*, CIB Publication 294

[35] HAAGENRUD, S., JERNBERG, P., LACASSE, M. (2004) *Guide and Bibliography to Service Life and Durability Research for Buildings and Components* CIB Publication 295

[36] TALON, A., CHEVALIER, JL., HANS, J. (2006) *Failure Modes Effects and critically analysis research for an Application to the Building Domain* CIB Publication 310

[37] DANIOTTI, B., RECECCONI, F. (2010) *Accelerated Laboratory Tests Procedures and Correlation between Laboratory Tests and Service Life Data* – CIB W080 – WG3 report. Publication 331

[38] CIB, *Master List*

[39] United Nations, *UN ECE ICP programme*

---

4) Also available as: MASTERS, L.W. and BRANDT, E., Systematic methodology for service life prediction of building materials and components, *Materials and Structures/Matériaux et Constructions*, **22** (131), 1989, pp. 385-92.

ICS 91.040.01

Price based on 25 pages