BS 7543:2015

BSI Standards Publication

Guide to durability of buildings and building elements, products and components

bsi.

...making excellence a habit.™

Publishing and copyright information

Published by BSI Standards Limited 2015

ISBN 978 0 580 85379 1

ICS 91.040.01; 91.060.01

The following BSI references relate to the work on this document:
Committee reference CB/101
Draft for comment 14/30295128 DC

Publication history

First published March 1992

Second edition July 2003

Third (current) edition April 2015

Amendments issued since publication

Date	Text affected

Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 42, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 April 2015. It was prepared by Technical Committee CB/101, *Service Life Planning*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 7543:2003, which is withdrawn.

Information about this document

This is a full revision of the standard, and introduces the following principal changes.

- Terms and definitions have been updated to reflect the BS ISO 15686 series.
- The basis of risk assessment for estimating durability has been revised (see Clause **5**).
- The data on climate have been revised to reflect current understanding, in particular in respect of climate change (see Annex A).
- Annex A gives guidance on the way agents can affect service life.
- Annex B gives guidance on standards and good practice for major building materials.
- Annex C describes some common examples of construction failure that have occurred reasonably recently where expectations of durability have not been met.
- Annex D is an example of a completed design life data sheet showing application of the principles of this guidance to a specific system (building facades).
- Annex E is an annotated list of further reading giving information sources on topics covered in this guide.
- There is also a bibliography updated to reflect the current guidance.

This revision of BS 7543 updates and reinstates certain areas covered in the 1992 version. A series of International Standards, BS ISO 15686, *Buildings and constructed assets – Service life planning*, have been published since 2000. The provisions of BS ISO 15686 have replaced many of the provisions of the previous edition of this standard. However, there are a number of elements of this standard which are complementary to BS ISO 15686. This edition of the standard incorporates the complementary elements.

As a guide, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

Presentational conventions

The guidance in this standard is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

 This page deliberately left blank

Introduction

In order to predict the durability and the possible overall life of buildings, many factors need to be considered. These include practitioners' experience of component or material durability in practice, results of assessments and tests, and the possible effects of the actions of agents on different parts of the building or civil engineering structures. It is also important that this information is communicated clearly to the client and the project team so that the long-term performance implications of proposed designs can be understood and agreed.

For simplicity the term "parts" has been used throughout to cover both whole buildings and building elements, products and components.

Predicting durability is not an exact science, but a risk-based approach to the consideration of failure and acceptable service life. Values calculated for the predicted service life of a building and its parts can sometimes be no more than an informed estimation (for example, for novel materials or for unusual combinations of specific project circumstances). It is usually helpful to state the facts, assumptions and references on which the values are based.

Predictions of the durability of buildings have to take into account the variability of operating conditions, environment, workmanship, the quality and frequency of maintenance and the practical problems surrounding the storage, handling, installing and inspection of materials or components on a construction site. Maintaining, repairing and replacing buildings and assets across many sites or projects can provide a wealth of experience(s) on durability. However, there is a lack of systematically collated data that can form a basis from which durability can be accurately predicted for future projects.

NOTE 1 Although BS 5760 dealt comprehensively with reliability, maintainability and availability, in all industries, it was considered necessary to provide a separate publication specifically for the construction industry. Many of the parts of BS 5760 (but not all) have been superseded by applicable CEN standards, and one in particular is relevant which is BS EN 60812 which describes failure mode effect and criticality analysis (FMECA). Specific guidance on the durability of particular parts of buildings is given in many other British Standards, some of which are referred to in Annex B and Annex C. The design life of parts of a building will often need to be less than the design life of the whole building and this can be perfectly compatible with the usage and refurbishment cycles of normal building occupancy. However, achieving adequate durability without excessive expenditure or consumption of scarce resources is essential for achieving sustainability.

NOTE 2 Attention is drawn to the Construction Products Directive [1].

NOTE 3 Further guidance on improving the collection of data from buildings during their in-use phase can be found in BS ISO 15686-7.

1 Scope

This British Standard gives guidance on durability, design life and predicted service life of buildings, constructed assets and their parts. It applies to both new and existing buildings.

This standard also gives guidance on communicating and recording information on the service and design life of buildings, infrastructure and their components and/or assets when a detailed brief is being developed.

The principles of this British Standard are applicable to civil engineering projects and the guidance is written for all members of a construction project or facilities management team who provide or require information on durability, including clients, designers, contractors, specialists, manufacturers and those responsible for maintenance. It might also be relevant to funders, insurers and those undertaking due diligence assessments for investment purposes. It also applies to situations when new products offer better performance without a corresponding increase in cost.

This British Standard does not cover aspects of obsolescence and fashion, i.e. when buildings, infrastructure or assets are replaced or altered either to suit different needs and changing conditions including change of use and mandatory requirements.

*NOTE 1 A decision to replace or alter obsolete buildings or their assets might be influenced by a reassessment of their predicted service lives. BS ISO 15686-1:2011, Clause **8** gives further guidance on obsolescence.*

NOTE 2 More durability guidance specific to individual sectors is available from bodies such as the Highways Agency and engineering institutions.

2 Normative references

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

BS EN 15643-1, *Sustainability of construction works – Sustainability assessment of buildings – Part 1: General framework*

BS EN 15643-2, *Sustainability of construction works – Assessment of buildings – Part 2: Framework for the assessment of environmental performance*

BS EN 15643-3, *Sustainability of construction works – Assessment of buildings – Part 3: Framework for the assessment of social performance*

BS EN 15643-4, *Sustainability of construction works – Assessment of buildings – Part 4: Framework for the assessment of economic performance*

BS ISO 6707-1, *Buildings and civil engineering works – Vocabulary – Part 1: General terms*

BS ISO 6707-2, *Buildings and civil engineering works – Vocabulary – Part 2: Contract terms*

BS ISO 15686-2:2012, *Buildings and constructed assets – Service life planning – Part 2: Service life prediction procedures*

BS ISO 15686-5, *Buildings and constructed assets – Service life planning – Part 5: Life cycle costing*

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

BS ISO 15686-9:2008, *Buildings and constructed assets – Service-life planning – Part 9: Guidance on assessment of service life data*

BS ISO 15686-10:2010, *Buildings and constructed assets – Service life planning – Part 10: When to assess functional performance*

BS ISO 15686-11:2014, *Buildings and constructed assets – Service life planning – Part 11: Terminology*

3 Terms, definitions and abbreviations

For the purposes of this British Standard, the terms and definitions given in BS ISO 15686-11, BS ISO 6707-1, BS ISO 6707-2, and the following apply.

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

EXAMPLE Person, water, load, heat.

[SOURCE: BS ISO 15686-2:2012, **3.1.4**]

3.2 asset
whole building structure or unit of construction works, or a system or component or part thereof

NOTE Component has been used to include both materials (e.g. sand or cement) and assemblies (e.g. cladding).

[SOURCE: BS ISO 15686-10:2010, **3.1**]

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

[SOURCE: BS ISO 15686-2:2012, **3.1.6**]

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

[SOURCE: BS ISO 15686-2:2012, **3.1.7**]

3.5 design life (DL)
DEPRECATED: intended service life; expected service life

service life intended by the designer

NOTE As stated by the designer to the client to support specification decisions.

[SOURCE: BS ISO 15686-1:2011, **3.3**]

3.6 durability
ability of a building and its parts to perform its required function over a period of time and under the influence of agents

3.7 durability limit
point at which loss of performance leads to the end of the service life

3.8 environment
natural, man-made or induced external and internal conditions that can influence performance and use of a building and its parts

[SOURCE: BS ISO 15686-1:2011, **3.4**]

3.9 estimated service life (ESL)
service life that a building or parts of a building would be expected to have in a set of specific in-use conditions, determined from the reference service life data after taking into account any differences from the reference in-use conditions

[SOURCE: BS ISO 15686-1:2011, **3.7**]

3.10 failure
loss of the ability of a building or its parts to perform a specified function

[SOURCE: BS ISO 15686-1:2011, **3.9**]

3.11 life cycle
consecutive and interlinked stages of the object under consideration

NOTE 1 The life cycle comprises all stages from construction, operation and maintenance to end of life, including decommissioning, deconstruction and disposal.

*NOTE 2 Adapted from the definition of ''life cycle'' contained in BS EN ISO 14040, **7.1**.*

[SOURCE: BS ISO 15686-5:2008, **3.3.4**]

3.12 maintenance
combination of all technical and associated administrative actions during the service life to retain a building, or its parts, in a state in which it can perform its required functions

[SOURCE: BS ISO 15686-1:2011, **3.13**]

3.13 performance
DEPRECATED: performance in-use

qualitative level of a critical property at any point in time considered

[SOURCE: BS ISO 15686-1:2011, **3.15**]

3.14 performance requirement
DEPRECATED: performance criterion

minimum acceptable level of a critical property

[SOURCE: BS ISO 15686-1:2011, **3.19**]

3.15 predicted service life
service life predicted from performance recorded over time in accordance with the procedure described in BS ISO 15686-2

[SOURCE: BS ISO 15686-1:2011, **3.20**]

3.16 reference service life (RSL)
service life of a product, component, assembly or system which is known to be expected under a particular set, i.e. a reference set, of in-use conditions and which can form the basis for estimating the service life under other in-use conditions

[SOURCE: BS ISO 15686-1:2011, **3.22**]

3.17 service life
period of time after installation during which a building or its parts meets or exceed the performance requirements

NOTE Adapted from BS ISO 6707-1.

[SOURCE: DD ISO/TS 15686-9:2008, **3.4**]

3.18 usage conditions
in-use conditions due to users of a building/constructed assets, and human activity adjacent to a building/constructed assets

*NOTE In BS ISO 15686-7:2006, the factor class (**3.1.39**) F is designated "usage conditions" rather than "in-use condition" as used but not defined in BS ISO 15686-1. This is called for in order to distinguish the factor class from the term "in-use condition" as defined in BS ISO 15686-2:2001 as "environmental condition under normal use".*

[SOURCE: BS ISO 15686-7:2006, **3.15**]

4 Requirements for durability

4.1 General

Requirements for durability vary from project to project and from one asset to another. Requirements can be related to intended use, to the financing of a project and to scheduling/carrying out periods of maintenance, repair or replacement of a building or its parts.

Very durable, long lasting construction is usually more expensive and might restrict the design to a limited range of materials. Consequently a long design life is likely to increase the initial cost of the project, but not necessarily the life cycle cost, and can limit the design solutions that meet the brief. Therefore the designer might challenge excessive design life requirements as well as other aspects of the brief, such as the initial budget.

Financing of building construction often presumes a design life at least as long as the period of any loan used to finance the building, which might be secured on the building value.

4.2 Communication of requirements for durability (client to designer)

The client should define the design life of the building in the initial brief, which should reflect the overall requirements. Design life categories for parts are given in Table 1 and categories for effects of failure are given in Table 2. In addition the client might wish to specify the design life for specific assets. An example of reference service lives for specific components is given in Annex D. The design life or reference service life should be given in years and can be related to the categories of building design life.

Table 1 **Categories of design life**

Category description	Life	Typical examples
Short-term	Shorter life than the building and readily replaceable	Door actuators and motors, taps
Replaceable	Shorter life than the building and replacement can be envisaged at design stage	Most floor finishes and services installation components
Maintainable	Lasts, with periodic treatment, for the life of the building	Most external cladding, doors and windows
Lifelong	Lasts for the life of the building	Foundations and main structural elements

Table 2 **Categories of effects of failure**

Category	Effect	Example
A	Danger to life (or injury)	Sudden collapse of structure
B	Risk of injury	Loose stair nosing
C	Danger to health	Serious damp penetration
D	Costly repair	Extensive scaffold required. Durability critical component failure (see note below)
E	Costly because repeated	Window fastening replacement
F	Interruption to building use	Heating failure
G	Security compromised	Broken door latch
H	No exception problems	Replacement of light fittings

NOTE Individual failures can be in two or more categories.

When a period for design life is given by or on behalf of the client the following information is essential:

a) time (or a time measure such as running time or cycles of use) against which durability is to be assessed;

b) usage conditions in which the item will have to perform (i.e. environmental conditions and levels of maintenance and usage); and

c) performance requirements to allow the durability limit to be assessed (i.e. the point at which performance becomes unsatisfactory).

NOTE 1 Annex A gives guidance on relevant environmental conditions. Annex B gives some details of specific materials and relevant durability considerations.

NOTE 2 For example the light transmission through some materials decreases over the period of use depending on the surface finish and levels of cleaning/planned maintenance. A decision has to be made on when to change the roof light for a new one that will give a greater light transmission.

NOTE 3 The maintenance of thermal performance is achieved by ensuring that thermal conductivity characteristic of the material along with its dimensional stability (especially thickness in the direction of heat flow) is maintained. Before specifying a product the designer should be satisfied that the aging method required by the product standard is appropriate for the intended use.

NOTE 4 When designers receive a clear statement of requirements for durability from a client, they are more likely to be able to specify appropriately for all assets and avoid disappointments where, for instance, assets require early replacement. However, the process of agreeing the design lives with the client might involve the designer challenging competing client requirements (such as very long design lives against very low costs or short design periods or low fees), or indicating where design life requirements cannot be reasonably met by available design options.

Where the client has not specified the usage conditions or performance requirements that apply to the assets, the designer should record and agree with the client which conditions or requirements have been assumed.

The design life for a building should be qualified by additional information on future maintenance activity, based on the level of accessibility and feasibility for replacement of parts.

NOTE 5 Further guidance on maintenance can be found in BS 8210. There are three groups of maintenance approaches described in BS 8210:2012, Annex A. BS EN 13306 has definitions of corrective maintenance, maintenance plans, etc.

When a designer is developing a performance specification containing requirements for durability, it might be necessary to consult the client to ascertain their requirements. Any assumptions or cycles implied should be discussed and agreed with the client. For example, certain parts of the building might only be required to last until the first major refurbishment, in which case this timescale should be agreed.

For most parts or components it is clear how they are required to perform throughout the specified required service life. Some reduction in performance during the life cycle is generally acceptable (e.g. prior to replacement or maintenance), provided the performance requirements continue to be met. However, in the case of cosmetic appearance, some change might be acceptable. If changes in appearance are to be avoided this should be discussed at the briefing stage.

NOTE 6 For example the weathering of external claddings might be acceptable or even desired. A gradual change in the appearance of many floor finishes in trafficked areas is inevitable.

4.3 Communication of requirements to manufacturers and suppliers

The designer, or the person responsible for maintenance, should give requirements for durability when ordering a product from a supplier. Design life requirements should be given in years, and be related to design life categories in Table 1 and building design life.

When seeking predicted service life statements from manufacturers, designers or the person responsible for maintenance should give the following information on the design life for parts:

a) information on exposure to agents; and

NOTE 1 More detailed advice on specific agents and their effects on durability is given in Annex A.

b) details of adjacent materials and fixings.

NOTE 2 Information on exposure to agents is particularly important where the design life is part of a performance specification presented to a manufacturer supplying external components.

NOTE 3 The extent of cyclical movement of adjacent components and the chemical compatibility of materials is often critical to the durability of an assembly. These details are particularly important when the design life is given to a manufacturer of components in a performance specification. General statements and schematic details might not be enough to identify risks.

Allowances made for thermal and moisture movement, and methods of isolating incompatible materials should be fully described to the manufacturer.

A predicted service life from a supplier or manufacturer should indicate the service life environment (the specific or generic set of in-use conditions), as described in BS ISO 15686-2:2012, **5.1.2.1**.

5 Researching and calculating durability

A designer needs information on durability in order to be able to meet the client's requirements and assess the adequacy of intended durability of the whole building under construction. Information on durability of buildings and building components can be obtained from various sources, including:

a) codes of practice, text books and trade association publications;

NOTE 1 Such sources often embody experience in the use of traditional methods and materials.

b) national or international construction product certification bodies;

NOTE 2 For resources such as certificates assessing the performance of products.

c) publications from research bodies, professional institutions, or authoritative bodies;

d) manufacturers, providing predictions or warranties of the service life of their products.

*NOTE 3 Such predications or warranties can include details of the method of assessment, the variability of test results, the assumed conditions of use, and maintenance requirements as described in BS ISO 15686-2:2012, Clause **5**.*

NOTE 4 Relevant test certificates are not always available from manufacturers and might have to be obtained by testing for a specific project. This is time-consuming and expensive to do properly and might not be possible for smaller or for fast-track projects.

Predicted service life should be expressed in accordance with Table 4 (an example is shown in Annex D.

6 Service life assessment

6.1 General

The predicted service life is an expert judgement by the designer or supplier based on:

a) available information on service life;

b) site conditions;

c) expected quality of workmanship; and

d) the expected maintenance levels.

A cautious interpretation (avoiding too much optimism in interpretation) of available information is justified where:

1) the usage of parts of the building cannot be foreseen;

2) unfamiliar or novel products or products that are unfamiliar to the designer or supplier are to be incorporated; and

3) exceptionally large assemblies of components are involved.

6.2 Modelling of degradation of components

6.2.1 General

There are three main methods of modelling degradation of components for use in probabilistic analysis.

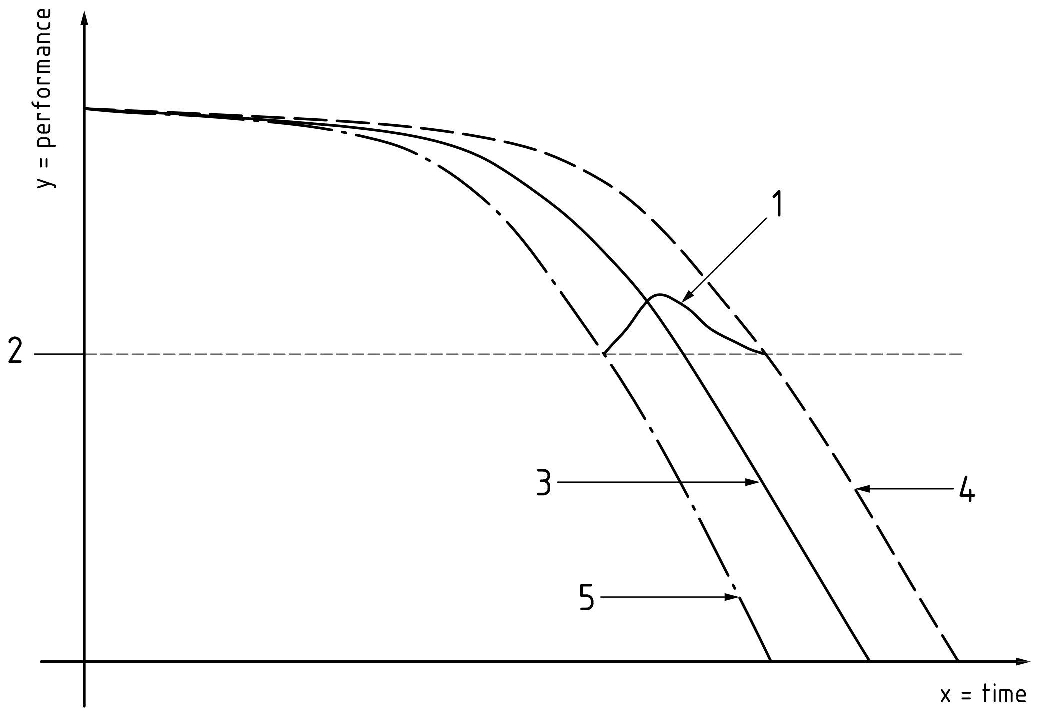
a) **Method 1** (see **6.2.2**): The use of past performance data to provide probability information regarding the service life of the building and/or parts: e.g. time to repair, replacement or failure. When complete data are unavailable, theoretical considerations and laboratory tests canbe used to complement them.

b) **Method 2** (see **6.2.3**): Physical modelling of the degradation of material properties and dimensions under the environmental conditions expected or specified. The knowledge for developing and calibrating these models can come from past performance data, laboratory tests and theoretical considerations.

c) **Method 3** (see **6.2.4**): Use of national data sets of typical reference service life estimates. These are expert judgements, often by a panel of experienced professionals. They might be published or available only within an organization, based on the previous experience of the professionals concerned. They can also include a range of values with guidance on which aspects of environment might influence selection on a single value estimate within the range.

Figure 1 shows a simple case of a single component with various possible service lives due to different environmental and load conditions.

Figure 1 **Degradation of a component and its relation to service life distributions and physical modelling (Method 2)**



Key

1 Probability distribution of service life

2 Minimum acceptable service level

3 Deterioration under "average" reference condition

4 Deterioration under "best" conditions

5 Deterioration under "worst" conditions

6.2.2 Method 1: Assessments based on past performance data

Past performance data on (reactive) intervention times, replacement times, etc., can be analysed to provide mathematical or probability distributions for the time-to-failure or repair of components. In addition, by separating the data to reflect different environments, previous preventative maintenance, quality of material, etc., it is possible to develop (conditional) probability distributions for these subsets of the data.

Method 1 is the easiest of the three methods, especially if numerous components in a similar situation (such as those in housing generally) are being considered. Also, for this type of modelling, most information is available in databases.

There are several difficulties with applying the statistical methods involved in this approach to service life modelling, e.g.:

a) Future environmental conditions might not be the same as that of the past (see Annex A).

b) The materials used in the current time might be different from what existed previously, and on which the performance data are based.

c) Small sample sizes might reduce the statistical reliability of modelling.

d) Available data might not contain the required information.

e) It is difficult to accurately predict future interventions, e.g. cleaning, repair or replacement.

This method is most suitable where the component involved is used repeatedly and is frequently maintained and replaced (for example, windows), thus giving rise to a statistically valid data set. This method is less appropriate for civil engineering structures or components that rarely structurally fail prematurely (such structures need Method 2, described in **6.2.3**).

6.2.3 Method 2: Physical modelling of degradation

The physical modelling of degradation of a component can give the best information required by a mathematical or probabilistic analysis that considers future repair and maintenance schedules. However, these models could have significant uncertainties in them.

A physical model can describe the time-dependent behaviour of selected physical characteristics of a building and/or its parts, in terms of a set of parameters that include information on the materials used, the components, load histories, interactions between components, and the exposure of the building to environmental agents. Using mathematical analysis or probabilistic analysis will result in either a deterministic (single value) result or a probability distribution of predicted service life. However, the model assumptions introduce risks and uncertainties.

Physical degradation models, which can be of different sophistication and detail, are useful when:

a) sufficient performance data are not available for obtaining the probability distributions of service lives;

b) degradation mechanisms and agents, and other influences, are well known;

c) effects of different, previously untried, interventions need to be evaluated so that the best approach can be chosen.

NOTE Accelerated testing of components by itself can seldom be used to give an accurate basis for predicting service life. It is often the best method of assessing the performance of novel components or materials, or assemblies. Accelerated testing is not usually feasible for large assemblies of components and caution might be needed in interpreting the results for novel design options.

6.2.4 Method 3: Evaluation of national datasets

National datasets are assessments of reference service lives with stated methodology. Their reliability typically depends on the adequacy of the methodology, expertise and level of care in seeking evidence for the results. They are national rather than project specific estimates, and require adjustment in order to provide estimates for any particular project. They are typically the starting point for most durability predictions.

Sources of national datasets (see Annex E) within the UK include:

a) manufacturers' certified service life data with associated reports or certificates by third party assessors;

b) tools or publications by independent bodies; and

c) publications or tools which depend on service lives to make assessments of other metrics, such as environmental performance or life cycle cost (such as various proprietary tools by cost consultants or building modelling software suppliers).

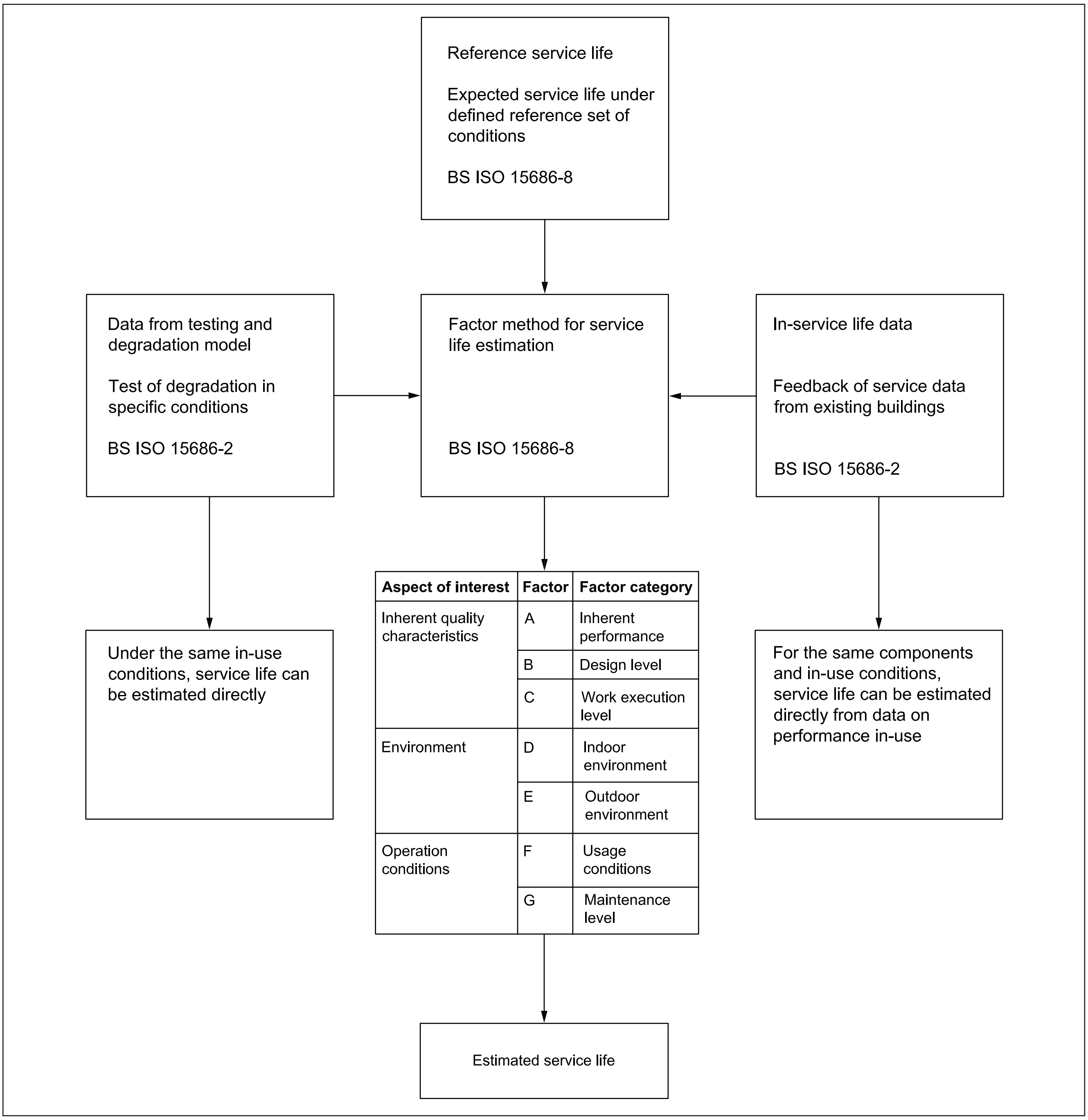
6.3 Adjusting reference service lives to provide estimated service lives

Guidance on how to interpret and adjust reference service lives to meet project conditions is given in BS ISO 15686-8:2008, Annex A. This includes information on how to take account of a range of factors including:

- Factor A – Factor Category: Inherent performance level
- Factor B – Factor Category: Design level
- Factor C – Factor Category: Work execution level
- Factor D – Factor Category: Indoor environment
- Factor E – Factor Category: Outdoor environment
- Factor F – Factor Category: Usage conditions
- Factor G – Factor Category: Maintenance level.

This is represented in Figure 2.

Figure 2 **Approaches to service life planning (based on BS ISO 15686-2)**



6.4 Categories of design life

The client should define the design life of the building in the initial brief. In addition the client might wish to specify the design life for specific assets.

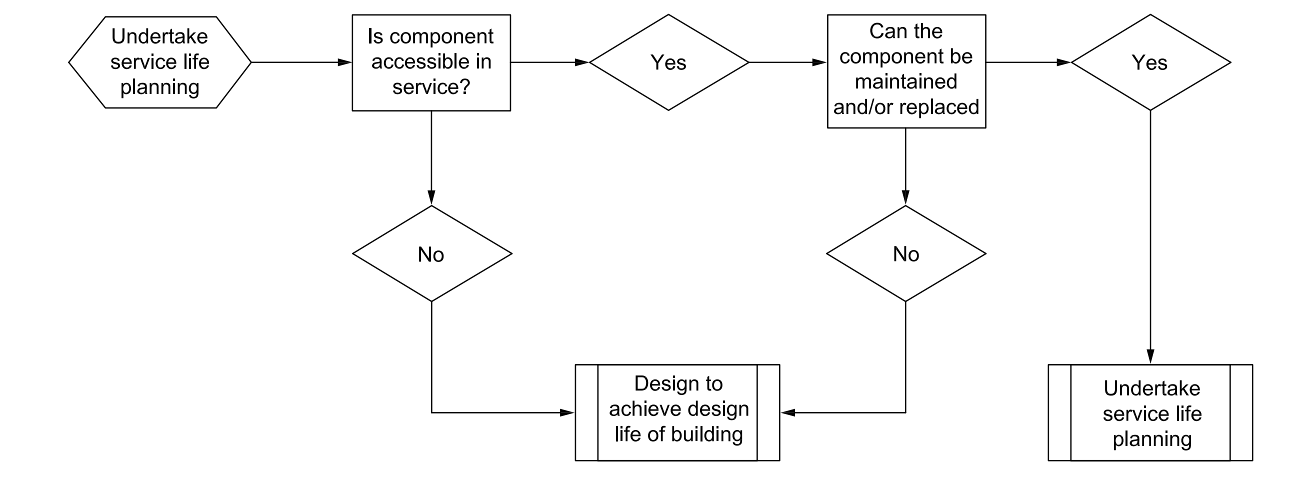
NOTE An example of reference service lives for specific components is given in Annex D.

The design life or reference service life should be given in years and can be related to the categories of design life in Table 1.

The designer should categorize proposed or actual designed parts of the building into one of the category descriptions as shown in Table 1.

A skilled decision process, such as that highlighted in Figure 3 should be followed to determine whether a category is acceptable or not.

Figure 3 **Decision process in support of categorization of design life**



6.5 Assessment of criticality of durability – FMECA

Once the overall category of the design of parts has been assessed as either short-term, replaceable, maintainable or lifelong, the probable effects if failure does occur should be assessed. Failure mode, effect and criticality analysis (FMECA) is a technique for assessing the effects of failure and the associated criticality of durability.

FMECA helps to identify potential failure modes based on experience with similar products and processes, or based on common physics of failure logic. Processes of degradation should take account of varying levels of exposure to environmental agents if relevant, in particular foreseeable changes in climate. Microclimate and the effects of key agents are discussed in Annex A.

Effects analysis refers to studying the consequences of those failures on different system levels.

Failures are rated or prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. The purpose of the FMECA is to take actions to eliminate or reduce failures, starting with the highest-priority ones. The approach can be summarized as answering the following questions:

a) Failure modes (what could go wrong?)

b) Failure causes (why would the failure happen?)

c) Failure effects (what would be the consequences of each failure?)

Depending on the likely effects of failure, the part or component should be placed into a criticality category as shown in Table 3. Note that there are inter-dependencies between components and failures, and therefore failure of one component or part could lead to failure and associated effects of other components or parts (examples are provided in Table 3).

NOTE More guidance on how to categorize failure during surveys, how to evaluate causes and consequences of failure, and the evaluation of risks (such as hidden failures) and associated recommended actions, is provided in BS ISO 15686-7:2006 ***5.3.5****.*

The combination of the probability of failure at a particular point in time and the assessment of the severity of consequence of failure is used to provide an understanding of which estimate of service life is appropriate for a particular project, with its specific client requirements.

Table 3 **Examples of effects of failure in different categories**

Category	Description	Example	Consequence
Durability Critical Components (DCC)	Parts or elements whose durability is critical to the performance of the whole building or structure. Failure of these elements would lead to the immediate or foreseeable failure to provide the required minimum level of performance, and can trigger the durability limit of the whole building.	Membrane on a flat roof	Failure of the roof causes water ingress into a booking office making the room unusable.
		Expansion joint between sections in bridge deck	Failure of sealant leads to reinforcement corrosion, ultimately risking structural integrity and excessive repair costs and disruption.
		Tarmac finish to pavements or station platforms	Failure of tarmac could allow water to permeate to fill and lead to erosion and collapse of surface.
Durability Sensitive Components (DSC)	Elements whose durability is not critical to the performance of the whole building or structure but are important to its ability to function effectively. Failure would not lead to immediate failure of the building to provide the required minimum level of performance, although eventual failure is conceivable.	Membrane on a flat roof	Failure causes water leakage into open platform shelter making the shelter damp and causing damage to internal finishes.
Unclassified Components (UCC)	Failure of these components would either be unlikely to occur or would not affect the ability of the structure to provide the required level of performance.	Concrete structures suffering sulfate attack in heated building or rust on door hinge	None or minor, e.g difficulty in opening or closing door.

Table 4 **Expression of durability (summary of guidance)**

Expression	Examples	Form of expression	Supporting Information	Comments
Design life	Service life intended by the designer	Years of service life	The design life of the building (DLB) places a maximum on the design life of parts of the building. For the design life of parts, see example sheet in Annex D.	Should be as follows: a) at least as long as the requirement for service life based on the client's brief; b) related to use, maintenance and renewal plans. Assumptions on which the design life is based should be recorded.
Estimated design life	Service life that a building or parts would be expected to have taking account of any differences from a reference set of in-use conditions	Years of service life	See BS ISO 15686-8.	Typically estimated by adjusting a reference service life.
Predicted service life	Service life predicted from performance recorded over time in accordance with procedures in BS ISO 15686-2	Years of service life	See BS ISO 15686-2.	Typically predicted through service life models or ageing tests under a set of reference in use conditions and for a specific product, component, assembly or material.
Reference service life	Service life known to be expected under a particular (reference) set of in-use conditions, and which can form the basis for estimating the service life under other in-use conditions	Years of service life	See BS ISO 15686-8.	Typically based on a number of predicted service lives for similar products, and included in publications such as those cited in the bibliography. The in-use conditions assumed may not have been captured in detail.
Service life	Period of time after installation during which a building or its parts meet or exceed the performance requirements	Period in years	See BS ISO 15686-1.	The service life itself can only be categorically fixed at the end of the service life.

6.6 Terms associated with communications of durability

An inconsistent use of terms to describe durability can lead to misunderstandings and incorrect specification of durability. Table 4 summarizes the guidance in this standard that is intended to encourage the provision of more consistent and comprehensive terminology for durability.

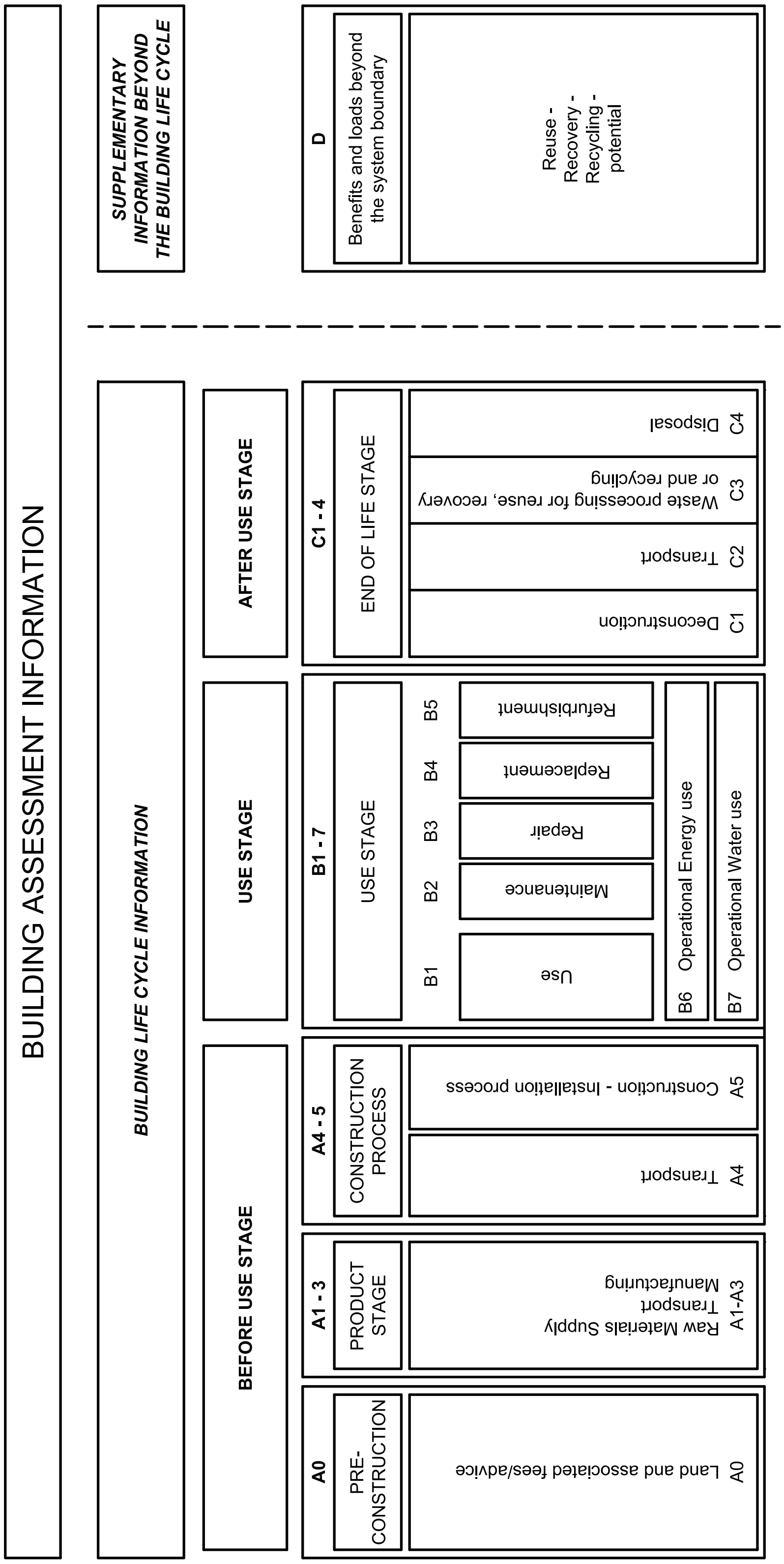
The start of the service life is when a building or part of a building is completed and handover for occupancy or use has taken place. It can also be measured from completion of refurbishment for an existing building.

The end of the service life is the point at which the only way to deal with unacceptable loss of performance (as identified in the brief) is by replacement or excessive expenditure on operation, maintenance or repair. The end of service life, when measured from the start of service life and guidance on what would be excessive expenditure should be sought from the client during briefing.

NOTE It is acceptable in terms of service life planning for any part of the building to have a shorter service life than the design life of the building provided it is capable of being replaced, and provided it meets the other service life requirements. In practice there are often durability requirements for certain parts of the building (such as the structure) to be lifelong, as indicated in Figure 1.

Durability assessment might form an input to other assessment processes. For certain assessment processes, the entire life cycle of the building or part should be considered, for example for integrated assessment of sustainability in accordance with BS EN 15643 (all parts), whereas for other aspects of assessment, such as life cycle costing in accordance with BS ISO 15686-5, only a limited period of assessment (an agreed period of years) might be required. The entire life cycle is shown in the Figure 4.

Figure 4 **Phases of the life cycle**



Key

1 Highest severity of consequence of failure
2 Anticipated severity of consequence of failure
3 Lowest severity of consequence of failure
4 Minimum service life
5 Most likely service life
6 Maximum service life

Annex A (informative) Climatic agents affecting durability

A.1 Microclimates in the UK

A.1.1 General

A microclimate is the distinctive climate of a small-scale area, such as a garden, park, valley or part of a city. It is the local microclimate that has the most impact on the durability of a building.

As far as the UK is concerned microclimates include the following:

a) upland regions;

b) coastal regions;

c) forest regions; and

d) urban regions (as distinguished from their surrounding rural regions).

Features of each regional type that might affect durability are highlighted below.

NOTE Generally the term "coastal" is used in this standard, but where the term "marine" has been used in other standards the terminology has been retained.

A.1.2 Upland regions

Upland areas are usually defined as the land 300 meters above sea level. The majority are in the north and south west. They will normally have lower average temperatures and are windier than surrounding low lying areas. Temperatures can vary by as much as 5 °C or 10 °C per 1 000 meters. Rainfall patterns also vary across upland regions – the windward side will tend to be wetter than the leeward side, and south facing slopes will be warmer in the Northern Hemisphere. However, valleys can be cooler than hills on clear nights, particularly in winter, when cold air flows downhill resulting in frost pockets in low lying areas.

A.1.3 Coastal regions

Coasts are usually milder in temperature than inland regions during the winter, and cooler in the summer. Windward shores tend to be of similar temperature to the sea, but leeward shores will vary more – they tend to be prone to showers during spring and summer, unlike windward shores where the tendency for showers is greater during autumn and winter. Sea fogs or mists might also linger within several miles of coasts. Particular consideration should be given to wind-blown salt atmosphere and how far inland this will impact the design specification.

A.1.4 Forest regions

Trees act as a windbreak, particularly when trees are in leaf, and this can result in cooler, less windy conditions.

A.1.5 Urban regions

About three quarters of the UK population live in urban areas. In comparison to rural areas they tend to have fewer hours of sunshine, higher average temperatures, less frost, lower relative humidity, less rain (although possibly more rainy days), significantly less snow, but more fog.

NOTE A more detailed comparison and examples of specific micro-climatic effects can be found in Met Office Fact Sheets (see Annex E).

The interaction of the release (and reflection) of heat from industrial and domestic buildings, reflection of solar radiation by glass, pollutants from traffic and industry and relatively low winds can trap some of the heat from the day. Urban heat islands typically display significant higher minimum temperatures, particularly under clear skies and light winds. This can accelerate degradation (see **6.2.3**).

Urban areas are also prone to more thunderstorms and therefore more intense rain. Photochemical smogs can occur as a result of pollutants reacting with solar radiation. The consequent concentration of pollutants can have effects on weathering of materials.

Although urban areas are generally less windy than surrounding rural areas localized high buildings can result in marked gusts in the immediate locality due to wind tunnelling.

A.2 Microclimate effects on durability

A.2.1 General

In many instances degradation is not the result of action by a single environmental agent but the effect of a combination of agents. It is therefore important to consider each type of agent and the extent to which their combined effects are likely to affect a particular form of construction.

Frequently, the action of one agent is dependent on the presence of others, for example an increase in temperature of 10 °C can double the rate of a chemical reaction causing degradation. Moisture is probably the agent with the greatest influence on the durability of building materials. Many types of degradation, such as corrosion of ferrous metals and generally insect or fungal attack on timbers, can take place only if moisture is present.

The most relevant agents for degradation of building components usually originate from the atmosphere, such as the following:

- freeze/thaw and wind (mechanical);
- solar radiation (electro-magnetic);
- temperature (thermal);
- precipitation (solid, liquid or vapour, chemical);
- normal air constituents (chemical); and
- air contaminants (chemical).

NOTE 1 More detailed guidance on actions of agents can be found in BS ISO 15686-2 and BS ISO 6241:1984, Table 4.

NOTE 2 Atmospheric environments are classified in BS EN ISO 12944-2, and split into the following six atmospheric-corrosivity categories for metals:

1) *C1 very low;*
2) *C2 low;*
3) *C3 medium;*
4) *C4 high;*
5) *C5-I very high (industrial); and*
6) *C5-M very high (marine);*

Corrosivity categories for metals can also be estimated by considering the combined effect of the following environmental factors:

- *yearly time of wetness;*
- *yearly mean concentration of sulfur dioxide; and*

- *yearly mean deposition of chloride (see BS EN ISO 9223).*

NOTE 3 Exposure environment classifications for concrete are given in BS 8500-1.

A.2.2 Temperature

All external construction materials experience both diurnal and annual temperature variations. These are most pronounced when the construction is exposed to an un-obstructed sky, e.g. high level roofing, cladding and external structural members of buildings.

Changes of temperature are relevant when assessing the consequences of thermal expansion and contraction, e.g. due to stresses within materials when changes of size are restrained, and to strains imposed on jointing materials when components are free to change size. The actual temperatures reached can lead to temporary or permanent changes in physical or chemical properties, e.g. embrittlement at low temperatures, accelerated oxidation or loss of volatiles at high temperature. In some cases the distribution or gradient of temperature within a material or constructional element might be critical; for example in the case of assessment of interstitial condensation risk, or in the control of excessive temperatures due to heat of hydration during setting and initial hardening of concrete.

Properties that can be altered by changes of temperatures are:

a) shape or dimensions;

b) strength;

c) rheological (flow) properties;

d) resistance to solvents; and

e) electrical resistance.

Increases of temperature can accelerate irreversible consequences such as chemical action, creep and biological decay. Fluctuations of temperature might influence moisture content, crystallization and leaching actions.

A.2.3 Radiation

Although some solar radiation is absorbed the earth’s atmosphere the effect is varied by cloud cover and shading, which affects how much solar radiation in each waveband is received at the surface. Depending on the surface that it strikes, the opacity, colour and texture of the surface, the increase in surface temperature can be considerable. This particularly affects organic materials, including dyestuffs, bituminous and some synthetic polymers and yellowing or degradation of the surface can occur where UV radiation propagates degradation by moisture.

The absorbed radiation will raise the temperature of a material by an amount dependent upon the specific heat and thermal conductivity of the material and the structure behind. In clear, sunny weather in the United Kingdom, black mastic asphalt roofing can reach a temperature of 80 °C. Similar figures have been reported for black bituminous roofing. If a reflective coating is applied the maximum temperature rise can be reduced by 20% to 35%.

There will be considerable variation in the total radiation received at a given place on the ground depending upon:

a) the cloud cover both in type and quantity;

b) the season of the year; and

c) the local topography.

Peak solar radiation is likely to occur around noon inland, and during the late morning on the coast. Surfaces exposed flat (normal) to midday summer sun, or those receiving substantial reflected radiation from adjacent surfaces, reach the highest temperatures. In approximate terms, the radiation received on an overcast day is about one third of that received if it had been cloudless. On very dull days the proportion would be very much less.

The temperature of roofing surfaces in the UK can drop to –20 °C. The temperature of the roofing membrane is frequently more than 5 °C lower than the air temperature. Thermal radiation from black or dark coloured surfaces is greater than from light coloured surfaces.

A.2.4 Water

Snow or ice imposes structural loading, and is particularly important where drifting occurs or blown snow penetrates roof coverings which adequately resist rainwater.

Moisture has most effect when it is allowed to become absorbed either as liquid water or as water vapour. The quantity of water falling on the vertical faces of buildings is related to the combined effects of wind and rainfall. Most organic materials and many inorganic materials absorb moisture to varying degrees. The direct effect of water alone on a material or item can be as follows:

a) a volumetric change;

b) a change in mechanical properties (e.g. strength);

c) the development of bending and turning forces;

d) a change in electrical properties;

e) a change in thermal properties; and

f) a change in appearance.

The presence of moisture is likely to enable physical, chemical or biological reactions to take place which in turn can lead to degradation of some of the properties of the item. Examples are as follows:

1) frost damage;

2) effect of sulfate attack on Portland cement products;

3) corrosion of iron and steel and non-ferrous metals;

4) fungal decay of wood products; and

5) changes in dimensions, warping or delamination due to differential wetting or drying.

Water vapour's most damaging effects are seen when condensate forms on cool surfaces or within open pored materials that are cooled on one face. Condensation promotes the growth of biological agents such as surface moulds and rot in timber. It causes corrosion, as for example on the inside face of profiled steel cladding, and it accelerates chemical reactions such as the sulfate attack on mortar that can occur when flue gases condense on the inside face on an unlined brick chimney.

For ferrous metals in particular the time of wetness (how long the surface remains wet before it dries) directly correlates with how much corrosion takes place. However, different metals have different levels of susceptibility and appropriate grades should be specified for the end use intended, as different coatings are available (e.g. PVC or PU or PVdF) which might change the performance from that of uncoated metals.

Water vapour generated by users of a building can create very high levels of humidity inside the building, irrespective of the outside climate.

A.2.5 Gases and pollution

Certain gases present in air will chemically react with materials, usually in association with natural moisture.

Oxygen is involved in the corrosion of metals and in the oxidation of paints, plastics, sealants and bituminous products. It has little effect on non-metallic inorganic building materials.

In the presence of moisture, carbon dioxide will attack susceptible materials since it forms a slightly acidic solution. Atmospheric carbon dioxide is a major cause of degradation in exposed reinforced concrete structures. Rate of carbonation depends on concrete quality. When it has reached the depth of the embedded steel, moisture can cause corrosion with severe expansion disruption of the concrete.

In coastal environments salt spray can be considered as a form of pollution which can travel several miles inland. It can affect metals (for example, by accelerating corrosion of ferrous metals and aluminium). It can also have additional deleterious impacts on stone and masonry.

Gases, such as sulfur dioxide and oxides of nitrogen, are soluble in water. In the presence of moisture they form acids that can attack susceptible materials such as unprotected metals, concrete, other cementitious products and some building stones. In addition the products of the reaction can themselves be reactive towards other materials.

Gases released into the atmosphere from industrial processes have contributed to the acidity of the rain falling in the lee of the industries causing the pollution. In some places this acid rain has severely affected stonework.

Particulate pollution in the form of dust and grit, other than localized pollution from industrial processes, arises but mainly from natural and agricultural sources. Particulate pollution has no direct chemical action on materials. However, its accumulation in crevices and on horizontal surfaces encourages other chemical actions from water or solutions.

Particulate pollution from specific industrial processes will each have a different composition. Each process effluent should be examined separately as a potential agency for causing changes in the properties of building materials.

In industrial areas there might arise micro-droplets of acid or alkaline solutions, or low volatility hydrocarbons or oils. The effect of each of these has to be considered.

A.2.6 Freeze/thaw cycles and frost

When water freezes it expands, and when it thaws the effects of this expansion can become apparent in the form of frost damage. Frost damage occurs when there is sufficient water entrapped in pores to disrupt the material on freezing. The necessary conditions therefore include wetting (tending towards saturation) shortly before freezing. The wetting might be due to rainfall or to driving rain, or melt-water from a partial thaw of snow or ice.

The air temperature at which frost damage occurs can be substantially below freezing, since temperatures just below zero might not freeze water in small spaces, and the temperature of the material can remain higher than the surrounding air temperature. Therefore the number of freeze-thaw cycles might vary from those implied by measuring air temperature alone. Neither the temperature at the time of thawing nor duration of frost are as significant for durability as:

a) severity of frost (lowest air temperature);

b) speed for freezing (rate of fall of air temperature, and therefore rate of thermal change in materials);

c) change of air temperature during periods of frost; and

d) numbers of frost cycles (i.e. daytime thaw after frost at night).

Frost can cause delamination and detachment of layers (e.g. renders) and lifting of shallow foundations or pavings due to the expansive force of the ice within small pore spaces.

A.2.7 Wind

The two major considerations which relate to wind and durability are as follows:

a) the effects of the driving of rain and of particulate solid matter; and

b) the effect of differential pressures that might be developed in localized positions on a structure.

The former is instrumental in causing erosion and inducing the penetration of rain into vertical structures. The latter tends to affect areas such as roof coverings, cladding panels and glazing. These can cause deflections or loosening from fixings. They can also affect flashings, joints and seals.

A.2.8 Biological agents

Bacterial activity can induce decay in metals when suitable nutrients are available. Concrete structures can be attacked by sulfuric acid produced by bacteria and both aerobic and anaerobic bacteria can attack metals.

Insects can attack a range of building materials, for example wood-boring beetles with timber and timber-based products and, more rarely, masonry bees with soft mortar, soft brick and stone. The moisture content of timber is the predominant factor when considering its susceptibility to both fungal and insect attack. Timbers kept at a moisture content of 20% or less are not normally subject to fungal attack. Rainfall, humidity and temperature also have a general influence on natural habitats which determine the types of insects available to attack timber in buildings in different parts of the United Kingdom. The moisture content of timber is affected by rainfall or driving rain, changes in atmospheric humidity (for example swimming pools or other areas with significant condensation can result in humidity levels above 20%), the difference between internal and external humidities, the integrity of vapour barriers and the adequacy of ventilation.

Infestations are generally inhibited by low temperature and encouraged by warmth. However insects can sometimes be destroyed by hot conditions. Insect attack is possible at 12% (*m*/*m*) moisture content and above, which often applies to roof and ground floor timbers, and sometimes to mid-floor timbers.

Rodents can cause damage by chewing organic materials and casings to electric cables. Birds can damage fragile roofs by pecking, and their dropping or debris dropped by birds can block or damage roofs and rainwater systems. Animal waste matter is a source of nutrient for plants, insects and bacteria that may cause damage.

Surface growths such as fungi, algae, lichen, and mosses can grow on many building materials. Surface growths do not necessarily harm the material but, particularly in the long term, some classes of biological agents cause damage by releasing acid metabolic products; others invade the surface of substrates and this leads to degradation.

Tree and plant roofs can damage foundations and below-ground drainage and rainwater disposal systems. Growing plants can also damage masonry walls through root development in cracks and jointing.

Annex B (informative) Guidance on materials and durability

COMMENTARY ON Annex B

Further information and guidance on each material group can be sought from the various professional bodies and trade associations. A list of relevant associations and some specific publications on particular materials is included in informative Annex E. Durability is affected by the environment in which the material is placed. However, it is important to recognize that durability is not the only critical aspect of performance, and that the most durable material might not necessarily be appropriate for the application.

B.1 Metals

B.1.1 General

Metals are chosen for their structural qualities (tensile strength and hardness), appearance (which can be changed by surface finishes or coatings), ability to be joined by welding or fastening, malleability into various forms (sheet, pipe, bar etc.) as well as their durability. The most durable metal might not necessarily be appropriate for the application.

Generally there is good guidance available for metals through the specialist associations of manufacturers. Specific metals guidance is highlighted in **B.1.2.1** to **B.1.2.6**.

A form of corrosion which has often caused unexpected failures and inadequate durability in the UK is bi-metallic or galvanic corrosion. This can arise where dissimilar metals are in contact in the presence of an electrolyte such as rainwater or condensation. Guidance on this specific aspect of durability is given in PD 6484.

NOTE Generally, control of this form of corrosion is by separation of the dissimilar metals (e.g. by gaskets), avoidance of presence of electrolyte or by careful selection of appropriate metals for the application.

B.1.2 Iron and its alloys

B.1.2.1 Steel

Ordinary mild steel rusts when exposed to air and moisture. However, it is rarely used exposed. Normally it is either protected by a coating (such as paint, bitumen or zinc galvanizing) or it is embedded in other materials (typically concrete).

Steel is used without corrosion protection, for example driven steel piles, steel in a controlled environment in a building, and steel in internal spaces such as cavities and parts of bridges. In these cases a corrosion allowance is often used based on data published in standards such as BS EN 1993-5, BS EN ISO 12944-2, BS EN ISO 9223 etc.

*NOTE See also **B.1.2.2** for stainless steel.*

Mild steel protected by zinc has durability roughly dependent on the thickness of zinc deposited by galvanizing (see **B.1.2.4**).

Steel reinforcement is typically protected by the high alkalinity of the surrounding concrete. Permeability and level of cover to reinforcement are key issues. Corrosion of reinforcement or pre-stressing steel might also occur in the presence of calcium chloride (historically sometimes used as an admixture). Attack by sea spray or de-icing salts can introduce chlorides causing rusting and spalling to occur.

B.1.2.2 Stainless steel

The durability of stainless steel is dependent on grade, environment and surface finish. Chloride ions are the most critical environmental agent of decay– these can typically be found in marine environments and also where chlorine is used, for example in swimming pools. Acid conditions (due to pollution or industrial processes) are also relevant.

While stainless steel is generally very corrosion-resistant there are a number of types of corrosion which need to be considered. These are:

- pitting corrosion;
- crevice corrosion;
- bi-metallic (galvanic) corrosion;
- stress corrosion cracking;
- general (uniform) corrosion; and
- intergranular attack and weld decay.

NOTE 1 There is a downloadable classified index of reference materials for architects and structural engineers in the technical library of the BSSA, which includes guidance on particular applications such as exterior cladding or use in swimming pools. This was last updated in 2008. This can be found on http://www.bssa.org.uk/sectors.php?id=1 [viewed 10-3-2015].There is a table covering the applicable CEN standards to different grades and applications which can be found on http://www.bssa.org.uk/topics.php?sub_category=23 [viewed 10-3-2015]. There is international guidance on a searchable online information resource at http://www.stainlessconstruction.com/ [viewed 10-3-2015].

NOTE 2 See BS EN 1993-1-4 for guidance on type and grade of stainless steel for structural applications.

B.1.2.3 Copper and its alloys (including bronze and brass)

The main uses for copper are in roofing, cladding and plumbing. Generally copper used in mixed metal applications forms the non-corroding anode (i.e. copper is deposited elsewhere).

NOTE 1 Guidance is provided by the Copper Development Association (http://www.copperalliance.org.uk [viewed 10-3-2015]).

NOTE 2 Life cycle information on these sites is in respect of environmental life cycle assessment, not service life assessment.

Copper tube is manufactured in accordance with BS EN 1057. It comes in a number of tempers (hard, half-hard, and soft or annealed). It is also manufactured with plastic coatings or with chrome plating. Fittings are manufactured to BS EN 1254 (all parts).

Copper can be attacked by flue gases containing sulfur dioxide. Copper is corroded by ammonia and some metal acids, but these are rarely present in water circulating in buildings. Water with a high carbon dioxide content can corrode copper, but normally this effect occurs slowly and is rarely the cause in itself of significant damage.

Historically some copper pipework suffered serious pitting corrosion. Carbon derived from the lubricant formed a nearly continuous film which was cathodic to the copper. Pitting corrosion occurred at small breaks in the film. Mechanical cleaning of tubes in accordance with BS 2871-2, BS 2871-3 and BS EN 1057-1 has largely resolved the problem, but it should be noted when there are British supply shortages and imported tubes might be used.

Copper-zinc alloys used in brass water fittings (alpha-beta alloys) can suffer dezincification in the presence of either acidic water or alkaline water where there is a high chloride content. This leaves behind a spongy copper residue.

B.1.2.4 Zinc (including galvanized coatings)

Zinc is used both in sheet form as roofing, cladding or flashings, and also as a coating in the form of galvanizing.

The pollution of zinc in dry, unpolluted environments is very slow. It is accelerated in the presence of moisture (roughly four times as fast), and significantly increased (roughly ten times as fast) in polluted, moist conditions.

Both hot-dipping and cold-plating/spraying are methods of applying zinc to base metals as a means of protection. Hot-dipping is generally more effective, in part because a thicker layer of zinc in deposited, and in part because all cut or exposed edges of the base material are coated in the process.

Rapid corrosion of galvanized wall ties was experienced historically in the UK in the presence of black ash mortar (which contained sulfur compounds). Soft water can lead to corrosion of galvanized metal cisterns and tanks. Pitting corrosion can occur where copper or brass debris is left within unprotected galvanized cisterns (a form of bi-metallic corrosion, see **B.1.1**).

Where used as a protective coating over mild steel (see **B.1.2.2**) damage or partial removal and/or degradation of the zinc coating will accelerate corrosion of the base steel which the coating is designed to protect.

B.1.2.5 Lead

Lead is soft and can be shaped to numerous profiles. It has extensive history of use in the UK as both a roofing material and for flashings, cappings, etc.

Rolled lead sheet should be laid on a smooth base which is sufficiently strong to take the self-load and any imposed loads, and which allows for thermal movement to occur. Fixings should also support the weight of the lead, be resistant to corrosion, allow for thermal movement and be resistant to wind uplift.

Contact between lead sheet and fresh mortar (e.g. in damp proof courses in contact with cement-rich mortar) can cause corrosion and staining, which can be prevented by applying bituminous paint to both surfaces of the lead sheet. Acid run-off from lichen or moss growth should be avoided. Adequate ventilation can help to avoid build-up of condensation.

Where rainwater or dew runs down a lichen or moss growth covered roof the resulting action can cause failure, which can be prevented by installing sacrificial flashings at the eaves drip-off points.

NOTE There have been examples of failures on roofing applications despite the outer layer continuing to perform successfully. It is exposed to rainwater (which contains dissolved carbon dioxide, leading to formation of relatively inert lead carbonate). The underside however, if exposed to condensation might not develop the protective layer, leading to corrosion. This can severely reduce the service life of the lead sheet. Certain wood-borne acids, such as from Western Red Cedar, Elm, Douglas Fir or Oak, might exacerbate the problem. Sufficient ventilation and/or vapour barriers can control the problem.

B.1.2.6 Aluminium

The main uses for aluminium in construction include framing members for windows, curtain walling and other glazed structures. It is also used for rolling blinds, doors, exterior cladding and roofing, suspended ceilings, wall panels and partitions, heating and ventilation equipment, solar shading devices, light reflectors and in the manufacture of prefabricated buildings and structural components.

Aluminium exposed to the natural environment does not absorb moisture, will not rot, swell, shrink or crack, or be affected by sunlight or low temperatures. Aluminium's durability stems from the oxide layer that rapidly forms when fresh metal is exposed to air. This inert, hard layer is an integral part of the metal, reforming spontaneously if it is scratched or cut, providing a barrier to atmospheric attack. Aluminium is highly resistant to chemical attack from solutions of CO, CO_2, SO_2 and HCl. It is also inert to petrol, oil and modern greases.

The surface of aluminium construction products is usually finished in some way, typically by anodizing or powder coating, but it is not always necessary. Mill finish products can darken over time depending on the amount of atmospheric pollution levels. If there is a weak spot in the oxide layer, pitting and corrosion can occur. Having an organic coating or anodised film layer will help to further protect the metal, particularly in more aggressive environments.

Bi-metallic or galvanic corrosion can occur where dissimilar metals are in contact in the presence of an electrolyte, as noted in **B.1.1**. Aluminium is one of the more anodic metals in the electrochemical series and will corrode when placed in contact with a more cathodic metal. For example, contact between copper or copper alloys and aluminium products should be avoided (water run-off from copper or copper alloys onto aluminium products should also be avoided). Several measures can be taken to reduce the effects of galvanic corrosion, including electrically isolating dissimilar metals from each other, using appropriate washers for example, and ensuring moisture is unlikely to accumulate between dissimilar metals.

Crevice corrosion of aluminium can occur in areas where there is localized depletion of dissolved oxygen (e.g. under deposits of dirt), as this can prevent the formation of the natural protective oxide film. The regular removal of dirt and avoiding details that trap water can help to prevent crevice corrosion.

Filiform corrosion refers to the growth of thread-like strands or filaments of corrosion that can develop beneath coatings. It usually originates in component areas where the coating is providing insufficient protection, such as scratches, cut edges or surfaces where the coating thickness is thinner; it usually only occurs in high humidity atmospheres and is more likely to occur in coastal zones. Filiform corrosion can be prevented by ensuring a high standard of surface pre-treatment and coating application, along with detailing to ensure free drainage of water and careful handling and installation of panels.

Mortar and concrete are highly alkaline, and aluminium reacts with wet concrete. In areas where aluminium could be exposed to splashes or drops of wet mortar, it should be protected and such protection can be provided by an easily removed coating such as strippable plastic or oil. Some timbers, particularly western red cedar, oak, sweet chestnut and Douglas fir, contain organic acids that can attack metals including aluminium. Some timber preservatives also contain chemicals that can attack aluminium. Aluminium can be protected with bituminous paint where it is in contact with run-off from new oak and cedar.

B.2 Timber

B.2.1 Durability of timber and timber-based materials

Timber can be exposed to various durability hazards (as indicated in Table B.1):

- non biological factors – such as general weathering, fire, mechanical damage or chemical decomposition; or
- biological factors – such as insect damage, marine borers, bacterial damage and fungal attack.

To avoid the deterioration caused by such factors, prolong and even improve the life performance of wood based materials, different mitigation strategies can be used as indicated in Table B.1. Careful consideration should be given to the type of species, preservatives available and methods of treatment, as applying the wrong type of treatment for the intended use might end up in a costly repair process.

To reduce the risk of, or the extent of, deterioration caused by such factors, wood and wood-based materials can be protected by impregnation with preservative or fire retardant treatments. In addition, coatings may be used to reduce the impact of weathering and protect against flame spread.

Some wood-based materials can be manufactured with protection against insect attack and fire. Designers should always consider the impact of weathering and remaining wet in service. Similarly with products treated with fire retardants to avoid potential loss of mechanical strength.

B.2.2 Untreated timber

COMMENTARY ON B.2.2

Timber can be used successfully without the need for preservative treatments provided that it is carefully selected to provide appropriate durability for the end use.

Table B.1 **Untreated timber durability hazards** *(1 of 2)*

Durability hazard	Mitigation measures
Moisture (biological durability [fungal/insect attack], strength, movement, resistance of resins in wood-based panels, adhesive)	Design detailing Treatment with preservatives Species selection (including modified wood) Coat (e.g. intumescent paint) and maintain Wood-based panel selection Structural design Adhesive selection
Weathering (UV, frost, rain, snow)	Design detailing Treatment with preservatives Species selection (including modified wood) Coat (e.g. paint) and maintain Wood-based panel selection

Table B.1 **Untreated timber durability hazards** *(2 of 2)*

Durability hazard	Mitigation measures
Fire	Design detailing Treatment with fire retardant Species selection (including modified wood) Coat (e.g. intumescent paint) and maintain Wood-based panel selection (including those with fire resistance treatments) Structural design
Mechanical damage	Design detailing (e.g. protection) Species selection (including modified wood) Coat (e.g. melamine facing) and maintain Wood-based panel selection
Creep	Structural design
Interaction with other materials (e.g. fixing)	Design detailing Species selection (including modified wood) Wood-based panel selection Fixing selection
Chemical resistance	Design detailing Species selection (including modified wood) Wood-based panel selection

B.2.2.1 Selection of untreated timber

The heartwood of different species has different levels of durability. Designers/engineers should select and specify the appropriate timber species giving consideration to the performance of a component for its specific application. Sapwood of all species is non-durable. If sapwood is included in the selected wood then if a biological durability hazard exists the wood should be treated with a preservative to raise the durability of the sapwood to the required level.

NOTE Current classifications used for most commercially viable of timber species are given in BS EN 350-2. Other standards used for guidance when selecting the appropriate timber species are referenced in BS EN 1995-1-1. BS EN 350-2:1994, Table 2, lists timber species from across the world and their corresponding durability class with regards to different types of algae and organisms affecting the timber material. Guidance for the selection of an appropriate durability class for a given end use is given in BS 8417.

Durable timber materials and components selected and designed with appropriate consideration of factors such as the impact of micro-climates, have the potential to remain useful and therefore reduce the need for replacement. When choosing untreated timber for a specific application, consideration should be given to the interaction of the material and the associated building elements that come in contact with the timber. Some timber species are acidic and if not used with appropriate ancillary products, such as ferrous fixings, corrosion or material, stains can occur, especially when used in external environmental conditions.

Typically, finishing products, such as cladding and decking, that can be used untreated should be installed using galvanized, stainless steel or austenitic steel fixings to avoid corrosion of the fixings, which can result in timber staining.

More recently, driven by requirements for sustainability and interest in local procurement, designers and specifiers might wish to select home-grown timber. However, due to different growing conditions, UK home-grown wood might not be as durable as imported timber equivalents. Therefore it is very important to ensure the correct selection for the intended application with reference to BS EN 350-2.

B.2.3 Treated timber

B.2.3.1 General

The environment and the anticipated level of maintenance required for the element should be considered when assessing and planning for the durability of treated timber elements.

NOTE 1 Some timber elements are used in applications where regular maintenance can take place, such as external or internal cladding and applications with exposed elements, such as timber frames, fencing, decking. Others are used in applications without easy access or no access at all throughout the life of the building. In the latter situation such elements are expected to have a durability equal to that of the building into which they are placed.

Where timber that will not be inherently durable in the proposed environment is required, an appropriate preservative treatment should be selected.

In-service conditions for wood are defined in five use classes in BS EN 335. These should be used in every case, taking preservative treatment recommendations from BS 8417.

When a decision is made to require enhanced durability consideration should also be given to the use of modified wood. The Wood Protection Association, *Guide to the selection of wood and wood-based products* [2] and its Modified Wood Manual provide guidance [3].

NOTE 2 The use classes described in BS EN 335 differ from the service classes described in BS EN 1995-1-1. The difference between these two classifications is explained in BS EN 335:2013, Annex A.

When deciding to treat timber, component(s) should be allocated to one of the use classes defined in BS EN 335. BS 8417 provides guidance on appropriate preservation treatment for different species, use classes and desired service lives (15, 30 and 60 year service lives).

It is best practice to treat wood in its final dimensions. Reworking should be limited to cross-cutting, boring, drilling or notching and exposed surfaces should be given two liberal brush coats of a suitable preservative as recommended by the manufacturer of the wood preservative.

For treated timber to be used in Use Class 4 of BS EN 335, an uncut end should always be put in the ground.

If mixing heartwood and sapwood when treating timber is inevitable, the treatment processes should take account of different regimes applicable.

B.2.3.2 Types of preservative treatment

The Wood Protection Association Manual [4] (*Industrial Wood Preservation - Specification and Practice*) describes the types of preservatives available for the treatment of wood in the UK and their suitability for different end uses and use classes.

NOTE Attention is drawn to the Control of Pesticides Regulations 1986 *(as amended) [2] or authorised under* Biocidal Products Regulation (EU 528/2012) *[6]. Conditions of consent, label information and Safety Data Sheets provide guidance on their use.*

B.2.3.3 Treatment application

There are two main types of process for treating timber:

1) Penetrating processes with features designed to overcome the natural resistance of wood to penetration of preservative. These include vacuum-pressure and double vacuum processes.
2) Superficial processes. These include such processes as dipping spraying and brushing.

Treatment is defined by the penetration and retention of the preservative into the timber.

BS 8417 gives advice on the conditions of the timber (e.g. moisture content) required prior to treatment. BS 8417 sets out the penetration and retention requirements for wood to be used in the various use class and service life combinations. BS EN 351-1 provides details of the classification of levels of penetration.

After treatment the timber should be conditioned to the moisture content expected in service.

B.3 Concrete

B.3.1 General

The achievement of durable concrete in a concrete structure should start at the conceptual design stage and depends on:

a) the appropriate selection of exposure class related to environmental conditions;
b) the appropriate cover to reinforcement;
c) suitable structural design and detailing;
d) an appropriate specification for both the concrete/precast elements and the execution of concrete works;
e) the supply of fresh concrete/precast elements to the specification;
f) good site workmanship, particularly with respect to achieving the specified depth of cover to reinforcement for concrete formed in-situ; and
g) a schedule of maintenance, carried out as planned.

The importance of exposure assessment, design, detailing, specification and execution in the achievement of durability in a structure cannot be over-emphasized. Failure to reach expectations at any of these stages can result in lower than intended durability.

B.3.2 Specification for durable concrete

Detailed guidance on how to derive an appropriate specification for durable concrete in UK conditions, i.e. the material aspect of "design for durability", in order to resist identified/standardized exposure classes is given in BS 8500-1.

BS 8500-1:2006+A1:2012, Annex A covers the determination of cover to reinforcement and concrete quality for structures to be built in the UK or similar environments. Such an approach to the provision of durability is adequate for most structures provided that the minimum cover is achieved in the element/structure and the concrete is properly specified, supplied, compacted and cured. For more extreme environments, particularly where very long lives are required, consideration should be given to additional methods of protection, such as corrosion-resistant reinforcement, surface protection and special admixtures. Guidance on additional protective measures for chemically aggressive environments is given in BRE Special Digest 1.

The required concrete quality to provide adequate durability depends upon the: intended working life (BS EN 1990);

a) environmental actions (BS 8500-1 :2006+A1 :2012, Annex A);

b) additional protective measures (APMs), if any;

c) minimum cover to reinforcement (BS 8500-1 :2006+A1 :2012, Annex A);

d) structural requirements (BS EN 1992-1-1).

The selected minimum cover to reinforcement should take account of:

1) the safe transmission of bond forces;

2) fire protection (BS EN 1992-1-2);

3) durability requirements;

4) any additive safety element e.g. for prestressing steel;

5) any reduction in cover due to use of stainless steel reinforcement; and

6) any reduction in cover due to use of additional protective measures.

Annex A of BS 8500-1 tabulates detailed durability recommendations, in terms of limiting requirements for appropriate parameters (e.g. compressive strength, concrete composition, properties), to achieve durable concretes resistant to:

i. carbonation and chloride-induced corrosion (de-icing salts and sea water) of reinforcement;

ii. freeze/thaw attack;

- chemical attack (including sulfates) from aggressive ground, and;
- internal alkali-silica reaction;

For service lives of 50 years and 100 years, where appropriate. The concrete material in precast concrete products (and masonry concrete units) also conforms to these durability criteria but, in addition, individual product standards for precast concrete products include performance requirements for the factory-formed products.

BS 8500-1 is designed to be used with BS 8500-2 which covers the detail of the specification of constituent materials and concrete, including conformity testing/criteria and production control by reference to BS EN 206 the European standard for concrete, plus additional criteria where required for UK purposes.

B.4 Sustainability

B.4.1 General

The technical interface between durability and sustainability is described in *Specifying sustainable concrete* leading to recommendations for sustainable concrete solutions for designers which cover fire, acoustics, adaptability and durability.

B.4.2 Cellular PVC Products

Cellular PVCu profiles can be manufactured to BS 7619 and BS EN 13245-2.

NOTE Attention is drawn to the Building Regulations [7], [8], [9], [10] for roofline or cladding installations. Components designed to ensure adequate ventilation are available as part of any cellular PVCu system, and installation and product guidance is available from all manufacturers.

Plastic pipe systems are lightweight, flexible, corrosion-resistant and easy to handle on site. Plastic materials differ in performance and the variety of plastics used in construction products is diverse.

Plastics pipes are corrosion-resistant but can be impacted by:

- certain chemicals – e.g. solvent spillage, diesel/petrol spills;
- direct sunlight – plastic fittings stored in plastic bags should avoid direct sunlight during storage due to possible excess heat generation; and
- extreme cold – e.g. a condensate discharge pipe should be insulated when temperatures fall below freezing

There are two main types of plastics used in the manufacture of windows and doors, the dominant one being UPVC, with Glass Reinforced Plastics (GRP) recently appearing more recently

Annex C (informative) Examples of UK material or component failures

Table C.1 **Examples of UK material or component failures** *(1 of 3)*

Material or component	**Action causing deterioration**	**Effect of deterioration**	**Service life** years	**Design life** years	**Notes**
Untreated softwood windows (with paint system	Rain or condensation run-off entering timber through joints or finish	Level of moisture raised to > 20% and rot damages frame	5+	60	Preservative treatment is recommended
Treated softwood windows (with paint system	Rain or condensation run-off entering timber through joints or finish	Level of moisture raised to > 20% and rot damages frame	20+	60	Lack of required maintenance causing exposed joints.

Table C.1 **Examples of UK material or component failures** *(2 of 3)*

Material or component	Action causing deterioration	Effect of deterioration	Service life years	Design life years	Notes
Exposed reinforced concrete	CO_2 causes the carbonation of concrete, rain causes corrosion	Reinforcing steel corrodes and concrete face spalls	20 to 30	80+	Design life will be achieved if design code recommendations for cover, concrete quality, compaction and curing are achieved in practice.
Galvanized steel wall ties in black ash mortar	Salts in solution attack coating of ties leading to corrosion	Outer leaf of cavity wall is disrupted or detached	30 to 50	60+	Can also occur where wall is exposed to sea spray. Corrosion can also occur in non-black ash mortars.
Sealants in external cladding	Movement, solar radiation, temperature changes, atmosphere	Sealant cracks or becomes detached causing leaks	5 to 20	20	Good joint design and workmanship are essential.
Domestic heating pumps, boilers and automatic valves	Wear of moving parts	Breakdown of component that stops system	5 to 15	20	Many building clients are not aware of the short life of some of these components.
External wood stains and varnish	Solar radiation and moisture	Erosion or stains and blistering of varnish, that allow saturation of substrate	1 to 2	4 to 5	More recently introduced high build stains are longer lasting.
Certain building stones in exposed construction	Rain – particularly when the atmosphere is polluted, and frost action	Erosion and crumbling leading to falling masonry	50 to 70	120+	The results of accelerated tests have not always been reliable for durability prediction.
Sealed double-glazing units	Moisture, atmospheric gases and solar radiation acts on edge seal	Edge seal deteriorates allowing condensation on inner face	5 to 35	20+	Detailing of frames and gaskets and workmanship also affect life.
Mosaic and tiling on external surfaces	Water in backing or adhesives including frost damage. Poor workmanship	Detachment and failing of tiles expose backing	5 to 10	60+	Guidance on bedding should be followed.

Table C.1 **Examples of UK material or component failures** *(3 of 3)*

Material or component	Action causing deterioration	Effect of deterioration	Service life years	Design life years	Notes
Certain plastics damp roof	Migration of plasticizers and movement of structure	Exudation and puncturing under pressure and sliding masonry	3 to 10	60+	British Board of Agrément (BBA) and similar independent certificates give guidance on use.

Annex D (informative) Design life data sheet: Worked example for facade components

D.1 Use of the data sheet

The design life data sheet can be used by the designer during the briefing and early design stages of a building project, to record proposals for the building and its parts. It provides a statement of the designer's intentions that can be used for discussion with the client on durability with a view to reaching an accord on detailed design and specification. It should alert the client to the need for maintenance and replacement of parts of the building at a time when the design of the building can still be changed.

Examples of typical contents for a building facade are included.

D.2 General details

It is important to identify the version of the brief and preliminary design or specification to which the data sheet applies. Other key features which should be noted are the design life of the building, which should normally reflect the requirements of the client. Any specific environmental or climatic features of relevance to durability should also be noted.

D.3 Assumptions

The following assumptions have been made for the completed example below:

a) Atmospheric conditions:

  1) external: C3, i.e. urban industrial, coastal low salinity;

  2) internal: C1, i.e. internal heated in accordance with BS EN ISO 12944-2, BS EN ISO 14713 and BS EN 10169;

2) Building design life: 60 years.

Table D.1 **Design life data sheet** *(1 of 2)*

System component	Reference service life	Category Lifelong (as Table 1)	Category Maintainable (as Table 1)	Category Replaceable (as Table 1)	Failure Category (as Table 2)
Rain screen cladding, louvers, renders, cement board and other cladding materials, excluding timber	40 years		•		B/C
Coated/Uncoated timber cladding	30 years		•		B/C
Backing walls to cladding	60 years	•			F
Secondary structural steelwork	60 years	•		•	A/D
Insulating glass units (excluding NiS breakage where heat soak tested)	25 years			•	B/D/G
Other glass types (excluding NiS breakage where heat soak tested)	40 years			•	B/D/G
Door and window framing (excluding timber), panels and brackets	40 years		•		F/G
Timber and door and window framing, panels and bracket	25 years		•		F/G
Door and shutter motors, closers pivots, moving parts and control gear	15 years			•	F/G
Door ironmongery (medium usage)	25 years			•	F/G
Powder coating gloss retention and colour fastness	40 years		•		H
Powder coating adhesion	60 years	•	•		D
Paint coatings (except timber)	60 years		•		E
Anodizing	60 years	•			D
Gaskets and dry seals (except moving swipe seals and brushes)	40 years		•		E
Wet seals accessible for maintenance	25 years		•		D
Fire stopping	60 years	•			A/B
		•			

Table D.1 **Design life data sheet** *(2 of 2)*

System component	**Reference service life**	**Category Lifelong (as Table 1)**	**Category Maintainable (as Table 1)**	**Category Replaceable (as Table 1)**	**Failure Category (as Table 2)**
Insulation	60 years	•			A/B/C/D
Precast concrete	60 years		•		D
AVCL membrane, in accordance with BS 5250	60 years		•		D
Breather/weather membranes in rain screen facades	40 years		•		D
Structural load-bearing masonry and associated structural and damp proofing accessories	60 years	•			A/B/D
Facing and non-structural masonry	60 years	•			D
Damp proof courses and cavity trays in facing masonry	60 years	•			D

Annex E (informative) Further Reading and sources of information on durability

COMMENTARY ON Annex E

The lists in this annex are not intended to be exhaustive and there will be other useful data sources available through particular trade associations for particular materials and for specific applications.

E.1 General

DORAN and CATHER. *Construction materials, 2013.* Routledge: London. ISBN 1135139202, 9781135139209

YU and BULL, *The durability of materials and structures in building and civil engineering,* 2006. Whittles

DOUGLAS and RANSON, *Understanding building failures,* 2006. Routledge: London. ISBN 1136448799, 9781136448799

JERNBERG ET AL., *Guide and bibliography to service life and durability research for building materials and components (Report 295).*

TRADA, *Durability by design,* 2012

KING, N.P., *Efficient concreting practice: a review of current procedures*, CONCRETE 2000, 1993. Vol. 1, pp265-277.

HOBBS, D.W., MATTHEWS, J.D. and MARSH, B.K., *Minimum requirements for durable concrete. Carbonation and chloride-induced corrosion, freeze-thaw attack and chemical attack*, British Cement Association, 1993 ISBN 0-72101-524-7.

Developments in durability design and performance-based specification of concrete, Discussion Document, Concrete Society, 1996. ISBN 0-94669-154-1.

PD CEN/TR 16563 *Principles of the equivalent durability procedure*.

Specifying sustainable concrete. MPA The Concrete Centre, 2014. ISBN 978-1-90825-701-7.

E.2 Climate

MET OFFICE, *Fact Sheet 4 (climate of the United Kingdom)*

MET OFFICE, *Fact Sheet 14 (microclimates)* [viewed 10-3-2015] <http://www.metoffice.gov.uk/learning/library/publications/factsheets>

E.3 National Datasets on Service Lives

BPG, *Building fabric component life manual,* 200. Spons: ISBN 0419255109.

BUILDING LIFE PLANS, *Building services component life manual,* 2000. Wiley Blackwell: London. ISBN 0632058870, 978-0632058877

CIBSE, *Guide M: maintenance engineering and management,* 2014 (2nd edition). ISBN 9781906846503.

BMI, *Life expectance of building components,* 2006. BCIS. ISBN 9781904829393.

E.4 Materials data sources

NPL, *Guide to good practice in corrosion control – bimetallic corrosion*, 2000. HMSO.

E.5 Concrete

BRITISH CEMENT ASSOCIATION, *Carbonation and chloride-induced corrosion, freeze-thaw and chemical attack* 1993. ISBN 0721015247

E.6 Plastic

RAPRA, *Practical guide to the assessment of useful life of* plastics, 1998. RAPRA Technology Ltd. ISBN 1-85957-312-6

PRITCHARD, *Reinforced plastics durability,* 1998. Woodhead Publishing ISBN 978-1-85573-320-6

E.7 Stone

BRE, Selecting natural building stones, 1997. BRE ISBN 1-86081-125-6

BRICK DEVELOPMENT ASSOCIATION, *BDA design note 7 on brickwork durability*, 2011 BDA

E.8 Websites

Stainless steel [viewed 9-3-2015] <http://www.BSSA.org.uk>

The Metal Cladding and Roofing Manufacturers Association Technical Papers [viewed 9-3-2015] http://www.mcrma.co.uk

Copper [viewed 9-3-2015] <http://www.copperalliance.org.uk>

Zinc [viewed 9-3-2015] <http://www.galvanizing.org.uk> and <http://www.zinc.org>

Lead [viewed 9-3-2015] <http://www.leadsheet.co.uk>

Aluminium [viewed 9-3-2015] <http://www.c-a-b.org.uk>

Timber [viewed 13-3-2015] <http://www.wood-protection.org> and <http://www.trada.co.uk/techinfo/tsg/>

The Concrete Centre [viewed 9-3-2015] <http://www.concretecentre.com>

Plastics [viewed 10-3-2015] <http://www.bpf.co.uk>

Masonry [viewed 10-3-2015] <http://www.brick.org.uk> and <http://www.cba-blocks.org.uk>

Various [viewed 13-3-2015] <http://www.brebookshop.com>

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 2871-2, *Surface active agents. Detergents – Determination of cationic-active matter content – Part 2: Cationic-active matter of low molecular mass (between 200 and 500)*

BS 2871-3, *Specification for copper and copper alloys – Tubes – Part 3: Tubes for heat exchangers*

BS 5250, *Code of practice for control of condensation in buildings*

BS 5760, *Reliability of systems, equipment and components. Guide to reliability and maintainability*

BS 7619, *Extruded cellular unplasticized white PVC (PVC-UE) profiles – Specification*

BS 8210:2012, *Guide to facilities maintenance management*

BS 8417, *Preservation of wood – Code of practice*

BS 8500-1:2006+A1:2012, *Concrete – Complementary British Standard to BS EN 206-1 – Part 1: Method of specifying and guidance for the specifier*

BS 8500-2, *Concrete – Complementary British Standard to BS EN 206-1 – Part 2: Specification for constituent materials and concrete*

BS EN 206, *Concrete – Specification, performance, production and conformity*

BS EN 335:2013, *Durability of wood and wood-based products – Use classes: definitions, application to solid wood and wood-based products*

BS EN 350-2:1994, *Durability of wood and wood-based products – Natural durability of solid wood – Guide to natural durability and treatability of selected wood species of importance in Europe*

BS 351-1, *Durability of wood and wood-based products – Preservative-treated solid wood – Part 1: Classification of preservative penetration and retention*

BS EN 1057-1, *Copper and copper alloys – Part 1:Seamless, round copper tubes for water and gas in sanitary and heating applications*

BS EN 1254 (all parts), *Copper and copper alloys – Plumbing fittings*

BS EN 1990, *Eurocode – Basis of structural design*

BS EN 1992-1-1, *Eurocode 2: Design of concrete structures – Part 1: General rules and rules for buildings*

BS EN 1992-1-2, *Eurocode 2: Design of concrete structures – Part 1: General rules – Section 2: Structural fire design*

BS EN 1993-1-4, *Eurocode 3: Design of steel structures – Part 1: General rules – Section 4: Supplementary rules for stainless steels*

BS EN 1993-5, *Eurocode 3: Design of steel structures – Part 5: Piling*

BS EN 1995-1-1, *Eurocode 5: Design of timber structures – Part 1: General – Section 1: Common rules and rules for buildings*

BS EN 10169, *Continuously organic coated (coil coated) steel flat products – Technical delivery conditions*

BS EN 13245-2, *Plastics – Unplasticized poly(vinyl chloride) (PVC-U) profiles for building applications – Part 2: PVC-U profiles and PVC-UE profiles for internal and external wall and ceiling finishes*

BS EN 13306:2010, *Maintenance – Maintenance terminology*

BS EN 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*

BS EN ISO 9223, *Corrosion of metals and alloys – Corrosivity of atmospheres – Classification, determination and estimation*

BS EN ISO 12944-2, *Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 2: Classification of environments*

BS EN ISO 14040:2006, *Environmental management – Life cycle assessment – Principles and framework*

BS EN ISO 14713, *Zinc coatings – Guidelines and recommendations for the protection against corrosion of iron and steel in structures – General principles of design and corrosion resistance*

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

BS ISO 15686-1:2011, *Buildings and constructed assets – Service life planning – Part 1: General principles and framework*

BS ISO 15686-7:2006, *Buildings and constructed assets – Service life planning – Part 7: Performance evaluation for feedback of service life data from practice*

BS ISO 15686-8:2008, *Buildings and constructed assets – Service-life planning – Part 8: Reference service life and service-life estimation*

DD ISO/TS 15686-9:2008, *Buildings and constructed assets. Service-life planning. Guidance on assessment of service life data*

PD 6484, *Commentary on corrosion at bimetallic contacts and its alleviation*

Other publications

[1] REGULATION (EU) No 305/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC. Published in the Official Journal L88, 04 April 2011.

[2] WOOD PROTECTION ASSOCIATION *Guide to the selection of wood and wood-based products*

[3] WOOD PROTECTION ASSOCIATION *Modified wood manual*

[4] WOOD PROTECTION ASSOCIATION *Industrial wood preservation – Specification and Practice*

[5] GREAT BRITAIN. Control of pesticides regulations 1986. London: The Stationery Office

[6] HSE. The EU biocides regulation (EU 528/2012). London: The Stationery Office

[7] GREAT BRITAIN. The building regulations (England), 2010. London: The Stationery Office

[8] GREAT BRITAIN. The building regulations (Scotland), 2010. London: The Stationery Office

[9] GREAT BRITAIN. The building regulations (Wales), 2010. London: The Stationery Office

[10] GREAT BRITAIN. The building regulations (Northern Ireland), 2010. London: The Stationery Office

Further reading

BRE Special Digest 1. *Concrete in aggressive ground*. Garston: BRE.

 This page deliberately left blank

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™