

Guide to

Durability of buildings and building elements, products and components

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- British Board of Agrément
- British Ceramic Research Ltd.
- Building Employers' Confederation
- Chartered Institution of Building Services Engineers
- Concrete Society
- Consumer Policy Committee of BSI
- Convention of Scottish Local Authorities
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- Royal Institute of British Architects
- Royal Institution of Chartered Surveyors
- Scottish Office (Building Directorate)
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- Timber Research and Development Association
- Trades Union Congress

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- Association of Building Component Manufacturers
- Federation of Civil Engineering Contractors

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Foreword

This British Standard has been prepared under the direction of the Basic Data and Performance Criteria for Civil Engineering and Building Structures Standards Policy Committee. It supersedes CP 3:Chapter IX:1950 which is withdrawn.

An International Standard, ISO 15686, on the service life of buildings is in course of preparation. It is expected that it will be adopted as a British Standard, when this British Standard will be withdrawn.

Since the publication of CP 3:Chapter IX there has been an increase in the range of materials used by the construction industry and advances in the understanding of how the agents that cause deterioration act on building materials. Instances of the premature failure of buildings have highlighted the need for more attention to be paid to all aspects of durability. This British Standard will assist the communication of information on durability between the parties involved in a building project, i.e. clients, designers, manufacturers, contractors and specialists. It is intended to discourage unrealistic expectations of service life of buildings and parts of buildings.

Appendix A and Appendix B give information on the prediction of durability for buildings and parts of buildings and guidance on the way agents can affect service life. Appendix C describes some common examples of construction failure that have occurred in the last 20 years where expectations of durability have not been met. Appendix D is an annotated bibliography giving further reading on topics covered in this guide.

NOTE Users are encouraged to investigate the possibility of applying the most recent editions of the bibliographic references given.

Although BS 5760 “Reliability of constructed or manufactured products, systems, equipments and components” deals comprehensively with reliability and durability, in all industries, it was considered necessary to provide a separate publication specifically for the construction industry [1]. However, some of the terms used in BS 5760 and the techniques that it recommends are referred to here.

This British Standard has been written for all members of a building team who provide information on durability, that is: clients, designers, manufacturers and those responsible for maintenance. It is also relevant to the preparation of information in standards and technical approvals for products.

For simplicity the term “parts” has been used throughout to cover building elements, products and components.

Specific guidance on the durability of particular parts of buildings is given in many other British Standards, some of which are referred to in Appendix D. It should also be remembered that the design life of parts of a building will often need to be less than the design life of the whole building and that this can be perfectly compatible with the usage and refurbishment cycles of normal building occupancy.

In using this guide it should be remembered that predicting durability is not an exact science. It is essential to be aware that periods arrived at for the predicted life of a building and its parts will sometimes be no more than an informed estimation and that it will usually be helpful to state the facts, assumptions and references on which the periods are based.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 40, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

0 Introduction

0.1 General

To predict durability and building life many factors need to be considered. These include experience, results of assessments and tests and the effect of the actions of agents on different parts of the building. It is also important that this information is communicated clearly. Adherence to the forms of expression and terms defined in clause 2 will help to avoid misunderstandings.

0.2 Experience

Prediction has to take into account the variability of conditions, workmanship and maintenance and the practical problems of handling, installing and inspection of components on a building site. The maintenance, repair and replacement of buildings and parts of buildings provides a wealth of experience on durability. However, in all but a few cases, there is a lack of systematically collated data that can form a basis from which durability can be predicted with any certainty.

0.3 Assessment techniques and life cycle costing

Techniques are being developed to assess when items should be replaced. For example life cycle costing can be used to predict the limit of durability which is reached when it is no longer economical to maintain and repair an item rather than when it is no longer possible to do so. Life cycle costing can help to predict the limit of durability of some items on economic grounds. [1] [2] Other items, in particular mechanical services, may need to be replaced before they fail in order to avoid interrupting the use of a building. Hazard analysis techniques can help to identify such items.

0.4 Agents

Agents that cause deterioration in buildings, such as driving rain and foot traffic, can each be measured. An agent's action may vary nationally (for example the velocity and direction of driving rain varies from one part of the country to another) but local variations and variations from one side of a building to another may be just as significant.

0.5 Communications

To avoid misunderstandings that can lead to construction failures each member of a building-team should have a clear understanding of what is possible, what is required and what is provided in terms of durability. They may then need to communicate this information to others. This guide makes recommendations that will help with the communications of information about durability.

1 Scope

This British Standard gives guidance on durability, required and predicted service life and design life of buildings and their components and/or parts. It applies primarily to new buildings and their components and/or parts rather than to alterations and repairs. It also gives guidance on presenting information on the service and design life of buildings and their components and/or parts when a detailed brief is being developed.

This British Standard applies to civil engineering projects involving buildings, but only partially to other civil engineering projects such as roads, bridges and dams.

This British Standard does not deal with many aspects of obsolescence, i.e. when buildings or parts of buildings are replaced or altered either to suit different needs and changing conditions including change of use, mandatory requirements or when new products offer better performance without a corresponding increase in cost. It should also be borne in mind that a decision to replace or alter obsolete buildings or their parts may be influenced by a reassessment of their predicted service lives.

NOTE 1 The titles of the publications referred to in this standard are listed on the inside back cover.

NOTE 2 The numbers in square brackets in the text of this standard refer to the numbered references in Appendix D.

2 Definitions

For the purposes of this British Standard the following definitions apply together with those given in BS 6100. Where definitions are repeated from BS 6100 this is noted.

2.1

durability

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

2.2

durability limit

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

2.3

performance

behaviour related to use ¹⁾

2.4

service life

actual period of time during which no excessive expenditure is required on operation, maintenance or repair of a component or construction (as recorded in use)

NOTE Referred to in EEC directives as "working life".

¹⁾ Repeated from BS 6100-1.7.1.

2.5 required service life

service life specified to meet users' requirements (e.g. as stated in the client's brief for a project or in a performance specification)

2.6 predicted service life

service life predicted from recorded performance or accelerated tests (e.g. as stated by the manufacturer or in a European Technical Approval)

2.7 design life

period of use intended by the designer (e.g. as stated by designer to the client to support specification decisions)

NOTE The design life for components need not be the same as the design life for the building that they are part of (see Table 1 and Table 2).

2.8 premature deterioration

failure to achieve predicted service life

2.9 agent

whatever acts on a building structure or its parts, e.g. person, water, load, heat²⁾

2.10 action

application of an agent, e.g. use, wetting, compression, warming²⁾

2.11 effect

result of an action, e.g. wear, dampness, deformation, expansion²⁾

3 Requirements for durability

Requirements for durability vary from building to building and from one component to another. Requirements may be related to intended use, to finance and to periods for maintenance, repair or replacement. The building owner should define the required service life of the building in the initial brief. Life categories for buildings are given in Table 1. In addition the owner may wish to specify the required service life for specific components. Life categories for components are given in Table 2. The required service life of the component should be given in years and can be related to the categories of building life.

Where the building owner has not specified the conditions that will apply to the building or its parts the designer should record, for the client, what conditions have been assumed.

Requirements for durability may also be given when a component is ordered from a manufacturer either by a designer or by those responsible for maintenance. Again this should be given as a required service life in years and related to component category and building life.

When designers are provided with a clear statement of requirements for durability they are more likely to be able to specify appropriately for all parts of a building and avoid disappointments where, for instance, components require early replacement.

The designer will interpret the building owner's requirements when a performance specification containing requirements for durability is prepared for a building or component. For example certain parts of the building may only be required to last until the first major refurbishment.

4 Predictions of durability

A designer needs to have information on durability to meet the building owner's requirements and to develop a rational policy for the durability of the whole construction. Information can be obtained from various sources including:

- a) experience in the use of traditional materials embodied in codes of practice, text books and trade association publications;
- b) certificates assessing the performance of products issued by the British Board of Agrément and other authoritative bodies [3];
- c) publications from the Building Research Establishment (BRE) and other research bodies [4];
- d) predictions of the service life of products provided by their manufacturers. Where possible such predictions should include details of the method of assessment, the variability of test results, the assumed conditions of use, and maintenance requirements.

²⁾ Repeated from BS 6100.

Table 1 — Categories of design life for buildings

Category	Description	Building life for category	Examples
1	Temporary	Agreed period up to 10 years	Non-permanent site huts and temporary exhibition buildings
2	Short life	Minimum period 10 years	Temporary classrooms; buildings for short life industrial processes; office internal refurbishment, retail and warehouse buildings; (See note 1.)
3	Medium life	Minimum period 30 years	Most industrial buildings; housing refurbishment
4	Normal life	Minimum period 60 years	New health and educational buildings; new housing and high quality refurbishment of public buildings
5	Long life	Minimum Period 120 years	Civic and other high quality buildings

NOTE 1 Specific periods may be determined for particular buildings in any of categories 2 to 5, provided they do not exceed the period suggested for the next category below on the table; for example many retail and warehouse buildings are designed to have a service life of 20 years.

NOTE 2 Buildings may include replaceable and maintainable components (see Table 3).

Table 2 — Categories of design life for components or assemblies

Category	Description	Life	Typical examples
1	Replaceable	Shorter life than the building life and replacement can be envisaged at design stage	Most floor finishes and service installation components
2	Maintainable	Will last, with periodic treatment, for the life of the building	Most external claddings, doors and windows
3	Lifelong	Will last for the life of the building	Foundations and main structural elements

A form of expression of predicted service life is given in Table 3 and a proforma for use by designers in Appendix A.

It is important to note the following.

- i) Prediction of durability is subject to many variables and cannot be an exact science.
A new building is a unique design to meet a specific set of conditions on a specific site. Unless these conditions are the same as those previously recorded for precisely the same form of construction, the predicted life for the building and its parts can only be an estimation.
- ii) Accelerated testing of components by itself can seldom be used to give an accurate basis for predicting service life. Accelerated testing is not usually feasible for large assemblies of components.
- iii) Relevant test certificates are not always available from manufacturers and may have to be obtained by testing for a specific project.

5 Design life of buildings and components

The designer has the task of matching, as far as possible, the building owner's requirements with the available information on predicted life, taking into account site conditions, expected quality of workmanship and the expected maintenance levels. The result of the designer's judgement is the design life.

When stating the design life for a building or its parts a time shorter than the predicted life should be allowed, particularly where:

- a) the usage of parts of the building cannot be foreseen;
- b) untried products are to be incorporated;
- c) exceptionally large assemblies of components are involved.

Table 3 — Expression of durability (summary of guidance)

Expression	Examples	Form of expression	Supporting information	Comments
Required service life (clause 2.5)	Client's brief (for a building or its parts)	Years of service (preferably one of the five building categories or three component categories given in Table 1 and Table 2)	Conditions that will apply, i.e. level of maintenance, use and other factors affecting durability, financial information, acceptability of changes in appearance. For components give design life of building element and maintenance/replacement cycles and also details of adjacent materials and fixings	Levels of maintenance are given in Table 4
Predicted service life (clause 2.6)	Manufacturer's statements of product durability. Durability in BS specifications for products. Durability of elements of construction	Years in service (in specified conditions) (often expressed as a range, e.g. 15 to 20 years)	Conditions assumed Criteria for durability limits Methods used to establish expected life Durability of component parts	Should be accompanied by a warning of known associated defects, to be referred to specifically and not in a general way
Design life (clause 2.7)	Designer's proposals to client Offer for contractor designed items	Years in service (preferably one of the five building categories or three components categories given in Table 1 and Table 2)	Design life data sheet given in Appendix A	Should be as follows: a) more than required service life; b) less than predicted service life; c) relate to use, maintenance and renewal plans. State that many assumptions have been made and allow a margin of safety over the predicted life
Service life (clause 2.4)	Durability records (feedback from building in use)	Years (or decimal parts of years) in service. Will be given as a range of years (i.e. 30 to 50) when applying to many items	Conditions of use (actual conditions that product survived)	There is an unpublished study by BRE of the systems for recording the service life and maintenance of components

Section 2. Expression of durability

6 Standard form of expression

An inconsistent use of terms to describe durability can lead to misunderstandings and wrong specification. Table 2 summarizes the guidance in this standard that is intended to encourage the provision of more consistent and fuller information on durability. Recommendations are given in more detail in clauses 7 to 10. Standard periods for the design life of buildings and components are given in Table 1 and Table 2.

7 Service life

The start of the service life is taken from when a building or part of a building is completed and handover for occupancy has taken place.

The end of the service life is taken as the point in time when the only way to deal with unacceptable loss of performance is by replacement or excessive expenditure on operation, maintenance or repair. This point is called the durability limit (see clause 12).

For most items it is clear how they are required to perform throughout the specified required service life. However, in the case of appearance, some change may be acceptable. For example the weathering of external claddings may be acceptable or even desired. A gradual change in the appearance of many floor finishes in trafficked areas is inevitable. If changes in appearance are to be avoided this should be discussed at the briefing stage.

8 Required service life

A badly stated requirement for service life, can lead to misunderstanding at a later date. When a period for required service life is given the following information is essential:

- time (or a time measure such as running time or cycles of use) against which durability is to be assessed;
- conditions in which the item will have to perform (i.e. environmental conditions and levels of maintenance and usage);
- performance point at which functions become unsatisfactory (for example the light transmission through a glass reinforced plastics (GRP) rooflight decreases over the period of use. A decision has to be made on when to change the rooflight for a new one that will give a greater light transmission).

The required service life for a building should be qualified by additional information on conditions of use and maintenance levels. Table 4 lists three levels of maintenance based on the types of inspection described in 4.2.3 of BS 8210:1986.

When seeking predicted service life statements from manufacturers the required service life for parts of buildings should also be qualified by information of the following two types.

Table 4 — Maintenance levels (other than daily and routine cleaning)

Level	Description	Scope	Examples
1	Repair only	Maintenance restricted to restoring items to their original function after a failure	Replacement of jammed valves; reglazing of broken windows
2	Scheduled maintenance plus repair	Maintenance work carried out to a predetermined interval of time, number of operations, regular cycles etc. (see note).	Five yearly external joinery painting cycle. Five yearly recoating of roof membrane with solar reflective paint
3	Condition based maintenance plus repair	Maintenance carried out as a result of knowledge of an item's condition. [The condition having been reported through a systematic inspection (procedure)]	Five yearly inspections of historic churches etc. leading to planned maintenance

NOTE The length of the regular maintenance cycle is an important factor. It may be stated in the brief or agreed while the design is being developed.

BS 8210 recommends systematic inspections as follows:

- continuous, regular observation by the building user as part of the occupancy of the building; and
- annual visual inspection of the main elements under supervision of suitably qualified personnel; and
- full inspection of the building fabric by suitably qualified personnel at least every 5 years.

There may be statutory requirements for more frequent inspections.

a) *Information on exposure.* This is particularly important where the required service life is part of a performance specification presented to a manufacturer supplying external components for use in a building that is not known to him.

b) *Details of adjacent materials and fixings.* The 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 required life is given to a manufacturer of components in a performance specification. General statements and schematic details may not be enough to identify risks. It is essential that the allowances made for thermal and moisture movement and for isolating incompatible materials are fully described.

Very durable, long lasting construction is usually more expensive and may restrict the design to a limited range of materials. Consequently a long required service life is likely to increase the cost of the project and can limit the design solutions that meet the brief.

Funding of building construction often implies a required service life at least as long as the period of the loan used to finance the building.

9 Predicted service life

9.1 Method of assessment

The predicted service life of a building should be assessed in one or more of the following ways.

- a) Assess by reference to previous experience with the same, or similar construction and in similar occupation or climatic circumstances.
- b) Assess by measuring the natural rate of deterioration over a short period of use or exposure and estimating from the measurement when the durability limit will be reached.
- c) Assess by interpolation from accelerated tests that have been devised to shorten the response time to the action of an agent. The science of accelerated testing is complex; care should be taken not to produce different effects by changing the natural intensity of agents. Figure 1 shows a procedure for prediction based on correlation of b) and c). [5]

Examples of accelerated tests are when a hinge is put through the same number of opening and closing movements in a few weeks as it would be likely to undergo in many years of normal use or when a paint sample is continuously exposed to a very high light intensity to test colour fastness.

Prediction of service life will normally apply to components and small scale assemblies. Whole buildings and large assemblies are more often one-off designs which makes previous experiences of durability less relevant and because of their size it is less easy to test their performance under controlled conditions. [6]

Whatever method is used to assess it, the predicted service life is unlikely to be a precise figure because the effect of an action in any building is not likely to be accurately predictable. More reliable predictions can be made when there is a correlation between the results of different assessments (see Figure 1). For example the correlation of accelerated tests and natural wear has proved useful in assessing the durability of flooring materials for operating theatres in hospitals. [7] In cases where the prediction of service life cannot be very accurate it may nevertheless serve a useful purpose when items are being ranked in order of durability. The interpretation of data from tests requires skill and experience and a knowledge of building maintenance. It is often necessary to rely on an informed opinion for service life prediction.

9.2 Provision of test results

Manufacturers should, when requested, provide relevant test certificates from accredited laboratories to support predictions of service life.

9.3 Expression of predicted service life

9.3.1 General

Statements of predicted service life can help designers to select products. However, it is only possible to make full use of such statements when they are expressed in common terms preferably by an independent body, such as the British Board of Agrément for new products. One manufacturer may state that a roof membrane may be expected to be effective for a period similar to that expected for mastic asphalt, whereas another may state that all available evidence indicates that the product should have a life of at least 20 years. The two statements are difficult to compare. Direct comparison is only possible when the predicted service life is given as a period of years in specified conditions.

Predicted service life should be stated as years of service, or a range of years of service (e.g. 30 years to 50 years), or, in particular cases, as periods or cycles of use (e.g. 4 000 h running time). The period should be qualified, where it is relevant:

- a) by information on the conditions assumed in the prediction, for example where not in contact with the ground;
- b) by information on recognized associated defects, for example the component should not be used in contact with bituminous materials;

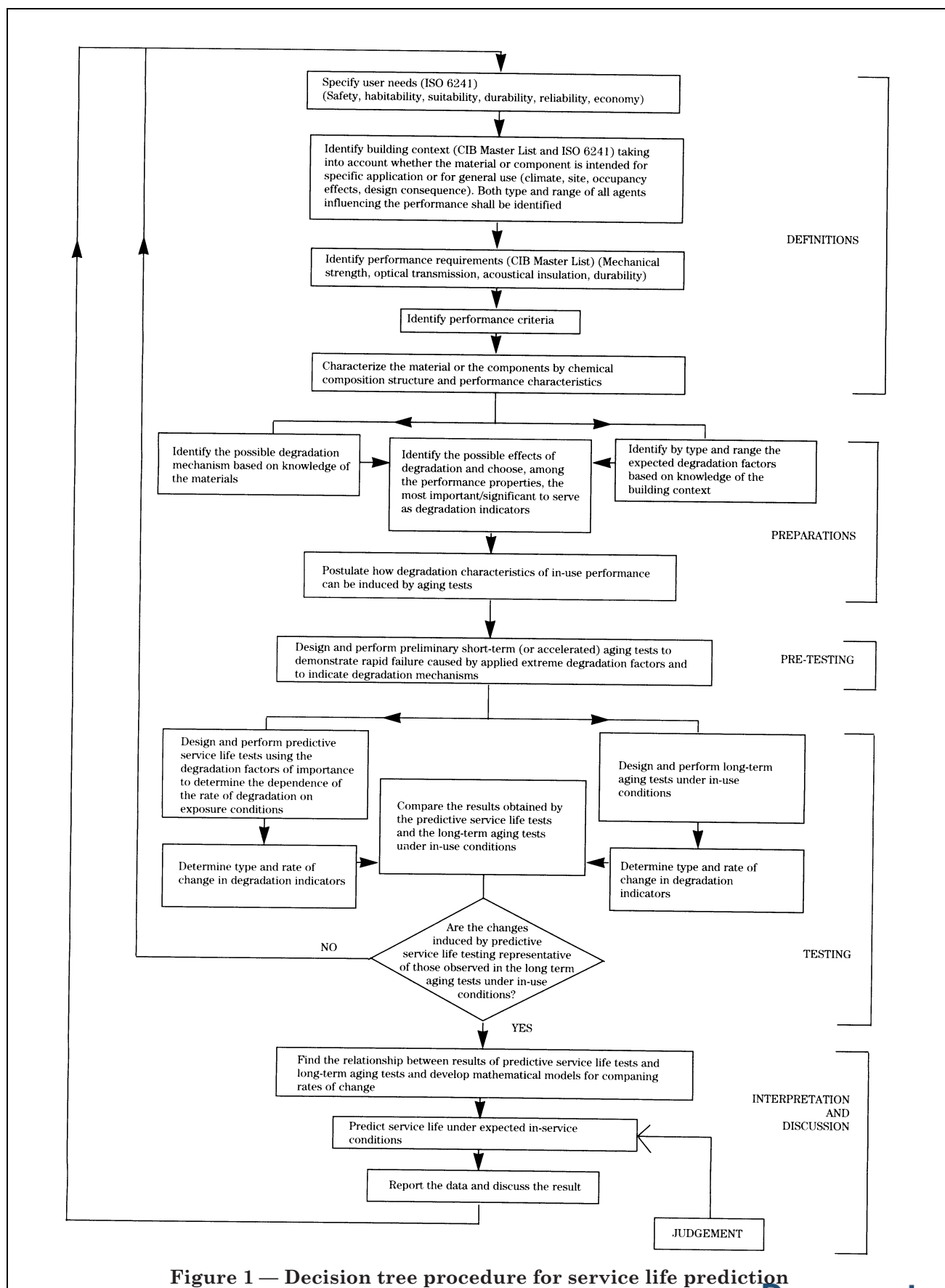


Figure 1 — Decision tree procedure for service life prediction

- c) by stating the basis for the prediction, either experience or accelerated test; in both instances precise details will help to assess whether the prediction is relevant to a particular case;
- d) by stating what has been taken as the durability limit, i.e. whether it is an estimate of when the item needs replacement or of when the risk of failure rises to an unacceptable level.

Designers should take into consideration warning statements by manufacturers on predicted service life.

It should also be remembered that many items fail through the combined application of two or more agents.

9.3.2 Conditions

- a) When a statement of the predicted service life is given it is normally on condition that:
 - i) suitable materials and components will be used in construction;
 - ii) the construction will be detailed correctly;
 - iii) once installed, the materials and components will be properly used and maintained;
 - iv) the quality of workmanship on site is to a satisfactory standard. (See BS 8000.)
- b) Statements of the predicted service life for products therefore would for instance not cover:
 - i) design defects, e.g. the incorrect use of bricks of an unsuitable type in parapets and below damp proof course level where they are not durable; [8]
 - ii) workmanship defects, e.g. use of adhesives beyond their specified shelf life;
 - iii) usage that is known to have been a common cause of damage to the product, e.g. use of metal wheeled trolleys on industrial rubber flooring;
 - iv) common errors and lack of maintenance, e.g. repainting without adequate washing down of greasy surfaces.
- c) It may be important to distinguish between the predicted service life of a product such as a brick or a tile and the predicted service life of the element of construction that is made up of bricks and tiles. The interaction of materials, workmanship and design may mean that the element of construction has a shorter predicted service life than the components that go into it.

If warnings by manufacturers are made in a very general way they are less likely to be followed and more likely to lead to associated defects that can shorten the service life of the product. For example statements such as “only to be used in normal exposure conditions”, or “to be regularly maintained” may not be specific enough to warn of the known risk or particular associated defects.

10 Design life

It is desirable for the design life of a building or of parts of a building to be evolved by discussions between the building owner and the designer (or in the case of contractor designed items, between the project designer and the contractor). The design life is the designer's intended durability for the building and its parts. It may well be the same as the required service life specified by the client or as the predicted service life stated by the manufacturer, but there are circumstances when it is essential that the designer should consider the need for durability from a different point of view because of his detailed knowledge of the project and of the combination of components from which it is assembled. In such cases the designer may recommend that the design life of a component should not be the life predicted in the manufacturer's literature or the appropriate European Technical Approval because of the circumstances applying to the project.

The design life should be:

- a) no less than the required service life stipulated by the client for the building or, in certain circumstances, for parts of the building;
- b) shorter than the predicted service life of those parts of the construction that will lead to the failure of the whole, for example the design life of a slated roof covering should be shorter than the predicted service life of the slating nails;
- c) related to a rational plan for use and renewal of parts of the building and of the building itself; for example in planning the layout and periodic refurbishment of a department store, walls that will have to be removed after 25 years for the purpose of replacing an escalator need not have a design life of more than 25 years although the predicted service life may be longer.

Unlike the required service life specified by the client or the predicted service life given by a product manufacturer, the designer's statement of a design life is not necessarily related to the time taken by an item to reach its durability limit. For example a durable polished granite floor may be specified for a temporary exhibition building. If the floor is given the same short design life as that of the building itself there will be no misunderstanding when the temporary services laid beneath the floor make it necessary to take up the floor at the end of the exhibition rather than allowing it to be reused for a more permanent building on the same site. Further guidance on design life is given in Appendix D.

11 Design life data sheet

Appendix A gives an example of a design life data sheet for completion by a designer to record proposals on durability of the building and its parts. The data sheet is intended to provide an agreed basis for selecting components and detailing construction, particularly where short lived products are to be used for economic or other reasons or where renewal work can be foreseen that involves major interruption to the use of the building.

The design life specified for a building will often be greater than that specified for the components used in its construction. However, if there is a need for extensive replacement of components within the design life of a building, it will be a matter of judgement whether the durability of the building is likely to be jeopardized. In extreme cases the cost of rebuilding may need to be considered as an alternative.

12 Durability limit

Communication about the service life of a building and its parts depends on a mutual understanding of the durability limit. Consultation between the designer and client/user is desirable. Areas in which explanation may be needed to avoid misunderstanding are where:

- a) there is a gradual deterioration in performance, particularly a deterioration in appearance, such as corrosion and pitting of aluminium windows;
- b) major repair or partial replacement is needed to keep an item in service, such as replacement of lift door equipment;
- c) there is a high risk of early failure of one or two items in a large number supplied at one time, such as light bulbs or plumbing joints, after they have been installed;

d) the critical nature of failure to perform in a particular situation has not been properly evaluated, such as the thermal movement of cladding materials in large areas that can damage fixings that have proved satisfactory for smaller areas of cladding;

e) no information is provided to manufacturers and suppliers on the intended use of their materials.

13 Effects of failure

If failure would involve high risk of injury or extensive damage replacement will be necessary before failure occurs. If repair involves the use of costly equipment or seriously affects the use of the building it may then be found better to replace items than to repair them. BS 5760-5 discusses the general principles and techniques for evaluating the effects of failure. Table 5 shows a simple categorization of failure effects likely to be relevant to most buildings. For a particular building each effect can be given a ranking, or number of points, to highlight where a failure of durability would be most serious. The design life data sheet in Appendix A provides space for noting the failure effect category.

Table 5 — Effects of failure

Category	Effect	Example
A	Danger to life (or of injury)	Sudden collapse of structure
B	Risk of injury	Loose stair nosing
C	Danger to health	Serious damp penetration
D	Costly repair	Extensive scaffolding required
E	Costly because repeated	Window fastening replacement
F	Interruption of building use	Heating failure
G	Security compromised	Broken door latch
H	No exceptional problems	Replacement of light fittings
NOTE Individual failures can be in two or more categories.		