EOTA

GUIDANCE DOCUMENT

Assessment of working life of products

Guidance Document 003

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EUROPEAN ORGANISATION FOR TECHNICAL APPROVALS

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Introduction

This document has been produced to give **general guidance** to EOTA Working Groups on the approach that should be taken in the development of European Technical Guidelines on the subject of Assessment and/or Prediction of Working Life of products. In as much as ETAGs will only be able to give general guidance on the subject, the document will also be of use to the Approval Bodies in developing CUAPs and in the assessment of products for individual ETAs.

The objective of the document is to achieve a consistent and harmonised technical approach between different Working Groups, and to limit the amount of long term ageing to be performed during assessments.

It is not possible to envisage the full range of products and usage of products in which EOTA will be involved in the future. Consequently the document sets out the general approach to be followed. Any reference to specific products, uses, degradation factors, methods of test etc are given as examples only and cannot be taken as being exhaustive.

It is the task of the Working Group to identify the most appropriate factors to be taken into account for the specific product and usage under consideration. This is particularly true in the case of use related factors. It is proposed that further annexes, dealing with specific cases, will be added to this basic document as and when the need arises.

The general term "building" has been used throughout this document, and many of the examples relate specifically to buildings. However the principles described may be applied to any construction works as defined by the CPD.

2 Approach

The approach taken is based on the methodology proposed in section 5 "The Service Life Prediction" of the "Guide for Service Life Design of Buildings" : Part 1 - General Principles ISO Draft Number 2 November 1995. The guide is being drafted by ISO TC 59/SC3/WG9 and section 5 is primarily based on the RILEM Technical Recommendations "Systematic Methodology for Service Life Predictions of Building Materials and Components" developed by RILEM TC71-PSL working jointly with CIB W80.

The methodology proposes an initial problem definition stage during which the user needs, building context, performance requirements and criteria and product characterisation are established. Based on the information gathered at this stage the possible degradation mechanisms, degradation factors, degradation indicators and suggested ageing tests are identified. This is termed the Preparation stage and is to be followed by a period of Pre-testing which involves carrying out short-term tests, possibly under extreme conditions, in order to check the validity of the proposed degradation mechanisms and the effects of the extreme loads.

Following these preparatory stages it is proposed, by the ISO methodology, that one should carry out testing both in the short term and for longer periods to verify that the degradation achieved is similar in both cases. Data on long term performance can, it is proposed, be obtained from field exposure tests, inspections of actual buildings, in-use testing and experimental buildings. If the behaviour under the effects of short term testing is similar to that observed in the longer term the results of the short term testing may be used to predict the service life. If not then the process is repeated under different conditions until agreement is reached. Figure 1 sets out the approach to the systematic methodology for service life prediction of building materials and components.

This document describes how this methodology, suitably amended where necessary, may be applied by Working Groups to the Assessment of Working Life of Products.

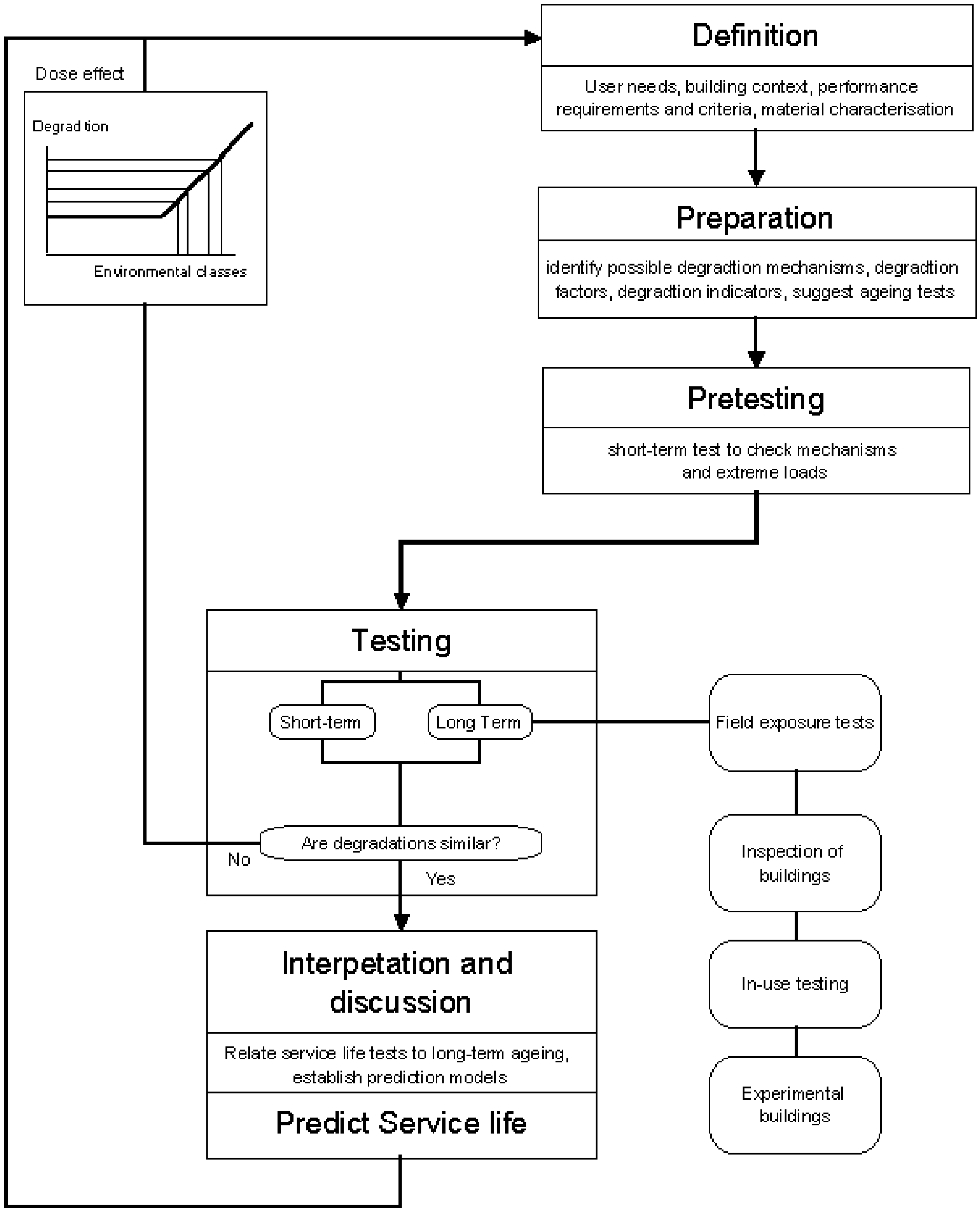

Figure 1 - Systematic methodology for service life predictions of building materials and components (copied from Draft ISO)

3 Problem definition

3.1 Definition of Working Life and its implications

The definition of working life and preferred periods of time for the working life of structures, components or materials is given in Technical Board paper WG 96/21/8. Section 5 Working Life (Durability) of the Interpretative Documents gives guidance on the treatment of working life.

The complex factors that effect the true working life of a construction product - climate - environment - user stresses etc are in general ill defined and can be highly variable from one location to another. In order to carry out a working life assessment it is necessary to make assumptions as to the "normal" worst conditions that the product will see in use. These conditions are not usually the absolute worse conditions but are chosen so that the majority of the product population will be at or below these conditions. As many of the product population will be at conditions less severe than the "normal" it is obvious that many products will achieve working lives greater than that predicted, in some instances by factors of 2 or 3.

3.2 User needs

The term "User needs" relates, essentially, the definition of what is expected of the product and relates to the product's fitness for purpose. In the context of the work of EOTA this will be defined, within limits set by the Working Group and its Mandate, by the applicant for an ETA by his claims made for the product. Assessments should be limited to user needs only in so far as they relate to the Essential Requirements of the CPD.

3.3 Identification of the building context

The Building Context relates to aspects such as the climate and/or site in which the building will be located, the effects of its occupancy and use, incorporation into the works etc.

Again this will largely be defined by the applicant but must be taken into account when assessing durability or working life. Where the precise building context is not known, or where more than one context is anticipated by the applicant, a "worst case" situation should be assumed. Alternatively each context should be considered separately. Appendix A gives further guidance on the building context.

3.4 Identification of performance requirements and criteria

Performance requirements for particular products or components have been defined by the Essential Requirements of the CPD and expanded upon by the Interpretative Documents. The most appropriate performance requirements, performance criteria and methods of verification to be used in the assessment of working life will be identified in the Mandate and should be elaborated upon in the ETA Guideline.

3.5 Characterisation of the product

In order to ensure that a predicted working life relates to the product on the market it is essential that all products are adequately characterised in terms of structure, chemical composition and performance values corresponding to the selected performance criteria.

4 Preparation

4.1 General

This stage is the most critical stage in terms of the deliberations of the Working Group. It involves the identification of the possible degradation factors (eg weathering, biological, incompatibility, use etc), identification of the degradation mechanisms and the effects of degradation on the product. The result will be the proposal or selection of the most appropriate approach (including ageing tests) to be used.

4.2 Degradation factors

Appendix B lists possible degradation factors and their effects in relation to building context. This list is not exhaustive and relates mainly to the effects of degradation factors on materials. However other factors, such as use related factors, the possible effects of interaction between the product and other parts of the building (eg due to dimensional changes) etc should be taken into account.

Whilst the effects of degradation factors on products are often considered in isolation the possibility of synergistic effects between two or more factors which may cause a greater than predicted change (eg UV radiation in the presence of moisture) should not be overlooked.

4.3 Sources of information for developing a programme for the assessment of working life

Many sources of information are available which may be used to identifying the most appropriate assessment procedure. Working Groups should consider all of them and select that which is of greatest value taking into account the nature of the product and its intended use.

4.3.1 Knowledge and experience

The chemistry and physical make up of the material and a knowledge of the proposed use for the product often provides a means of making the initial selection of the degradation factors which have to be taken into account to assess the working life of products.

a) The chemistry of the product and a knowledge of the phenomena involved identify some of the factors that may cause changes in the properties of the product (for example UV, thermal, chemical etc).

b) The physical make up of the product may identify other factors.
For example : porous materials - risk of frost damage.
composite materials - differential movements.

c) The use identifies such physical or mechanical factors as fatigue, wear, creep etc and also the risk of exposure to chemicals.

d) With certain materials, that are well known in the construction industry, it may be possible to define the working life of the product by specification. The specification may be for the product itself or for the protection that is provided.

Examples : thickness of galvanising on mild steel
anodic protection of aluminium
specified preservation of timber
concrete quality and depth of cover to reinforcement
concrete specifications for different environmental conditions
specified maintenance eg painting of timber and steel work
corrosion resistant grades of stainless steel.

4.3.2 Natural exposure data

Analysis of existing results obtained from natural exposure of construction products either under service conditions or under defined exposure conditions are of fundamental importance and can provide information that enables a significant reduction in the amount of durability testing, the establishment of rates of reactions and correlation with test data. The longer the period of natural exposure and the greater the number of exposure sites under differing environmental conditions the more useful the information will be.

In the absence of existing data natural ageing remains a possible source of useful information. However when climatic conditions of exposure are similar to those of the intended use the period of natural exposure should be at least one tenth of the anticipated working life in order to create useful data, and could be considerably longer. If the product is to be used in climatic conditions more severe than the exposure site (eg higher ambient temperatures and/or radiation) then even longer periods of natural exposure will be required (2 to 3 times) to obtain equivalence. If natural exposure is to provide the maximum information the aspects described in 4.3.2.1 and 4.3.2.2 should be taken into account. Appendix C gives proposals as to how samples should be examined following exposure.

4.3.2.1 Types of natural exposure

(i) Under service conditions - product, component system installed in the structure.

Considerations
- exposure conditions
- number of examples
- age of installations
- intensity of user loads etc

(ii) Exposure sites

a) Traditionally natural exposure is on samples exposed at a slope of 45° facing south or under other defined conditions.

Considerations
- exposure conditions
- samples restrained or unrestrained
- period of exposure.

b) In order to accelerate exposure solar tracking systems (ie those which maintain the orientation of the sample normal to the solar radiation) may be used. These have the same considerations as (a) above with the additional consideration of establishing the acceleration factor.

4.3.2.2 Information characterising natural exposure

Often incomplete records of the natural ageing conditions are kept. The following are some examples of information that can be recorded so that maximum use of the data collected can be made.

1) Materials subject to U/V or thermal degradation (chemical reactivity)
   - Monthly total solar energy at least measured on horizontal surface
   - Monthly mean of maximum daily ambient temperature
   - Monthly mean of minimum daily ambient temperature
   - Mean monthly wind speed

2) Material subject to freeze thaw (or low temperature fatigue) degradation
   - Number of frost cycles per month
   - Rainfall per month
   - Number of times the temperature falls to

     0 to -2°
     0 to -5°
     0 to -10°
     below -10°

3) Materials subject to corrosion (for example metals and coated metals)

   Type of site
   - Coastal (high chloride levels)
   - Urban
   - Rural
   - Industrial (high SO_2 , H_2S, NO_x levels etc)

4.3.3 <u>Tests</u>

Testing following accelerated ageing will generally form the basis of predictions of working lives. The tests available to Working Groups will fall into three main groups, direct , indirect and torture tests.

a) Direct testing is mainly performance or use related and relates to the measurement of the characteristic in question (for example abrasion tests, fatigue tests etc).

b) Indirect testing relates to the measurement of properties which have a known relationship to performance in use. When using indirect tests it is critical that a proven correlation between the property measured and long term performance exists (ie the property measured must be significant in terms of performance). Examples of indirect tests :

   Porosity or compressive strength tests as an indication of freeze/ thaw resistance
   Hardness tests as an indication of abrasion resistance.

c) Torture tests are short term tests where the conditions of test are significantly more severe than the service conditions of the product and may be used to remove the need for long term ageing. If the product passes the severe test then no further work has to be done on that particular factor.

If the product fails the test it does not necessarily mean that the product will not perform well but additional testing over a longer period will be required under conditions closer to the service conditions (ie simulative ageing conditions) to establish its credentials. The tests are usually material specific.

Examples include
- water boil test on glass reinforced polyesters
- water boil test on laminated timber products
- artificial weathering using UVB radiation

Torture tests should be used with extreme caution. Their use assumes a knowledge of the performance of the material in question under the conditions proposed. Any ageing conditions applied and subsequent testing should be related to the "basic" phenomena observed on site.

4.3.4 Accelerated ageing conditions

Accelerated ageing may be undertaken in a number of different ways. The most appropriate method will depend on the nature of the product and its intended use. Generally simulative ageing conditions are used. Simulative ageing methods are those in which the ageing conditions attempt to simulate natural conditions usually with only a moderate acceleration of the factors. Examples of simulative ageing methods include:

- artificial weathering
- heat ageing
- freeze / thaw
- water resistance
- chemical resistance

Such methods are usually long term tests and hence expensive. The maximum amount of information therefore needs to be obtained when such methods are used. It is important that the effect of the ageing conditions on the product is well understood and accurately reflect what will happen in real life.

When establishing the most appropriate ageing conditions it may, in the absence of existing data, be necessary to ensure that the condition do not give rise to abnormal changes within the product. It may be necessary to carry out ageing over a range of conditions, performing tests at a number of time intervals, to establish the shape of the degradation curve. Examples of intermediate periods that may be used are:

Artificial weathering -UV exposure time (hours) : 500, 1000, 2000[1] etc
Heat ageing (days) : 1[2], 7, 28, 56, 112 etc

Extrapolation can only be made if it is known that the material is not subject to sudden reduction in properties after a stable period. ***Extrapolation should not exceed more than 1 logarithmic unit of time beyond experimental data without adequate justification and in no case beyond 1.5 units.***

Appendix C gives proposals as to how samples may be examined following exposure.

1 For some materials exposure to UV for longer than 2000 hours does not produce any additional useful information due to a protective layer of degradation products which is not removed in service.

2 Many materials show improvement in properties after initial heat ageing therefore the measurement after 1 day which should be used when considering further change.

5 Pretesting

In the methodology envisaged by the draft ISO Pretesting is designed to validate the proposed ageing test. In the context of EOTA's work this stage will generally not be possible. It is therefore essential that Working Groups make full use of all existing knowledge and data held by Approval Bodies and others.

The guidance given in 4.3 should be followed in order to justify the selection of a particular ageing test.

6 Testing

ETA Guidelines should describe fully any ageing test proposed, including conditions, periods, performance criteria etc. Tests should be as short term as possible and should generally be related to a fixed period of exposure, with the overriding requirement that it allows the prediction of working life with an acceptable degree of confidence.

The ISO methodology anticipates the comparison of the results of relatively short term tests to those of long term tests under in-service conditions and a dose effect loop. This will not be possible in the case of assessments for ETAs and consequently Working Groups should, wherever possible, utilise existing and generally accepted tests. The Review procedures envisaged for ETAs, and the associated increase in knowledge and experience of a product, will give Working Groups the opportunity to re-assess the methods of verification selected for the determination of working life.

Wherever possible Working Groups should take a harmonised approach to ageing tests and use similar conditions unless there is good justification for doing otherwise.

APPENDIX A
BUILDING CONTEXT

The wide variation in European climatic conditions and in the user stresses imposed on structures depending upon type of structure and use intensity will make it necessary with many construction products to restrict their usage to defined situations in order that these achieve the predicted working life.

The following are examples of possible sub-divisions.

1 Climatic sub-divisions of Europe

The sphere of activity of EOTA is approximately between latitudes 35° and 70° N which covers a wide range of differing climatic conditions. The most important of these in terms of working life are the difference in ambient temperature and the differences in solar energy intensity at different locations. The combination of these factors indicate that the ratio of rates of chemical reactivity from the North to the South of Europe may be of the order of 1:4.

Although it may be possible to produce a Euromap sub-divided by iso-chemical reaction rate lines this would be more complicated than is presently required and a simple sub-division of Europe into three temperature zones based upon general climatic conditions is given in Table I.

Table 1 European Temperature Sub-division

Zone	Winter Conditions DEC, JAN, FEB	Summer Conditions JUN, JUL, AUG
A	Cold winters. Several months temperature rarely above 0°C. Average daily temperature below 0°C. Min temperatures may be below -30°C.	Max temperature rarely above 30°C.
B	Moderate winters. Frequent frosts. Average daily temperature 0 to 5°C. Min temperatures may be below -20°C	Max temperature occasionally above 30°C.
C	Warm winters. Infrequent frosts. Average daily temperature above 5°C.	Max temperature frequently above 30°C. Occasionally above 40°C.
Mountainous regions above 1000 m	Zone A conditions	Zone C or B conditions

Special conditions (examples)

- Industrial regions (high $S0_2$, H_2S, NO_x levels etc)
- Coastal regions (high chloride levels)
- Regions with high wind and driving rain (possibly in combination with freezing conditions)

Table 2 gives an example of a climatic subdivision developed by WG 4.02.01 relating temperature and UV radiation, other sub-divisions may be possible.

Table 2 Subdivision relating temperature and UV radiation,

	Moderate Climate	Severe Climate
Annual radiation on horizontal surfaces	< 5 GJ/m^2 and	≥ 5 GJ/m^2 and/or
Average temperature of the warmest month of the year	< 22° C	≥ 22° C

2 Other external sub-divisions

Orientation of product in structures:

- Horizontal & low slope surfaces (less than 20°)
- Steep slope surfaces (more than 20°)
- Vertical surfaces
- Underside of horizontal or sloping surfaces

Position of building:

- proximity to locations giving rise to special conditions eg trafficked road
- no special conditions eg at distance from trafficked road

3 Internal environment sub-division (conditions are related to use of buildings or compartments of buildings)

3.1 Temperature
- unheated buildings or parts of buildings
- normal living and working conditions
- refrigerated buildings or rooms
- special conditions - factory processes
- localised radiation - radiators etc

3.2 Humidity
- dry conditions less than 50% RH
- normal conditions 50 - 80% RH
- wet conditions more than 80% RH
- intermittent
- permanent

3.3 Liquid water
- only occasional spillage
- frequent exposure to liquid water
- permanently wet

3.4 Chemicals
- Household chemicals - cleaning and cooking etc
- Special conditions
  - commercial and industrial processes
  - laboratories
  - hospitals etc

4 Other internal sub-divisions

Orientation of product in building:

- floors
- walls
- ceilings
- other surfaces

Use of building or compartments of building:

- domestic
- residential
- schools
- offices
- public buildings
- farm buildings
- commercial
- industrial
  - light industries
  - heavy industries
- storage
- refrigerated

5 Subterranean

Free draining	)	acid conditions
	)	alkali conditions
Permanently wet	)	saline conditions
Special conditions	-	industrially contaminated land
	-	made up land (eg land fill)

APPENDIX B

1 Degradation factors

The degradation factors which have to be taken into account in an assessment of working life, in the three main exposure situations, are given in tables 1.1 (External), 1.2 (Internal) and 1.3 (Subterranean). This list is not exhaustive and relates mainly to buildings but the general principles may be applied to any construction works.

In each table the degradation factor, the likely actions and reactions are listed together with a list of materials or type of material which may be at risk and indications of the possible requirement for a sub-division of the degradation factor.

Change of appearance has not been included in the list of reactions but almost any action may cause change of appearance and where this is important will need to be taken into account.

TABLE 1.1 EXPOSURE SITUATION EXTERNAL

Degradation factors that have to be taken into account

Degradation Factors	Actions	Reactions	Materials possibly at risk (examples)	Sub-division of factor
Solar radiation U.V. [1]	Chemical - disruption of bonds in organic compounds	**Opaque materials:** - surface degradation - reduction in impact strength - loss of degraded surface[2] - change in colour **Translucent materials:** - loss of light transmission - loss of surface appearance - reduction in impact strength - change in colour	Plastics Resins Rubbers Bitumens Organic pigments Timber surfaces	Climatic zones Orientation of product
Thermal	Absorption of energy by materials creating rise in temperature above ambient	**Chemical:** Increased rate of thermal degradation - loss of thermal stabilisers - embrittlement - loss of extensibility - loss of impact resistance - loss of appearance	Plastic materials containing thermal stabilisers	Climatic zones Orientation in building Colour, reflectivity
		Increased rate of chemical reactions - UV degradation - oxidation - carbonization - hydrolysis etc - reactions various (see chemical degradation factors)	Plastics Metals Bitumens Concrete etc	
		Post cure of materials - shrinkage	Resins	

1 Protection from UV radiation may be given to a product by a thin UV resistant coating applied

a) in the factory in which case the working life assessment is an assessment of the protective efficiency of the coating and the risk of damage or loss of the coating

b) applied on site in which case the assessment has to cover the efficiency of the coating and the possible maintenance requirements of replacement.

Protection may be given by the use of UV stabilizers. Other forms of UV protection eg layers of gravel etc may be applied.

2 The degradation process is continuous if the degraded surface is progressively lost otherwise the degraded surface acts as a protective layer to the bulk of the material.

TABLE 1.1 EXPOSURE SITUATION EXTERNAL (continued)

Degradation factor	Actions	Reactions	Materials possibly at risk (examples)	Sub-division of factor
Thermal (continued)	Absorption of energy by materials creating rise in temperature above ambient	**Physical:** Loss of volatiles or gases - embrittlement - shrinkage - loss of thermal properties Loss of plasticiser - embrittlement - shrinkage Softening of materials - loss of penetration resistance - loss of bond **Mechanical:** Stress relief - shrinkage - deformation (ie creep) **Thermal expansion:** - bowing or twisting temporary permanent - loss of bond **Cyclic expansion/contraction:** - fatigue damage **Thermal shock:** - breakage - loss of bond - cracking, crazing	Bitumens Adhesives Plastic foams Plasticised PVC Bitumens Adhesives Plastics Metals Plastics Thin sheet materials Multilayer materials Concrete Mechanically fixed products Bonded products Brittle materials Adhesives Cementitious materials - surface coating	Climatic zones Orientation in building Colour, reflectivity
Depressed temperatures	Change from ductile to brittle properties	**Physical** - loss of impact strength - loss of fatigue resistance	Plastics Bitumens - Rubbers - Resin	Climatic zones
Water - liquid - vapour - solid	Chemical [1] Physical	**Hydrolysis** - loss of material - loss of properties ie strength - loss of bond **Solvation** - removal of soluble materials - loss of plasticiser - loss of preservatives **Moisture expansion** - permanent expansion - partial recovery on drying - recovery on drying	Cellulosic materials Glass fibres Certain polymeric materials Adhesives, sealants Reinforced materials Multilayer materials Concrete Plastics Timber products Ceramics Cellulosic materials	Orientation in building

[1] The presence of water is essential for many chemical reactions eg corrosion of metals, carbonation of concrete etc. This aspect is covered under the chemical degradation factor

TABLE 1.1 EXPOSURE SITUATION EXTERNAL (continued)

Degradation factor	Actions	Reactions	Materials possibly at risk (examples)	Sub-division of factor
Water (continued)	**Physical** (continued)	**Cyclic wetting & drying-** progressive expansion - twisting - bowing - fatigue	Cellulosic fibres & particles Thin sheets Multilayer products	
		Capillary attraction - loss of bond between reinforcement and body of product - loss of bond at adherent surfaces	Reinforced plastics - reinforced bitumen products Sealants Adhesives	Climatic zones
		Freeze/thaw - disruption of materials	Porous materials - ceramics - concretes - natural stone - plastic foams	National zones
	Mechanical	**Impact (hail)**		
Chemical Atmospheric Oxygen	Oxidation (corrosion of metals)	**Chemical-** embrittlement - crazing - cracking - loss of material	Plastics Bitumens Resins Metals[1]	Climatic zones (?)
		Physical - expansion - shrinkage	Metals Plastics	
Ozone	Oxidation	**Chemical** - embrittlement (hardening) - cracking[2]	Rubbers	Climatic zones (?)
Carbon dioxide	Carbonation	**Chemical** - embrittlement - crazing - cracking	Cementitious materials	Climatic zones (?)
Sulphur dioxide	Acid attack	**Chemical** - loss of material - corrosion	Cementitious materials Metals Surface coatings Natural stone	Industrial zones
Hydrogen sulphide	Acid attack	**Chemical** - loss of material - corrosion	Metals Natural stone	Industrial zones
Sodium chloride	Chloride attack	**Chemical** - loss of material - corrosion	Metals	Coastal zones
Oxides of nitrogen	Acid attack	**Chemical** - loss of material - corrosion	Metals Natural stone	Industrial zones

1 Metals- type of corrosion important (eg surfaces, pitting, inter laminar - coating on metal)

2 Stress related

TABLE 1.1 EXPOSURE SITUATION EXTERNAL (continued)

Degradation factor	Actions	Reactions	Materials possibly at risk (examples)	Sub-division of factor
Chemicals (continued) Chemical cleaning solvents	Solvation	**Physical** - swelling - loss of surface - softening of surface	Plastics Resins Surface coatings	
Acids	Acid attack	**Chemical** - loss of material - corrosion	Metals	
Alkali	Alkali attack	**Chemical** - loss of material - corrosion	Metals Surface coating	
Deicing salts		**Chemical** - loss of material - corrosion	Metals Natural stone	
Compatibility[1] Plasticiser migration	Physical	- embrittlement - softening	Plastics Sealants Plastic foams Adhesives	
Bimetallic	Chemical	Corrosion	Metals	
Stress corrosion	Chemical	Oxidation of plastics - embrittlement	Metal/plastics connections	
Alkali/aggregate reaction	Chemical	Disruption of material	Concrete	
User stresses Wear	Mechanical - abrasion	Loss of material	All materials	Orientation of product Type of wear Intensity of wear
Impacts	Mechanical	- penetration of material - breakage	Thin materials Brittle material	Climatic zones Position of building Position in building Orientation of product Use of building Type of impact (intensity and frequency)
Fatigue - wind - loading	Mechanical	- disruption	Bonded materials	National wind codes

[1] Compatibility with materials in contact or subject to water run off from other parts of works

TABLE 1.1 EXPOSURE SITUATION EXTERNAL (continued)

Degradation factor	Actions	Reactions	Materials possibly at risk (examples)	Sub-division of factor
Biological - Animals	Gnawing Nesting	Damage to materials Loss of materials	Cellulosic Plastics Fibrous materials Insulation	
- Birds	Pecking Nesting	Loss of materials Penetration of material Loss of materials	Various Waterproofing Fibrous materials Insulation	
- Insects[1]	Boring	Loss of material	Cellulosic materials	
- Plants	Root penetration	Penetration of materials	Waterproofing	
- Mosses & lichens	Surface growth	Damage to surface	Cementitious materials Ceramic materials Surface coatings	
- Fungi and bacteria	Penetration of materials	Rotting	Cellulosic materials Plastics	Moisture Temperature conditions

1 National zones - eg long horn beetle in UK, Termites

TABLE 1.2 EXPOSURE SITUATION INTERNAL
Degradation factors that have to be taken into account

Degradation factor	Actions	Reactions	Materials possibly at risk (examples)	Sub-division of factor
Solar radiation U.V. Thermal	Products are generally protected from UV radiation[1]			
	Solar heat gain causing rise in internal temperature [2,3]	**Thermal expansion** - bowing or twisting) temporary) permanent - loss of bond **Cyclic expansion/contraction** - fatigue damage	Metals Plastics Thin sheet materials Multilayer materials Concrete Mechanically fixed product Bonded products	Climatic zones Orientation of building or building compartment
Differential temperatures Internal/external[4]	Thermal expansion/contraction	**Mechanical** - bowing - twisting - delamination	Thin panels Multilayer materials	Climatic zones Internal conditions
Internal/internal[5]	Thermal expansion/contraction	**Mechanical** - bowing - twisting - delamination	Thin panels Multilayer materials	Internal conditions
Localised heating [6]	Localised chemical/physical degradation Localised thermal expansion contraction	**Chemical** - embrittlement - change in appearance **Physical** - embrittlement - change in appearance - loss of thermal properties **Mechanical** - bowing - distortion - delamination	Plastics Thin panels Multilayer materials	Temperature of heat source Continuous/intermittent
Depressed temperatures [7]	Thermal contraction	**Mechanical** - shrinkage	Materials generally	

1 Products near windows may be affected

2 Only significant for unventilated buildings or building compartments

3 Most significant in un-insulated lightweight structures

4 Refrigerated buildings - special case

5 Separation of heated/unheated rooms

6 Materials behind radiators etc or special cases such as factories with elevated process temperatures

7 As for external in refrigerated buildings and unheated buildings or parts of buildings - minimum temperatures may be different

TABLE 1.2 EXPOSURE SITUATION INTERNAL (continued)

Degradation factor	Actions	Reactions	Materials possibly at risk (examples)	Sub-division of factor
Water - liquid - vapour - solid **Differential Humidity** - Internal/external - Internal/internal	Chemical[1] Physical Mechanical	**Hydrolysis** - loss of material - loss of properties ie strength - loss of bond **Solvation** - removal of soluble materials - loss of plasticiser - loss of preservatives **Moisture expansion** - permanent expansion - partial recovery on drying - recovery on drying **Cyclic wetting & drying** - progressive expansion - twisting - bowing **Capillary attraction** - loss of bond between reinforcement and body of product - loss of bond at adherent surfaces **Differential expansion and contraction (wetting/drying)** - twisting - bowing - delamination - loss of bond - fatigue	Cellulosic materials Glass fibres Polymeric materials Adhesives, sealants Reinforced materials Multilayer materials Plastics Timber products Ceramics Cellulosic materials Cellulosic materials Thin sheets Multilayer products Reinforced plastic or bitumen products Sealants Adhesives Cellulosic materials Composite panels Laminated materials	Orientation in building Use of buildings and individual rooms Climatic zones ? Internal conditions
Chemical Atmospheric Oxygen	Oxidation (corrosion of metals)[2]	**Chemical** - embrittlement - crazing - cracking - loss of material **Physical** - expansion - shrinkage	Plastics Bitumens Resins Metals Metals Plastics	
Ozone	Oxidation	**Chemical** - embrittlement (hardening) - cracking[3]	Rubbers	Climatic zones (?)
Carbon dioxide	Carbonation	**Chemical** - embrittlement - crazing - cracking	Cementitious materials	

1 The presence of water is essential for many chemical reactions eg corrosion of metals, carbonation of concrete etc. This aspect is covered under the chemical degradation factor. The risk of release of pollutants should also be considered

2 Metals - type of corrosion important (eg - surfaces, pitting, inter laminar - coating on metal)

3 Stress related

TABLE 1.2 EXPOSURE SITUATION INTERNAL (continued)

Degradation factor	Actions	Reactions	Materials possibly at risk (examples)	Sub-division of factor
Sulphur dioxide	Acid attack	**Chemical** - loss of material - corrosion	Cementitious materials Metals Surface coatings Natural stone	Industrial buildings
Hydrogen sulphide	Acid attack	**Chemical** - loss of material - corrosion	Metals Natural stone	Industrial buildings
Sodium chloride	Chloride attack	**Chemical** - loss of material - corrosion	Metals Natural stone	Coastal zones
Oxides of nitrogen	Acid attack	**Chemical** - loss of material - corrosion	Metals Natural stone	Industrial zones
Chemical cleaning solvents and spillage	Solvation	**Physical** - swelling - loss of surface - softening of surface	Plastics Resins Surface coatings	
Acids	Acid attack	**Chemical** - loss of mater - corrosion	Metals	
Alkali	Alkali attack	**Chemical** - loss of material - corrosion	Metals Surface coating	
Compatibility[1] Plasticiser migration	Physical	- embrittlement - softening	Plastics / Sealants Plastic foams Adhesives	
Bimetallic	Chemical	Corrosion	Metals	
Stress corrosion	Chemical	Oxidation of plastics - embrittlement	Metal / plastics connections	
User stresses Wear	Mechanical - abrasion	Loss of material	All materials	Building/compartment use Orientation of product Type of wear Intensity of wear
Impacts	Mechanical	- penetration of material - breakage	Thin materials Brittle material	Building/ compartment use Orientation of product Type of impact
Fatigue	Mechanical	Wear of working parts	Window and door fittings	
Biological - Animals	Gnawing Nesting	Damage to materials Loss of materials	Cellulosic Plastics Fibrous materials Insulation	
- Insects[2]	Boring	Loss of material	Cellulosic materials	
- Fungi & bacteria	Penetration of materials Growth on surface	Rotting	Cellulosic materials Plastics	Moisture & temperature conditions

1 Compatibility with materials in contact or subject to water run off from other parts of works

2 National zones - eg long horn beetle in UK, Termites etc

TABLE 1.3 EXPOSURE SITUATION SUBTERRANEAN

Degradation factors that have to be taken into account

Degradation factor	Actions	Reactions	Materials possibly at risk (examples)	Sub-=division of factor
Solar Radiation U.V.	Products protected from UV radiation			
Solar Radiation Thermal	No significant effects			
Depressed temperature	Mechanical	**Freeze/thaw**[1] - disruption of materials	Porous materials - ceramics - concretes - natural stone - plastic foams	Climatic zones
Water - liquid - vapour - solid	Chemical [2]	**Hydrolysis** - loss of material - loss of properties ie strength - loss of bond	Cellulosic materials Glass fibres Certain polymeric materials Adhesives, sealants Reinforced materials Multilayer materials	Saturated soils Free draining soils
	Physical	**Solvation** - removal of soluble materials - loss of plasticiser - loss of preservatives	Plastics Timber products Concrete	
		Moisture expansion - permanent expansion - partial recovery on drying - recovery on drying	Ceramics Cellulosic materials	
		Cyclic wetting & drying - progressive expansion - twisting - bowing - fatigue	Cellulosic fibres & particles Thin sheets Multilayer products	
	Mechanical	**Capillary attraction** - loss of bond between reinforcement and body of product - loss of bond at adherent surfaces	Reinforced plastics - reinforced bitumen products Sealants Adhesives	Climatic zones
		Freeze/thaw[3] - disruption of materials	Porous materials - ceramics - concretes - natural stone	

1 Mainly Nordic zones

2 The presence of water is essential for many chemical reactions eg corrosion of metals, carbonation of concrete etc. This aspect is covered under the chemical degradation factor

3 Mainly Nordic zones

TABLE 1.3 EXPOSURE SITUATION SUBTERRANEAN (Continued)

Degradation factor	Actions	Reactions	Materials possibly at risk (examples)	Sub-division of factor
Chemical Atmospheric Oxygen	Oxidation (corrosion of metals)[1]	**Chemical** - embrittlement - crazing - cracking - loss of material **Physical** - expansion - shrinkage	Plastics Bitumens Resins Metals Metals Plastics	
Ozone	Oxidation	**Chemical** - embrittlement (hardening) - cracking[2]	Rubbers	
Carbon dioxide	Carbonation	**Chemical** - embrittlement - crazing - cracking	Cementitious materials	
Sulphates Nitrates Phosphates Acid Alkali Saline	Chemical Sulphate attack - corrosion		Cementitious materials Metals	Soil type[3]
Compatibility Plasticiser migration	Physical	- embrittlement - softening	Plastics Sealants Plastic foams Adhesives	
Bimetallic	Chemical	Corrosion	Metals	
Stress corrosion	Chemical	Oxidation of plastics - embrittlement	Metal/plastics connections	
Alkali/aggregate reaction	Chemical	Disruption of material	Concrete	
Biological - Animals	Gnawing Nesting	Damage to materials Loss of materials	Cellulosic Plastics Fibrous materials Insulation	
- Insects[4]	Boring	Loss of material	Cellulosic materials	
- Plants	Root penetration	Penetration of materials	Waterproofing joints	
- Fungi & bacteria	Penetration of materials	Rotting	Cellulosic materials	Moisture & temperature conditions

1 Metals - type of corrosion important (eg surfaces, pitting, inter laminar - coating on metal)

2 Stress related

3 Special conditions (eg made up ground, domestic waste, industrial waste, contaminated soil, industrial sites

4 National zones - eg long horn beetle in UK, Termites

TABLE 1.4 RISKS RELATED TO DEGRADATION FACTOR AND ORIENTATION (EXTERNAL)

Orientation of external degradation factor	Horizontal or low slope surfaces (<20°)	Steep slope (> 20°)	Vertical	Underside of horizontal and sloping surfaces
Solar radiation U/V & thermal	High levels of radiation	Maximum levels of radiation facing south No radiation on north facing slopes	Reduced level of direct radiation - maximum radiation at low latitudes ie zone C No radiation on north facing surfaces	Protected from direct radiation Temperature ambient
Water	Highest risk - in contact with water for long periods of time	Lower risk - free draining - dries rapidly from solar radiation - north facing slopes at higher risk than south facing	Further reduction in risk - as for steep slopes	As for vertical walls
Wear	Maximum risk from pedestrians and vehicles	Low risk - from pedestrians or vehicles	Different form of wear - people or vehicles brushing against	No risk
Impacts	High risk - dropping impacts	Low risk	Horizontal impacts from people, vehicles etc	No risk

TABLE 1.5 RISKS RELATED TO DEGRADATION FACTOR AND ORIENTATION (INTERNAL)

Orientation of internal degradation factor	Horizontal surfaces	Vertical surfaces	Ceilings
Water	High risk of liquid water Risk of condensation	Low risk of liquid water Risk of condensation	Low risk of liquid water Risk of condensation
Chemical spillage	High risk	Low risk	Low risk
Wear	High risk - pedestrians	Low risk different form of wear - people brushing against	No risk
Impacts	High risk - dropping impacts	Horizontal impacts from people, vehicles etc	Small risk, special cases eg sports stadia

TABLE 1.6 RISKS RELATED TO DEGRADATION FACTOR AND SOIL CONDITIONS (SUBTERRANEAN)

Soil conditions	Water	Freeze thaw	Chemical attack	Biological attack
Free draining	Risk due to liquid water	Risk in climatic zone C	Risk dependent on soil type	Risk dependent on soil type
Permanently wet	High risk due to liquid water	High risk in climatic zone C	High risk in certain soil types	High risk in certain soil types
Special conditions			Very high risk, dependent on nature of fill material or contamination	Very high risk, dependent on nature of fill material or contamination

APPENDIX C

EXAMINATION OF MATERIALS AFTER AGEING:

Ageing may be selected from the following list:

- **a) Natural exposure**
- **b) Artificial weathering** UV, moisture
- **c) Accelerated ageing**
  - eg: Heat ageing
  - Immersion in water
  - Chemical resistance tests
  - Etc

The following are example of the examinations to which aged samples nay be subjected. A comparison should always be made against control samples.

1 **Visual appearance**

a) Naked eye[1]

Observations
- change in colour
- loss of gloss
- change in texture - bubbling, patterning, roughening of surface
- salt deposits on surface - usually white
- cracking or crazing of surface
- delamination
- distortion

b) 20 x magnification (with or without the material being under stress

- change in texture
- cracking or crazing of surface.
- delamination

2 **Dimension and weight**

Observations - variation in: length, width, thickness
volume
weight

3 Tests (examples)

- compression - compression set
- tensile
- elongation - elastic recovery
- hardness - indentation
- impact - brittle point etc.

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1 Instrumented techniques are also available.

APPENDIX D

Suggested standard conditions

Internal Conditions

Temperature: 23 ± 2°C

Relative Humidity

	R.H.	Examples
Normal	65%	Living accommodation Offices
Dry	40%	Computer rooms Air conditioning without humidification
Wet	95% +	Intermittent: Bathrooms Kitchens Continuous: Laundries Covered swimming pools