

An Integrated Approach to Durability Assessment throughout Construction Procurement

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ABSTRACT

Durability assessment offers a mechanism by which to assess the durability risks associated with a building or structure, and to provide the desired function and design life by mitigation of these risks. It is intended as a practical tool for owners, facility managers, designers, contractors and any other party with an interest in achieving design life. Clients whose construction projects are reviewed benefit from a clear understanding of the structure they will eventually own. However, durability assessment can provide a competitive advantage to designers, specifiers and so on, by reassuring the client of the competence of the organisation. Equally, the designers, specifiers and so on, will benefit from the clarity of the client requirements and the discussion regarding the feasibility of these requirements.

Recent consultation with industry has demonstrated that the practice of durability assessment is increasing but that it still occurs in too few construction projects. However, there is a willingness to use this tool if cost-effectiveness can be proven. Durability assessment begins by the specification of durability in the client brief and is continuous through the life-cycle of the building or structure, until disposal. Although not required by the standard BS ISO 15686-3:2001, assessment of the conceptual designs is highly recommended to enable minimisation of the durability risks identified during the detailed design phase. This recommendation is exemplified by a recent case study.

Assessment of durability risks is an essential part of the process. The identification of such risks should pay attention to both the components elements and their interfaces. Risks are rated on the basis of the likelihood and consequences of failure, where the consequences include the costs of repair or replacement and the costs of disruption and loss of function.

KEYWORDS

Durability, assessment, tools, risks

INTRODUCTION

Durability assessment is essentially a check that a proposed building (e.g. residential accommodation, offices) or structure (e.g. bridges, roads) will be fit for its intended use and lifecycle. It is of growing importance to major construction clients. For example, HM Treasury's procurement guidance (1997) that applies to around £800 million of property procurement says decision-makers should ensure that "*risks have been properly identified, evaluated, allocated and managed effectively*" before investment is made.

Durability assessment is the consideration of design life at all stages of the construction process, from development of the client brief, through the design phases, construction phases and into the use and

life care of the building or structure itself. It enhances communication throughout the construction process by providing a standardised method to consider and feedback durability information that:

- identifies risks which may impair durability and evaluates the response
- addresses unrealistic performance expectations on the basis of design information
- captures the on-going inspection and maintenance requirements to ensure the durability of the building or structure once it has been transferred from the construction team to the users.

It is a useful tool for owners, facility managers, designers, contractors and any other party with an interest in achieving design life. The principles of such assessments are set out in the recently published BS ISO 15686-1: 2000, BS ISO 15686-2:2001 and BS ISO 15686-3:2001.

THE BENEFITS OF DURABILITY ASSESSMENT

A recent industry consultation exercise conducted by BRE highlighted the potential benefits arising from durability assessment (Hooper and Rizzi 2001).

Benefits to the construction project

- Better understanding of project priorities and where valuable resources should be most effectively applied
- Clear guidance and allocation of responsibilities in the design and construction phases
- Increased clarity in the client's understanding of the scope of the design and construction process
- Reduced costs due to over-specification of the durability of materials or components
- Improved construction quality, particularly of the aspects critical to durability
- Improved risk management by quantifiable decision making
- Optimisation between capital expenditures and operational expenditures through whole life costing of construction solutions

Benefits to the clients and users

- Reduced costs associated with durability failure
- Planned maintenance scheduling and reduced disruption associated with repairs
- Reduction in risk and uncertainty and improvements in budgetary control

Benefits to the construction industry

- Creation of marketing opportunities through standardisation of approach and traceability
- Information to feedback to improving Building Regulations, materials specifications and design procedures
- Minimisation of waste and ineffective use of materials
- Achievement of more sustainable construction by minimisation of under and over-specification

Clients whose construction projects are reviewed benefit from a clear understanding of the structure they will eventually own. Ultimately, effective durability assessment relies upon the capability of the construction team (designers, specifiers, engineers and so on) to design and build durable buildings and structures. In this way the assessment can provide a competitive advantage to the construction team by reassuring the client of the competence of the organisation. Equally, the designers, specifiers, engineers and so on, will benefit from the clarity of the client requirements and the discussion regarding the feasibility of these requirements.

REQUIREMENTS OF DURABILITY ASSESSMENT TOOLS

The BRE industry consultation indicated (Hooper and Rizzi 2000) there is a clear understanding of the benefits of inclusion of durability specification in the project brief and durability assessment of the construction indicating the drivers for uptake of durability assessment methodologies are present. Importantly, the consultation indicated that the costs of durability assessment would be accepted if proven to be offset by reductions in running costs of the building or structure. This suggests that one barrier to implementation is the requirement to prove the cost benefits of assessment. However, despite the understanding of the benefits of durability assessment still too few assessments are actually conducted. This demonstrates the requirement to disseminate the benefits and methodologies for durability assessment and to develop practical tools to implement methodologies.

The consultation indicated that durability assessment tools should:

- be flexible to differing procurement processes such as Traditional Procurement and Public Private Partnerships,
- be effective as an in-house tool but understandable by clients, and useable by third parties if required,
- recognise the importance of economic life care requirements over the design life of the building or structure, since the end of service life is often related to uneconomical to operation or maintenance.

REQUIREMENTS OF CLIENT SPECIFICATIONS

The industry consultation conducted by BRE (Hooper and Rizzi 2000) indicated that over 50% of the respondents currently include, or seek to include, specific service life requirements in project briefs. A previous whole life costing consultation conducted in 1998 (Clift and Bourke 1999) indicated that only one third of briefs often or always contained this type of information. This indicates that there is increased use of durability requirements in specifications, for both Government and commercial clients. The study indicated that currently, where durability is specified in the project brief, designs are checked against this specification. Hence tools to assist this specification within the briefing process need to be developed to assist this definition by the client.

The extent of the information given to the construction design team is a decision to be made by the client, but can include:

- The function of the building or structure
- The design life
- The period of tenure and the required residual value at the end of this period
- The minimum design life
- Factors leading to the end of service life
- Optimising flexibility and minimising obsolescence
- The required level of inspection, maintenance and replacement or repair
- Design considerations such as the aesthetic requirements or sustainability credentials
- The budget considerations in place at the time of writing the brief

THE PRINCIPAL STAGES OF DURABILITY ASSESSMENT

Table 1 sets out the possible stages to be included in the durability assessment of the procurement process although not all of these assessments are required by BS 15686-3:2001.

Table 1. Possible stages in durability assessment

<i>Assessment of</i>	<i>Reasons to assess</i>
The client brief	To ensure that the durability of the building or structure is specified, understood and agreed by both the client and the design team. This agreement ensures the client brief is a document that can be used as a benchmark against which to assess the later stages of the design and the construction process.
The conceptual design	To ensure that the specified durability requirements of the building or structure are fulfilled, by identifying the broad durability issues connected with the construction project before the detailed design process begins. This assessment is not required by BS 15686-3:2001 but is highly recommended as decisions that are made could have durability implications at a later stage. An overview of such an assessment is included.
The detailed design	To ensure that the specified durability requirements of the building or structure are fulfilled by the detailed design. BS ISO 15686 -1: 2000, BS ISO 15686 -2:2001 and BS ISO 156686-3:2001 contain substantial advice concerning predicting the service life of a detailed design.
The life care plan	To ensure the life care plan, developed from the detailed design, is in accordance with the requirements specified in the client brief and that this plan is understood and usable by the client. This is not required by BS ISO 15686-3:2001 but is again highly recommended. The assessment should include check that the plan is feasible and that it will provide the appropriate durability, but is not excessive.
The construction	To ensure that the building or structure has been reasonably planned so that durability critical areas can be and have been appropriately constructed (not required by BS ISO 15686-3:2001).
Life care	To ensure that the requirements of the life care plan are being fulfilled and that the durability of the building or structure has not been impaired by other works (not required by BS ISO 15686-3:2001).
Disposal/ deconstruction	To ensure the disposal of the building or structure does not have future implications for the durability of the site and that the disposal is as cost-effective as possible (not required by BS ISO 15686-3:2001).

RELATIONSHIP TO CONSTRUCTION PROCESSES IN PLACE

Traditional procurement

Traditional procurement still forms the backbone of construction in the UK. The client develops a brief, the design team produces a detailed design for a buildable structure with specific materials and finally the construction team builds the design, handing the finished product over to the client or user. This process can be assisted by durability assessment at all stages. Durability assessment can be used

as a tool to help the flow of information concerning durability throughout this procurement process. It is there to help:

- clients understand what durability information designers need to design the buildings clients require
- designers to ensure that their designs are buildable and functional with respect to durability
- contractors to plan the construction of aspects critical to durability
- users to schedule inspections, maintenance and repair to minimise disruption
- budget holders to plan for operational costs.

PPP, PFI and Prime Contracting

Public Private Partnerships -PPP (HM Treasury 1999), the Private Finance Initiative -PFI (HM Treasury 2000) and Prime Contracting (Holti et al 1999) are procurement routes for UK public sector construction. They aim to develop partnerships with the private sector and hence deliver improved value for money. Durability assessment can assist both the client and the bidder in demonstrating that the value for money objectives will be met. For example:

- Clients can use durability assessment as a tool to develop improved client briefs (the output specification) that address the fundamental durability requirements of the contract, without specifying inputs, which are the bidders responsibility. Assessment can also be used to identify, at the selection of bidders stage, which bids address the durability requirements of the building or structure most effectively
- Bidders can use durability assessment to review the client brief, to determine if the information required to proceed with the initial bidding phase is present and whether to bid for the contract. Additionally durability assessment can be used to demonstrate how the durability requirements in the client brief will be addressed in the construction process.

Whole life costing

Whole life costing has been identified as a mechanism to deliver improved value for money (Construction Clients' Forum 1999). It accounts for both the capital costs and the operating costs to develop the most cost-effective solutions. It is carried out for the client at various stages of the decision making process. The aim of refining the calculation of the whole life costs is to reduce the uncertainty inherent in the construction cost. Clearly identifying the areas of the construction which are fundamental to the durability of the building or structure will influence the choice of options under consideration and assist in refining the whole life cost calculations. Examples of the decision stages where both durability assessment and whole life costing overlap are:

- the assessment of feasibility of alternative construction solutions
- the choice of components and services during the conceptual and detailed design phases
- a suppliers decision to tender and tender appraisal by the client
- assessment of variations during the course of construction
- determination of operational costs incurred through life care activities.

Value management / engineering

Value management / engineering is a pro-active, creative, team approach to problem-solving in projects to provide the best value for money (BRE 2000). It considers alternative solutions that include options other than construction solutions but accounts for both capital and operating costs of construction solutions. In a similar manner to assisting the whole life costing process, durability assessment supports value management / engineering by providing a structured method to assess the durability consequences of the construction solutions, and hence their impact upon the desired building function.

Compliance to BS EN ISO 9001:2000

BS EN ISO 9001:2000 requires that the design and development process be planned, reviewed, verified, validated and any changes to the process controlled. This is achieved through the effective maintenance of records, checking of inputs and outputs, assignment of responsibilities and clear communication. Durability assessment can assist in compliance to this quality standard by providing a documented quality and review procedures that ensure the design product meets the clients requirements.

ASSESSMENT OF RISKS TO DURABILITY

BRE has developed the concepts of Durability Critical and Sensitive Areas, which underpin the risk assessment strategy of its durability assessment procedure. The concepts have been developed to enable rapid and cost-effective assessments to be conducted. The differentiation between Durability Critical and Sensitive Areas depends on the contribution of the area to the durability of the building or structure. The definitions of these areas are:

- Durability Critical Areas (DCA) are the parts or elements whose durability is critical to the performance of the whole building or structure. Failure of these parts or elements would lead to the immediate or eventual failure to provide the required minimum level of performance.
- Durability Sensitive Areas (DSA) are the parts or elements whose durability is not critical to the performance of the whole building or structure but are important to the ability to function effectively. Failure of these parts or elements would generally not lead to the immediate or eventual failure to provide the required minimum level of performance, although eventual failure is conceivable.
- Other areas not identified as either DCAs or DSAs are regarded as Unclassified Areas (UCA). Failure of these parts or elements would either be unlikely to occur or would not affect the ability of the structure to provide the required minimum level of performance.

Clearly, identifying the DCAs and the DSAs is a very important matter. However, the identification of the costs associated with the repair work, including the costs of disruption, in the event of a durability failure is also very important to this process and these should be taken into account. This implies that the definition of DCAs and DSAs and hence UCAs is a matter of risk assessment, that is likelihood of failure and consequences of failure, including the cost consequences. Examples of DCAs, DSAs and UCAs are given in Table 2.

Identification of durability risks

The BRE assessment procedure particularly segregates the *at risk* areas into two categories, *at risk* elements and *at risk* interfaces. Advice concerning the service life of components, that is building elements, can be assessed by referring to benchmarking documents such as the HAPM Component Life Manual (1992) or from the experience of the design team, including the materials suppliers. It is important to note that although there may be significant data available regarding the service lives of components, excessive regard to this elemental approach could mask the need for durable interfaces between components that will function for the required service life. The interface between two components not *at risk* can be a cause of failure. For example, the most durable reinforced concrete, well compacted to limit carbonation and chloride ingress, will fail quickly if the expansion joints between sections are poorly sealed and allow chloride penetration. In order to facilitate the determination of elements *at risk* the assessment procedure expressly sub-divides the building elements into the following categories:

- Mechanical and Electrical
- Groundworks
- Frame and Envelope
- Internal Finishes

Table 2. Examples of DCAs, DSAs and UCAs

<i>Category</i>	<i>Example</i>
DCAs	<p><u>Membrane on a flat roof</u> failure causes water ingress to school classroom making the room unusable.</p> <p><u>Flooring in entrance lobby</u> excessive wear causing reduction in slip resistance and making the floor hazardous.</p> <p><u>Expansion joints between sections in a bridge deck</u> failure of sealants leads to reinforcement corrosion, ultimately risking structural integrity and excessive repair costs and disruption.</p>
DSAs	<p><u>Felt on a flat roof</u> failure causes water leakage into open bus shelter making the shelter damp and causing damage to internal finishes.</p> <p><u>Service pipes under entrance to building</u> failure will mean mosaic floor must be lifted at great expense and significant disruption.</p> <p><u>Thermal expansion mismatch between blockwork walls and tiling in hot kitchen facility</u> causes some tiles to become loose, causing inconvenience and a potential hazard to users.</p>
UCAs	<p><u>Sulfate attack of above ground concrete structures</u> is unlikely to occur.</p> <p><u>Improper fixing of door handles</u> is unlikely to occur and is easily rectified without disruption.</p>

These sub-divisions form the same supply chain *Clusters* as in Prime Contracting Procurement (Holti et al 1999). This correlation is specifically intended to maximise the benefits of Prime Contracting by using the specialist knowledge available by integrating the supply chain.

The various elements within the design are assessed against the specifications of the client brief. That is, will they match the durability and life care requirements specified by the client? Those that fail to match the requirements are *at risk*, for example, window frames that require re-painting every 4 years are *at risk* if the life care requirements only allow for preventative maintenance every 5 years.

Following this elemental analysis, the same procedure is followed with each of the group interfaces being analysed for risks in a similar manner, including analysis of interfaces between elements in the same sub-division. When specialists are identifying the DCAs and DSAs, it is pertinent to allow each to assess the design individually, from their own specialist knowledge, before comparing notes and agreeing a comprehensive list of *at risk* interfaces. Table 3 shows how this process works.

Table 3. Elemental and interface assessments required

<i>Elements "at risk"</i>	<i>Interfaces "at risk"</i>				
	<i>M&E</i>	<i>M&E</i>	<i>GW</i>	<i>F&E</i>	<i>IF</i>
Mechanical and Electrical (M&E)	X	X			
Groundworks (GW)	X	X	X		
Frame and Envelope (F&E)	X	X	X	X	
Internal Finishes (IF)	X	X	X	X	X

Assessing the consequences of durability failure

Once the *at risk* elements have been identified consequences of failure are assessed. The consequences should specifically relate to the ability of the building or structure to perform in accordance with the requirements of the client brief. At minimum, such assessment should include to consequences in terms of:

- Minimum level of performance required
- Impact upon structural integrity
- Financial consequences of repair or maintenance
- Disruption to function caused by repair or maintenance
- Reasons for initial design preference
- Forecast obsolescence or changes in circumstances

Table 4. Assessing of consequences of failure against the client brief

<i>Specified requirements in the client brief:</i>	
	<ul style="list-style-type: none"> • Required service life of whole building is 35 years. • Routine maintenance operations to be conducted every 5 years. • Major replacement operations after 10 years, to a maximum cost of £ 70, 000 for remaining life of building.
<i>Assessment of consequences:</i>	
Minimum level of performance required	<ul style="list-style-type: none"> • Require maintenance every four years to match design life <ul style="list-style-type: none"> • 5 yearly maintenance specified in client brief • With 4 yearly maintenance service life will be 25 years • Without maintenance service life will be 10 years
Impact upon structural integrity	<ul style="list-style-type: none"> • No impact
Financial burden of repair and/or maintenance	<ul style="list-style-type: none"> • Cost of four yearly maintenance = £1000 + 3% • Cost of five yearly maintenance = £1100 + 5% • Cost of replacement after 25 years = £10,000 • Total cost of replacement every 10 years = £20,000
Disruption to functionality caused by repair or maintenance	<ul style="list-style-type: none"> • Limited disruption from four/five yearly maintenance • Large disruption to function through replacement
Reasons for initial design preference	<ul style="list-style-type: none"> • Design restrictions imposed by client: • Wooden window frames from renewable source <ul style="list-style-type: none"> • Aesthetics of design with local area
Forecast obsolescence or changes in circumstances	<ul style="list-style-type: none"> • Potential extension to building, to accommodate more staff after 10 years, from south elevation
Conclusion	Wooden window frames are a DSA

Again, using the example of the *at risk* window frames, the client brief is used as the standard against which to measure the consequences, demonstrated in Table 4. This analysis of consequence highlights these window frames as a Durability Sensitive Area. That is, the level of life care requirements specified in the client brief prohibits the required maintenance, and the life care specified is likely to lead to failure to provide the required service life after 25 years. However, the choice of windows is

limited by the design restrictions imposed by the client. In this situation the windows will not impact on the economic function of the building and the replacement costs, and associated disruption, are acceptable if planned for. Hence, there is recognition of the mismatch in terms of durability but also that it is not critical to the building performance.

Having highlighted the window frames as a DSA this is fed back into the design process. In this way the options to rectify the issue can be addressed, for example:

- The client may agree to four-yearly maintenance of the windows to achieve desired service life, stimulating a change in the client brief.
- The costs of replacement after 25 years will be accounted for in the through life costs of the design.
- The inspection and maintenance plan will eliminate the requirement for painting of the windows on the south elevation.

CASE STUDY - DURABILITY ASSESSMENT OF THE CONCEPTUAL DESIGN

Recently, the BRE used durability assessment to identify and assess the risks related to function and buildability of a design of a medical practice. The study highlighted areas of concern within the conceptual design that should be addressed through the detailed design. The assessment process was able to form a discursive link between the client and architects. For maximum impact durability assessment was complemented by energy efficiency assessment and whole life cost analysis.

The client was involved in the refitting a medical practice through a lease arrangement and although the clients would not be responsible for the capital costs they would be responsible for maintenance, refurbishment and running costs during the period of the lease. There were obligations imposed on the design by UK Health Authority guidelines with regard to long term performance, and the clients had expressed a preference for reduced environmental impacts if cost-effective.

The durability assessment located several areas that were several areas that will be vulnerable to detailing and workmanship issues. The areas critical or sensitive to durability included:

Rooflight upstands – issues on both weatherproofing and security.

Downpipes through flat roofs / floors – requiring initial weatherproofing and regular maintenance to remove leaves etc.

Edge details around flat roofs – parapets should be avoided, and gutter sizing should be generous.

Areas below kitchens / bathrooms (especially floor-drained showers), including sealing details around sinks, basins and baths, and drainage details from shower trays and washing machine outlets (which should be accessible for clearing)

Pipework in screeds – contact with wet concrete can cause problems to copper or plastic pipework.

Sealing of gaps between walls and floors – particularly important in the consulting rooms for noise reduction and confidentiality

The recommendations to minimise durability risks included:

- Review use of roof lights and consider use of light tubes cast into roof slab.
- Provide inverted flat roof construction to flat roof / terrace area without parapet.
- Consider linoleum floor finishes on the basis of cost / hygiene / reduced environmental impact with sealed upstands and skirtings. Consider wall hung cupboards, sanitary ware and so on that is faster and easier to clean around.
- Where pipes are laid in floors an accessible ducting arrangement should be considered.
- Plan for maintenance of joinery and ironmongery, a system which allows minor repairs is to be preferred to one where major replacements are foreseeable, but these are critical to access and usability of the building, so should be a priority in terms of considering performance. Similarly, factory finishing can provide a longer interval to first maintenance. Consistent use of specifications reduces unfamiliar operation and the need to hold different spares.

CONCLUSIONS

Durability assessment is a powerful but underused tool for the construction industry. It not only has a role to play in establishing durable and functional buildings and structures it can assist in integrating the supply chain, procuring construction projects and bidding to win these projects, providing value for money and complying with quality standards related to product design.

Consultation with the UK construction industry has demonstrated that although consideration of durability in the procurement process is increasing it is only sought in 50% of projects. However, this is an increase over previous measures and is indicative of the growing recognition of the importance of durability assessment and other initiatives such as whole life cost analysis, value management / engineering and partnering in construction procurement.

Although not required by BS ISO 15686-3:2001, the assessment of the conceptual design is highly recommended to minimise the durability risks as an early stage and focus the detailed design stage. Structured and documented risk assessment is the foundation for durability assessment. This risk assessment should include consideration of the likelihood and consequences of failure, where the consequences include the costs of replacement or repair and the costs of disruption.

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