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PREDICTION OF DURABILITY FOR PERFORMANCE-BASED CODES

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Prediction of Durability for Performance-based Codes

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Abstract

New Zealand has had a performance based building code [1] for four years. The code superseded a prescriptive building system which effectively defined in detail how houses and low rise buildings should be built. The code sets out required performance levels in 35 areas which must be achieved in order for a building consent to be issued. These areas include structural design, weatherproofing, energy efficiency, plumbing and durability. The durability clause differs from the others in that it contains specific default minimum service lives for buildings and their components. The durability provisions apply to any part of a building which is fulfilling another code requirement (eg. structural stability), but do not cover aesthetic considerations.

Acceptable solutions and verification methods have been developed for most parts of the code which specify ways of meeting the building code or ways of establishing compliance through test or calculation. In the durability area however, methodologies and test procedures for predicting service life are still the subject of intensive research. Despite many hundreds of test methods published in reports and Standards, few accurate predictive techniques are available. As a consequence, the verification method for the durability clause provides guidance on the ways in which a durability assessment should be carried out rather than referencing test methods. This approach is also seen in the draft documents produced by the ISO TC 59 "Building Construction" subcommittee SC3 Working Group 9 looking at service life prediction methods. The New Zealand experience shows that while specific test methodologies which would enable durability predictions to be made for a wide range of materials would be preferred by industry, continued development and refinement of guidance documents such as those produced by TC59, offer the most realistic chance of improving service life prediction within the building industry.

Keywords: durability, performance, codes, prediction, test methods

1 Introduction

Ensuring that buildings have an appropriate service life has always been an important aspect of building design and maintenance and regulation. In New Zealand, traditional building regulations were based around standards produced by the national standards body. These regulations were adopted and amended by each local city and town council as they saw fit. Durability was implicitly recognised through tight adherence to prescriptive standards and limited availability of alternative designs and

materials unless "approved by the engineer". These standards specified materials and construction methods which were designed to produce buildings with an undefined but acceptable life.

In 1992, the New Zealand Building Code (NZBC) [2] was introduced. The New Zealand Building Code is a performance-based building code which replaced the previous regulations and centralised the development and administration of building regulations. The rationale for building regulation reform was to simplify and to reduce the cost of building control. The basic tenets of the New Zealand Building Code are health and safety, with some consideration also for protection of neighbouring properties, the safety of fire-fighting personnel and energy efficiency. Aesthetics, quality and amenity issues, unless related to health and safety, are not considered. The NZBC contains 35 clauses defining building performance requirements. The NZBC is a performance based code rather than a prescriptive code. This means that it specifies performance levels which must be achieved in a building rather than specifying how to build the building and what materials to use. There is one exception to this philosophy, the durability clause (NZBC B2), sets default lifetimes for buildings and their parts. The reasoning behind this is that without some provision for ensuring that a building continues to meet the performance requirements, the durability of buildings would be set by market forces. Since a significant proportion of building owners can be expected to have little expertise in assessing materials and system performance, a minimum degree of consumer protection was considered appropriate.

2 NZBC B2 Durability

B2 effectively demands, that materials or components required to meet a performance level specified in any other NZBC clause, must continue to meet that performance level with normal maintenance for a stated time. Typical examples are; elements contributing to structural stability, weather-tightness, insulation, acoustics and fire resistance. The durability required is defined by default as 50 years for items; contributing to structural stability or, that are difficult to access or replace or, where failure would not be detected during normal use and maintenance. Elements which are moderately difficult to access and replace and where failure would be detected during normal maintenance, have a 15 year durability requirement. The remaining categories have a 5 year requirement.

Alternative building lifetimes can be specified at the building consent stage. For example, with some agricultural buildings a 15 year life may be appropriate. In these cases the building would be subject to a demolition order after the 15 year period unless appropriate reports were provided to show that it would continue to meet New Zealand Building Code requirements. With other structures, such as hospitals or bridges, a 100 year or more service life might be specified. In these cases this becomes a matter of specification and contract between the client and the design/construction companies.

3 NZBC compliance

Prior to the start of construction of any building, a building consent must be obtained from the local territorial authority. Before issuing the consent, the authority must have reasonable grounds to believe that the building as planned would meet the NZBC. While the New Zealand Building Code allows for innovation, it was recognised that many buildings would be constructed along traditional lines. To assist with this process "Approved Documents" were also published with the NZBC. These include "Verification methods" and "Acceptable Solutions". These documents set out methodologies which allow builders and designers to show approving bodies that they have met the performance requirements of the New Zealand Building Code. The approved documents are largely based on traditional building standards which have proved largely satisfactory over a long period of time. B2 Durability contains both a Verification Method (B2/VM1) and an Acceptable Solution (B2/AS1). B2/VM1 includes a statement to the effect that materials and building elements complying with a publication referenced in the Approved Documents are, subject to their appropriate use for the conditions likely to prevail in the specific building, deemed to satisfy the durability performance. This means that materials listed in an acceptable solution for B1 Structural Stability, will under the appropriate usage conditions satisfy B2. Only recently has B2/AS1 referenced specific standards setting out materials and their uses which are deemed to satisfy B2. These are NZS 3602 [3] which covers the selection of timber and wood-based products in building, and NZS 3101 [4] which covers the design of concrete structures. These two documents are prescriptive standards which have been developed from many years of research and actual service history in New Zealand. B2/VM1 provides generic guidance on how to assess the durability of materials, but does not provide specific advice for any particular class of material.

4 Assessment of durability

One of the main criticisms of NZBC B2 Durability by industry, is the lack of detail in the Approved Documents. Manufacturers' frequently want to assess the durability of a new material or system or, may be using a conventional material in a new application. They find the lack of a list of specific test methods which can be carried out on a product which will give them a durability rating of 5, 15 or 50 years frustrating. Those involved in materials testing will appreciate the difficulties inherent in such a simplistic approach. There are thousands of test methods available covering almost every material and application imaginable. Many of these tests are designed to show compliance of new product with a performance standard. Others involve some form of accelerated ageing such as; heat, wet/dry, freeze/thaw or UV exposure. Others compare performance to historically durable reference materials. Relatively few tests allow the prediction of durability to the precise levels that end users would like. Even if such tests are available, they often do not take into consideration issues relating to the usage of a material on each specific building (eg. macro and micro climates, materials interactions, usage intensity etc).

Some standards have been developed which instead of prescribing a set testing regime, give guidance on how to develop test procedures. ASTM E632 [5] is a good

example which sets out a process for devising accelerated test methods. Lewry and Crewdson [6] discuss some of the issues involved in devising test procedures and relating these to real applications. Other standards and documents have been produced which take a wider view than testing and focus on the process of determining service lives for buildings and components. CIB and RILEM committee RILEM 140-TSL/CIB W80 committee has produced publications [7- 11] covering both service life prediction and the gathering of data for use in service life prediction. The British Standards Institution published BS 7543 [12] and the Architectural Institute of Japan a guide [13] both providing guidance on service life planning. Much of the previous work on service life prediction is being used in the development of ISO standards on service life planning. ISO/TC59/SC14 (previously TC59/SC3/WG9) currently has a draft standard on service life prediction methods in development [14]. Lacasse and Vanier [15] review work in this area in a paper presented at the most recent "Durability of Building Materials and Components" conference.

The approach taken in the durability verification method VM1 is to provide guidance on the principles involved in durability assessments. Three approaches are outlined:

- history of performance
- lab testing
- looking at the performance of similar products

4.1 History of performance

B2/VM1 recognises that a successful history of performance is recognised as the most reliable method of evaluating whether a product will be durable in any given application. Even if the period that the material has been used for is less than that required by NZBC B2, valuable information can still be obtained. A number of factors are raised which need to be considered when assessing the history of performance of a material.

4.1.1 Climate

For products used on the exterior of a building the general climate is the main factor. General climatic influences are described but no data is provided on degradation agents in contrast to BS 7543 which includes air temperature maps and driving rain indices [12]. VM1 emphasises the need to ensure that the performance history and usage must be representative of the proposed new usage. This is particularly relevant where materials are imported from other countries because differences in climatic conditions and building practices can result in significant differences in durability.

4.1.2 Microclimate

General climatic factors can usually be assessed with the aid of meteorological records and local knowledge. However, building details and surrounding topography and vegetation create a number of localised micro-environments particular to each building. These micro-environments can have a major influence on materials performance. Some common examples are, the sheltered corrosion effects on under roof eaves, brick veneer cavities and sub-floor spaces. The sheltered corrosion effect results when parts of a building are sheltered from direct rain washing, but open to wind blown salt and dirt. The accumulation of salt and dirt causes rapid corrosion of

metallic components unless they are regularly washed. Recent reports of failures of brick ties in masonry veneer cavities have also raised concerns that insufficient data is available on this microclimate [16].

4.1.3 Materials Interactions

- Individual materials that may be largely inert and durable by themselves, can, when in contact with other materials, degrade quite rapidly. This means that the specific use in building systems should be assessed as well the durability of each individual building material in question.

4.1.4 Changes in Formulation

It is very common for the formulation of a product to change over time. Changes may be made to improve properties, reduce costs, utilise new raw materials sources, or comply with health and environmental regulations. Whatever the reason, it is necessary to evaluate what the likely effect of any changes will have on new products compared to those used in the past. Major changes (eg. changing the resin type in adhesive) will make the past history of performance effectively irrelevant and the product will need to be evaluated as new. The effect of minor changes may be able to be accounted for by expert evaluation and or laboratory testing to confirm the relevance of previous formulations.

4.1.5 Degree of Degradation

New Zealand Building Code B2 requires that "elements and buildings must carry out their intended function for the life of the building. Simply showing that a product has survived for 20 years does not necessarily prove that it will still carry out its intended function for 50 or even 20 years. In obvious applications such as claddings, it will generally be easy to determine if a failure (ie, leakage, impact damage or wind damage) has occurred. For structural or fire applications, the design loading event may not have occurred over the history to date, and hence an appearance of soundness may not equate to adequate retention of physical properties to meet the original design loads. Retrieving samples from buildings and testing to establish whether deterioration has occurred and the nature of any deterioration, is highly recommended when assessing durability. This can give clues to the mechanism of degradation and also allow estimates of retained properties at the required lifetime.

4.1.6 Usage Intensity

Usage intensity refers to items (often mechanical hardware) which undergo some form of wearing action during use. One example would be closers on fire doors. The frequency of opening of the door over the life of the building will have a significant effect on the wear rate of the closer and the service life and maintenance requirements will vary accordingly. Usage intensity is most important in institutional, commercial and industrial buildings but may also be a factor in domestic housing (eg. specifying deck membranes where foot traffic occurs).

4.2 Laboratory Testing

In the event of a service history not being available, the only option available may be to carry out testing. The most reliable testing method is to set up natural weathering trials using the materials in question and attempting to simulate the actual exposure conditions as closely as possible. One of the drawbacks with this technique is that it can take a very long time to see any results. Manufacturers introducing products usually cannot wait more than 6-12 months so accelerated techniques then have to be employed. The key point in designing or assessing a "so called" durability test, is whether the test accurately reproduces the degradation mechanisms that take place in service. For this reason B2/VM1 requires expert interpretation of accelerated laboratory test results when used in determining likely service life.

5 Practical issues resulting from implementation NZBC B2

Acceptable solutions are intended to provide methods of construction which will meet the NZBC over a wide range of locations, building types and usages. As such, they are usually robust and provide solutions which may be very conservative in some applications. In most acceptable solutions, a material is selected from a table or list of options, or if it can be shown to meet set performance criteria. In contrast, when specifically designing a building, the opportunity is available to tailor each component to achieve the desired durability/cost/maintenance balance. In this case, durability assessments are just one source of information which can be used by the designer/engineer. Rather than a simple pass/fail scenario, the information required is what degree of degradation is likely to occur, how extensive will the degradation be over the building and what effect on physical properties will the degradation have. The decision on acceptability can then be made by the designer in light of the information provided by the durability assessment/testing and the other design parameters set by the client's requirements and the appropriate loading conditions. An unresolved issue associated with the NZBC is that it does not state what an acceptable level of risk is. Since it is impossible to completely eliminate defects in a construction process, the level of risk is never zero. Historically, the level of defects which can be tolerated is set largely by the market or by society through codes and standards and tends to be very small. The actual value being a compromise between quality or safety and cost. NZBC B2 Durability does not provide any guidance of what level of risk is acceptable in assessing durability. However, since the purpose of B2 is to ensure that the other NZBC functional requirements are maintained over the life of the building, some guidance on the degree of deterioration allowed can be found in the other functional requirements. For example, concepts of reliability are covered in the B1 Structure verification method B1/VM1. Engineers typically design fixings using a 5 percentile value for resistance. This means that there is a 95% probability that the resistance of any particular fixing will exceed the design parameters and that the mean of all the fixings will be well above the design level. Similarly, the design loads are set at a level which ensures a low probability of them being exceeded over the life of the building. In this context, one argument is that that the conservatism associated with the terminology "reasonable evidence" is in place and need not be duplicated in a

durability assessment. However, the levels of risk that can be inferred from B1/VM1 are not necessarily minimum risk levels, but they have been deemed acceptable. Work being carried out in Australia on timber durability, is attempting to bring engineering concepts such as reliability theory into durability design [17]. This approach requires quantification of agents causing degradation for each material as well as models which can predict degradation under a range on environmental conditions. Work is being carried out in New Zealand this areas [18].

6 Conclusions

While B2/VM1 provides general guidelines for assessing durability, and additional information is available in documents referenced previously [5-14], there are few organisations with sufficient expertise and resources in New Zealand able to carry out assessments of materials durability and service life prediction. This becomes particularly evident when new building systems utilising a range of traditional materials (steel, timber, concrete) are combined with polymeric materials such as plastics and resins. As well as materials expertise; structural, weathertightness, thermal, fire and buildability issues need to be worked through. The construction industry has placed a good deal of reliance on fitness-for-purpose system appraisals similar to the European Agrément system.

From an industry perspective, the realisation of the innovation and potential economic benefits offered by a performance-based building code will be enhanced by the development of improved acceptable solutions for B2 Durability. Improvements need to be targeted at three levels;

1. standards providing guidance on durability assessments and service life prediction
2. test methods for individual materials and systems
3. development of reliability-based models

The international effort going into the work of ISO/TC59/SC14, offers the potential of a unified approach being adopted for the process of assessing durability and service life for buildings and their components. A common methodology will assist those involved in assessing information presented as part of the compliance process particularly when material from another country is presented.

Improved predictive test methods for individual materials and their applications, continue to be developed by manufacturers, researchers and national standards bodies. These tests will eventually find their way into acceptable solutions when they become accepted by national standards bodies or major research organisations.

The incorporation of durability into the engineered design of buildings is still some distance away and requires considerable background work in each country as well as cooperative efforts within the international community. The eventual availability of reliability-based service life prediction techniques will mean explicit durability provisions in performance-based codes are likely to become more widely accepted.

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