A model for collecting durability data of building components for architects and building managers

Hermans, M.H.

Published in:
CIB W94 Seminar on Design Durability, 26-28 April 1993, Milan, Italy

Published: 01/01/1993

Document Version
Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

• A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 15. Dec. 2018
A model for collecting durability data of building components for architects and building managers.

Marleen Hermans
Eindhoven University of Technology
Faculty of architecture and building science
BPU / P. V. 8
P.O. Box 513
5600 MB EINDHOVEN
THE NETHERLANDS

§ 1. Abstract
The paper will present a model describing the data that have to be collected from real buildings to be able to forecast the durability of new buildings during design or management. It will describe the balance between the demand side of buildings (performance requirements) and the supply side (the performances of the building). This balance will consist of a solution which fits the demand best, it will not contain the most "durable" solution. The model focusses on facades of utility buildings. After the introduction of the theory of the research project, the paper will present the decisions taken during the building process (design and realisation) and use period responsible for the durability of building components by means of an hierarchical structure. The choices between different connections and facade types, materials and maintenance scenario's will be related to the surroundings of the building. Their relation to the technical lifespan of building components will be explained.

§ 2. Forecasting the technical behaviour of building components
§ 2.1. Introduction to the research programme
"Forecasting the technical behaviour of building components" Within the research project “Forecasting the technical behavior of building components” we (Eindhoven University of Technology) are working on a model to forecast the technical behavior of building components. Project leader of this programme is Prof. ir. H.A.J. Henket. The model will be used to collect and order empirical data from existing buildings, to transform this data to general information and to apply the information in the design and management of buildings. We study both the technical behavior regarding durability and changeability of building components.
We are specifically interested in the behavior of components rather than in the behavior of materials, since the components together form the materialization of a building and therefore its technical behavior, which is more than the sum total of all the materials used.
We are developing models to weigh the requirements of a building owner or user against the actual performances of the building.

In this paper, I will elaborate on the durability research carried out so far.

§ 2.2 Durability
This research is split up into two parts:
• Top-down research starting from buildings explaining the effect of design decisions on the durability of its components.
• Bottom-up research starting from building materials explaining the effect of decisions on materials and the way they are used on the durability of building components.

Top-down: Forecasting the durability of building components (End date: October 1994):
Researcher: M. Hermans (M.Sc.)
The research presents a model for forecasting the durability of building components. The main object of this research is to order the consequences of design decisions taken during the building process of an existing building to be able to validate the decisions taken in a new design or building management process.
The decisions influencing the durability of building components will be ordered in a qualitative descriptive model in order to define the most important decision for the durability of the component. During the design process alternatives will be developed. All the alternatives developed during the design process are split up hierarchically; on the highest level alternatives concerning the building as a whole are ranked considering their performance in time. On the lowest level alternatives concerning
A model for collecting durability data of building components for architects and building managers.

M. Hermans - Eindhoven University of Technology - The Netherlands

parts of building components will be evaluated on their performances in time. When using the model, a certain required performance level will be chosen and the solutions following from this level will be given. (Or vice versa: After choosing a certain solution the maximum performance level possible will be given)

In paragraph 3 this part of the project will be introduced in further detail.

Bottom-up: Forecasting durability from components starting from materials technology (end date: October 1996)

Building components are composed of several materials in a certain configuration and connected in a certain way. There is quite a lot of knowledge available in the field of materials technology on the durability of materials. This knowledge is usually collected from laboratory or in situ tests and very often show little relation to "real life" durability. Therefore, within this specific research, the relation between materials durability and "real life" components durability is investigated.

From the rough material onwards the building component is formed in several steps:
- giving the rough material the desired characteristics and shape
- protecting the shaped material with a coating or other form of coating
- connecting the coated and shaped component to other components

The research investigates the effects of each step for the components durability.

§ 2.3. Resources

The research project is carried out by a research assistant at the Eindhoven University of Technology. This will be done in a 4 year research period, resulting in a doctorate thesis. The project started in November 1990. And forms an integrated whole with the top down project described before.

Together these two projects form part of a research program called "Forecasting the technical behavior of building components" of which Prof. ir. H.A.J. Henket is project leader. Next to the durability research, Maha Choukry is working as a research assistant at a project called "Changeability of buildings". The total project is made possible with financial help from the Dutch publisher Misset, the foundation for building research SBR and the Dutch research organization TNO, who are also cooperating in the research work. VTT Building Laboratory in Oulu, Finland, offered facilities to work at their laboratory for three months on the development of an inspection method.

§ 2.4. Definitions

Durability: Durability is the amount to which a building component can fulfill its requirements over time under certain (known) circumstances.

Behavior: Performance of a building component over time

Requirements: Performance desired over time

Period of use: Period of time in which the requirements program is assumed to be constant

Changeability: The ability of a building to adapt to a new set of requirements

Functional system: Spacial quality of a building (sizes, relations between rooms and between building and surroundings)

Technical system: Material quality of a building (technical condition of structures)

Connections: Every place where building elements meet or end, counted from the place where the structure of the element changes in form and/or composition for the benefit of the connection.

m²-Package: Form and composition of a building element between two connections.

Composition: The way the different layers of a package are put together

Building component Part of a building, generally not accessible for people, meant for load bearing, partition and/or facilitating use of (parts of) rooms.
§ 3. Forecasting the durability of building components. The top-down approach.

§ 3.1. Introduction
The research project "Forecasting the durability of building components" is carried out under supervision of Prof. Ir. Hubert-Jan Henket. The project focuses on the determination of factors influencing the durability of facades of office buildings. These factors are studied from a building engineers viewpoint, focusing on design decisions rather than material technology. This paper will give an impression of design decisions under consideration.

§ 3.2. Restrictions
1. The model will focus on behavior and activities rather than on life cycle costing
2. The model describes technical behavior only, it does not validate this behavior, the user of the model should be able to set his own requirements for the building.
3. This project will focus on describing the behavior of a building component (the facade) during one period of use. It will not look at functional adaptability.
4. The model will be designed to collect, store and use empirical data

§ 3.3. Research sources
Literature, expert knowledge and data available from real buildings will be used to describe the model mentioned above.

§ 3.4. Short description of the durability model
A building components durability is determined by three main categories of factors:
- Requirements put forward by the building owner, user, society etc.
- Composition of the building component and its surroundings
- External factors, being climatological, chemical, physical, biological and social circumstances
- Management factors including maintenance

The requirements determine which is the minimum acceptable performance level a building component has to fulfill.
The composition of the building component (location, size, materials used, shape) determines the performance capacity of a building component.
External factors determine the amount of deteriorating agents "attacking" the building component.
Management factors determine the way the component will behave in accordance with its forecasted behaviour.

---

Fig. 1 The Durability Model
In two papers called “Forecasting the technical behavior of building components. The overall concept” and “Forecasting the durability of building components. An empirical approach” presented at the “Maintenance, management and modernisation of buildings” conference of CIB W 70 in October 1992 in Rotterdam these categories have been elaborated (1,2).

§ 3.5. Deterioration
The way a building component deteriorates can be described as follows:
1. The material within a component deteriorates due to particles, liquids or gasses from its surroundings
2. The component forms a medium via which particles, liquids or gasses from outside can pass through to another component which deteriorates due to these particles, liquids or gasses
3. The component sends out the particles, liquids or gasses itself which deteriorate another component
4. Due to moisture, temperature or chemical/biological changes the size of a material within a component changes, which causes mechanical damage to its surroundings
5. The component is subject to forces from its surroundings and therefore it poses these forces to surrounding components
6. The component is subject to erosion due to a stream of particles (liquid or solid) from its surroundings
7. The component causes a flow of particles (liquid or solid) to run in the direction of another component. This component is therefore subject to erosion.

Next to this component and/or material deterioration we can also distinguish “functional deterioration”. Functional deterioration can be defined as a deterioration which belongs to the behavior of a connection as a whole and is not strictly combined with material deterioration, but affects the functioning of the building component as a whole. This deterioration depends upon the type of connection used. Due to difference in shrinkage and expansion of the components connected, the connection will open up, allowing water, air or particles to slip through. Defects from this viewpoint are:
- Moisture transfer to the inside of the building or moisture transfer from the inside into the construction
- Air transfer to the inside of the building or air transfer between rooms or spaces within the building
- Lowering of fire protection rate between rooms or between building and surroundings.
§ 3.6. Seriousness of deterioration
Next to the amount of deterioration (deterioration phase and surface affected), we could define the seriousness of deterioration by its risk for consequential damage. This risk can be an economical issue or a safety risk, which would put peoples' health in danger.
In Dutch building industry, safety factors are usually of such a kind that direct risk for health or high economical damages is quite unlikely to occur. Basically, the more the structure of a building is depending on a certain component, the more costly a structural deterioration of this component will be.

For the facade this means we have to distinguish between:
1. Load bearing facades
2. Non-load bearing facades

And on facade construction level between
1. structural parts (safety)
2. parts influencing the comfort of the building or rooms within the building
3. parts influencing ergonomical aspects of the building
4. parts having only an esthetical value

§ 3.7. Maintenance costs.
The accessibility of a building component for maintenance, repair and replacement influences maintenance costs; the accessibility depends on the form and composition of the building and its surroundings, but also of the form and composition of the facade itself. This factor will influence the degree of complexity of the work that has to be done.

The availability of maintenance facilities ("wash balconies", scaffoldings, ladders, gondola) is another factor, influencing necessary amount of man hours to fulfill a maintenance task.

Of course, maintenance costs are not only determined by the accessibility of a component, but also by the complexity of the task to be fulfilled. For certain types of facades (for example, plastic parapet constructions) repair can be extremely cost consuming.

In choosing an appropriate maintenance scenario these factors have to be taken into consideration. If maintenance costs can be expected to be extraordinarily high, the necessity of maintenance has to be minimised. The design and choice of materials should be of such a kind that regular maintenance activities should not be necessary to fulfill the requirement level.

§ 3.8. Importance of connections for durability of facades
The number of connections in a facade gives a first impression of the risk of damage. This can be explained as follows:
1. As connections are the places where particles and liquids can easily enter a building and/or construction, the number of connections compared to the total amount of facade surface gives an indication of the vulnerability of the facade for deterioration.
2. If within the facade a huge number of components is used, compared to the total amount of facade surface, the total amount of $m^1$ connection and $m^2$ of surface to be maintained will be larger.

The type of connection indicates the ability of a connection to cope with agents, forces, water etc.

We can describe connections through the following characteristics:
1. Composition: The components connected
2. Form: The form of the connection used
A model for collecting durability data of building components for architects and building managers.
M. Hermans - Eindhoven University of Technology - The Netherlands

The composition determines the basic compatibility of a component in relation to its surroundings. The location of the components in relation to the location of components connected, determines the rate of protection against deterioration agents. The form determines how the components actually are connected and which influence this has on their behaviour or on the behaviour of the connection as a whole.

The following figure shows the different characteristics meant:

1. Composition
- Concrete wall
- Reinforced concrete floor

2. Form
- Non-overlapping
- Overlapping
- Number of overlapping components

- Flanged
- Non-flanged
- Number of flanged components

- Tilted (inclining with load)
- Non-tilted
- Line of surface shaped connection

§ 3.9. The composition of building components.
The influence of design decisions on the durability of facades can be described in several levels. These levels are linked to the type of decision taken, not to the actual phase of the design and/or building process.

At building level the amount of air pollutants, climatological, biological and social circumstances in the surroundings of a building can be determined to give a first impression of external factors. On a national level these circumstances can be derived from maps.

Fig. 4 Connection types

Fig. 5. Sulphate deposition in the Netherlands. Source: RIVM/KNM

On a regional level this national level will be worsened by the presence of busy traffic roads, rail ways, high rise buildings, factories etc. In case of uncertainty, measurements can be taken on site, but no general specifications can be made.

The key design decisions influencing durability at this level are:
A model for collecting durability data of building components for architects and building managers.
M. Hermans - Eindhoven University of Technology - The Netherlands

- building sizes and facade size in relation to floor surface
- shape of the building (height, depth, number of volumes)
- the connection of the facade to other building components can also be described

The basic influence on durability on this level lies in the length of connections. These decisions are explained by the following pictures:

Fig. 6. Building shape typology. Pictures: Staal (1987)

The relation between building size and facade surface will give an impression of the compactness of the building as a whole. If this figure can be compared to other buildings an optimum shape could be determined. This optimum shape would represent a building with the least facade surface. If facade surface is combined with roof surface, the total "skin area" can be calculated. If optimised, it would give a building with the least outer skin surface per m² or per m³. For durability this would minimise the deterioration risk.

The shape of the building in relation to the amount of separate volumes combined within the total building volume gives an idea of the amount of connections used to get this total building volume. It will therefore also indicate the deterioration risk.

At facade level we can describe:
- facade shape and sizes
- facade smoothness
- facade orientation

The first factor will give a first impression of the number of connections made within the facade and the over- or under measure of the facade compared to the actual facade surface needed to cover the required floor space.

The second factor gives an impression of the vulnerability for pollution of the facade; if the facade surface is very smooth, dust and dirt will be washed away easily. If many parts of the facade are sticking out, dust and dirt will accumulate and the facade will get stained with pollution. This factor is also related to the amount of window surface in relation to closed surface. The facade orientation will give further information on pollution and wind and rain effects.

The following pictures explain these factors in more detail:
At facade construction level a description of the actual composition of the facade can be given. In relation to the number of components used to built up the facade, we can describe the facade type:
- traditional
- parapet
- framework
These types describe not only the total amount of connections used, but also give an impression of numbers of horizontal and vertical parts of a facade.
Next to a description of the composition, also the location of this composition within the total facade area has to be described, in relation to the orientation.

§ 3.10. Choice of materials
Finally the designer can make a choice between materials available. These materials define the basic sensitivity of a construction for a certain agent. Possible assumptions are e.g. (6, 7, 9):

Ceramics are basically sensitive to moisture through absorption. If the moisture freezes, the stone will crack. The moisture can also cause bleeding; lime and other residues will be washed out of the brick, causing patches on the brick itself. Moisture between plaster and stone will loosen the plaster from its back ground. Algae may start to grow at stone when the amount of moisture is combined with a suitable temperature. Strong wind with sand particles might cause erosion of softer types of ceramics. Ceramics, unprotected by reinforcement, put under tension force, will crack.

Metals are sensitive to corrosion due to contact with other metals (galvanic series) and corrosive agents from its environments (SO2, NOx, Chlorides). Pollution is therefore the main degrading factor. High temperatures seem to aggravate the corrosion process.
Wood is sensitive to moisture. Combined with sufficiently high temperatures, wood rot might occur, mould and other biological deteriorators might grow. Water can also wash out substances from the wood which are essential for its durability. Furthermore, wood is susceptible to radiation, which will cause loss of color and even cracking through excessive drying.

The main deteriorator for plastics is radiation. This will not only cause discoloring, but may also provide the necessary environment for relaxation of the plastic.

The most important deteriorating factor appears to be moisture.

§ 3.11. Combination of material choice and design decisions

If this sensitivity is compared to the expected amount of agent from maps, regional figures and design criteria, the most likely places and types of deteriorations can be determined. This will lead to a number of rules of thumb.

For wood structures the amount of moisture is one of the main deteriorating factors. We can expect most problems in wood due to water coming from the outside from the building in horizontal parts (keeping water the longest), placed low in the facade (large amount of water), unprotected by roof or balconies from rain and sun. Wooden parts of a facade placed close to a "wet room" are also more likely to fail than other parts.

For ceramic structures also the amount of moisture is important, especially combined with changes of temperatures from below to above zero and back. We might expect these circumstances to occur first at the south facade, at the lower parts, unprotected by roof or balconies as temperature variates most at this facade, but also the east and north side, staying wet longest might show to be very vulnerable to freeze-thaw deterioration. Or even the west side (wind direction in The Netherlands) as it is most exposed to driving rains and therefore receiving huge amounts of water. Empirical investigation should clarify which of these factors is decisive.

For metallic structures the amount of agents is important and their connections to other (metallic) structures. The amount of agents is highest where the facade is not cleaned regularly (by maintenance or rainfall). These can be those parts of the facade which are not reachable for maintenance, or parts of the facade which are protected from the rain by balconies or a roof. Horizontal parts will collect dirt (and pollutants) more easily than vertical parts. It is also advisable to check if metals are covered with a protection layer before they were cut or after. In the first case the "cut sides" will be unprotected and more sensitive to deterioration. In unprotected facades the upper parts will be cleaned less than the lower parts. On the other hand the lower parts might suffer from more pollution from traffic and railways in the surroundings.

For plastics the amount of radiation is most important. This radiation might cause high temperatures (expansion), relaxation and discoloring. The south facade will be most exposed.

If these design and material characteristics are combined with possible maintenance scenario's possible performance schedules over time can be given. Or, vice versa, if the required life span and performance level are known, the materials and design choosen point out which maintenance scenario is necessary to fulfill this requirement level.

§ 3.12. Collection of empirical data

The main goal of this research project is not to re-state already existing rules of thumb, but to set a model for collecting data from existing buildings. The hypothesis described in the paragraph before, should therefore be tested in practice. The result of this testing should be an indication of the real importance of a certain factor for a certain type of facade in a measurable amount. This measurable amount could for instance be a difference in technical life span, or a required maintenance budget to upkeep a component to its requirements.

The description of the method to be used to collect data from existing buildings forms the next part of the research.

Investigations have started already via a three-month research period at the VTI building laboratory in Oulu. This research period resulted in a report on material technology and existing inspection methods. Later this year the second part of this report, combining material technology, existing inspection methods and design decisions will be completed. (9)
$§$ 3.13. Conclusions
This paper gives a first impression of the design decisions influencing the durability of office facades. These decisions form part of an expiatory system containing requirements, design decisions and external factors which can be used to forecast durability of new buildings from data derived from existing buildings. The method to collect this data will be the next phase in this research project.

$§$ 3.14. References


3-day seminar on Design for Durability - CIB W94 - Milan - Italy - 26-28 April 1993