

MAINTAINABILITY OF BUILDINGS

SUMMARY

The study focused on two main tasks:

1. improving the knowledge on maintainability, and
2. setting the maintainability benchmarks.

IMPROVING THE KNOWLEDGE

There is a need to improve the knowledge of maintainability, mainly due to the following:

- Facing difficulties in maintenance with increasing numbers of occurrences of defects, maintenance managers are becoming painfully aware of the lack of knowledge and tools in their organisations.
- Designers are not well focused to achieve maintainable designs, owing to their inadequate awareness of the maintainability problems during the service life.

SETTING MAINTAINABILITY BENCHMARKS

It is of compelling logic to improve the level of maintainability right from the design stage. The rationale of the benchmark is to enable the decision maker to choose a more maintainable design option. Yardsticks like scoring systems would assist in the selection of highly maintainable building designs.

RESEARCH FRAMEWORK

The research seeks to create an awareness of the current obstacles to good maintainability under tropical conditions. This is to be achieved by a compilation of a defect library with information about types of defects and their causes, maintenance and diagnostic methods, good practices and guidelines which can be applied during the design and the construction stage to control repetitive problems (Figure 1).

A maintainability grading system would establish itself as a benchmark by which the maintainability of buildings can be measured and compared. The system would provide

- an indicator to the extent of the maintenance of a building required through the design details before it is actually built.
- a device by which the maintenance costs over the entire building's life span can be predicted.

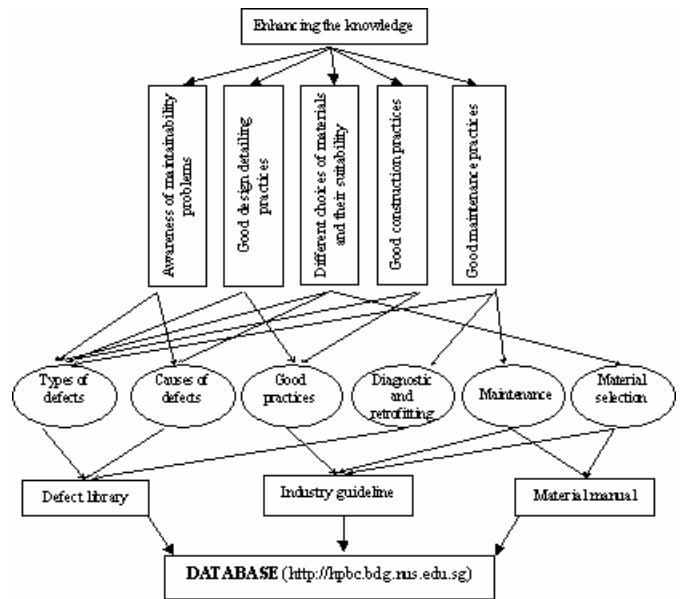


Figure 1. Framework of improving the knowledge on maintainability.

DEFECT LIBRARY

Common defects in different elements in a building were captured and all-inclusive explanations were compiled and gathered under a “first section” in the database which is called “Defect Library” which comprises seven individual inter-phases (Figure 2). Under the heading of Defect Library, the user can select any one of the intended building elements. Two building elements of façade and wet areas are discussed in the following paragraphs.

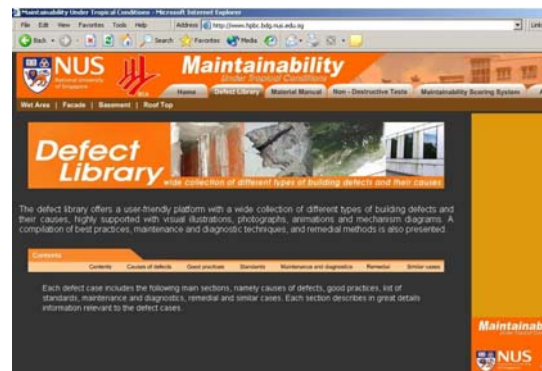


Figure 2. Interface of database.

Façade

Under the façade section, the defects were classified according to the various materials used (Figure 3).

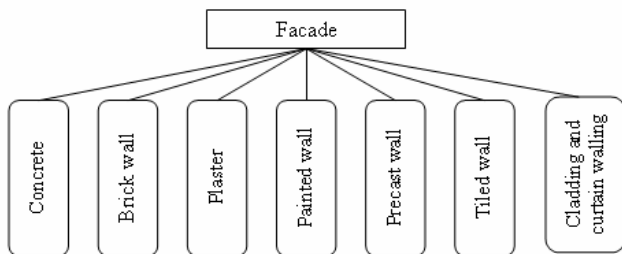


Figure 3. Various materials and systems in façade.

The navigation menu will allow users to explore the various defects relating to the available façade materials (Figure 4). In the first two sections, the problem type and possible causes were explained and illustrated with photographs, animations and diagrams. Good practices were compiled into the next section with many visual illustrations to provide guidelines to the building practitioners and the owners to prevent the occurrence of repetitive errors and omissions. In the fourth section, maintenance and diagnostic techniques were illustrated, giving an insight into the preventive measures and maintenance actions that could ensure continued performance of the structure in the sound condition (Figure 5). In addition, remedial techniques were also illustrated with videos, giving useful recommendations to the user to repair and prevent the aggravation of defects. A point to highlight in this defect library is the section on similar cases, where it serves as a “databank” in which defect records could be updated. This may help the user to explore the extent of the defect and apply the various recommendations in the first four sections appropriately.



Figure 4. Navigation menu for the façade section.

Wet Area

Defects in the wet area, which is an internal building element, are classified according to structural, wall and architectural, mechanical and engineering services (Figure 6). A similar approach to that in the façade section in detailing the causes of defects, good practices and maintenance methods was adopted (Figure 7).

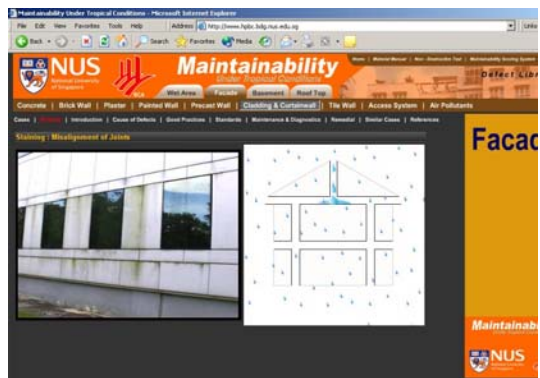


Figure 5. Typical case of staining of metal cladding.

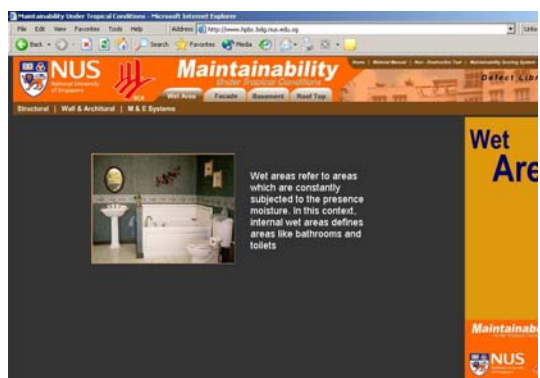


Figure 6. Navigation menu for wet areas.

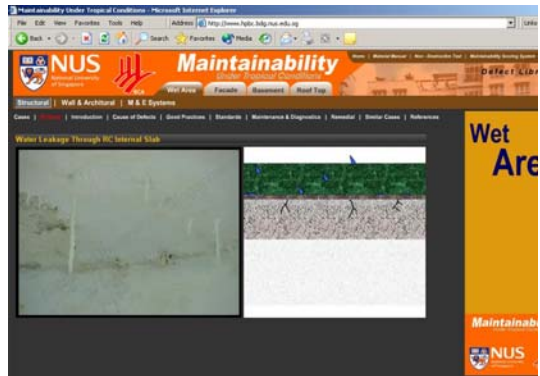


Figure 7. Typical case of water leakage through cracks.

Material Manual

The information about selection of materials and their suitability under tropical conditions were gathered into the next section in the database, known as “Material Manual”. It focuses on the various performances including durability, sustainability and cleanability of materials under tropical conditions as climatic conditions in the tropics are much harsher than those in the temperate climate due to the large diurnal temperature range and high relative humidity; the same materials would perform differently in differing climatic conditions. This guideline will provide a comprehensive reference for the various

industry participants (designers, building owners and managers), and will enable them to select appropriate materials that contribute to the long-term performance of a building throughout its lifetime.

The material manual deals with the various components of a building (Figure 8).

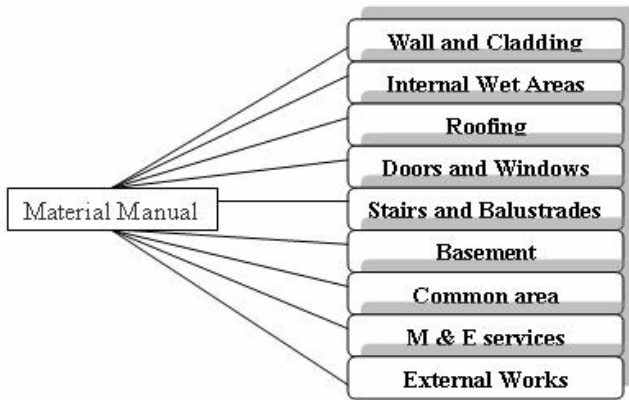


Figure 8. Contents of the material manual.

Each link leads to the various subcomponents typically used in Singapore and described quantitatively in terms of material type and durability, properties, maintenance and cleaning methods and the potential types of failures and repair methods (Figure 9).

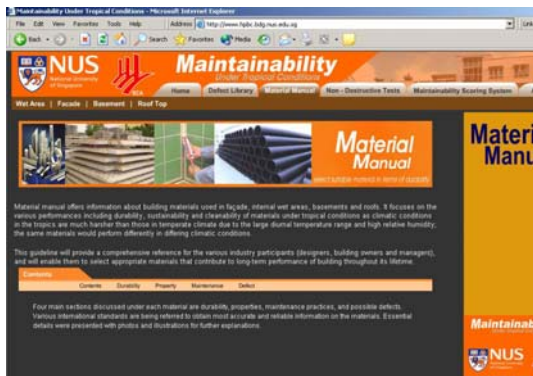


Figure 9. Navigation menu for material manual.

The following frame shows a typical example of aluminium panels as the infill panels under the curtain cladding section (Figure 10). Technical knowledge could be found in the various links in the side menu. References are also provided for further reading.

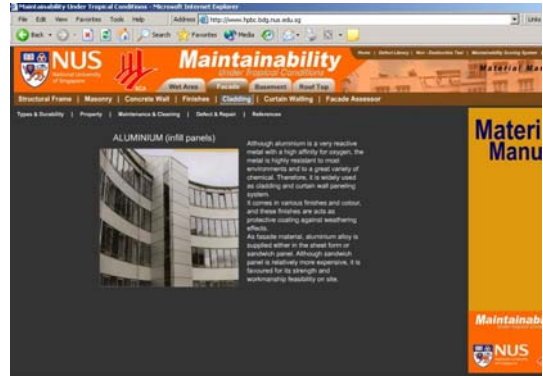


Figure 10. Typical case of aluminium for material manual.

Maintainability Grading System

The grading system takes on the approach of modelling the optimum maintainability upon minimum Life Cycle Costs (LCC) (Figure 11).



Figure 11. Example of the façade maintainability grading system.

The principle of risk management was applied here, where the risk is high level of maintainability:

- design (water-tightness, stress accommodation, water flow control, accessibility, downtime and material performance)
- construction (quality)
- maintenance (quality)
- environment and usage
- building's profile.

Figure 12 illustrates the preliminary risk factors that should be considered throughout the phases of design, construction and maintenance.

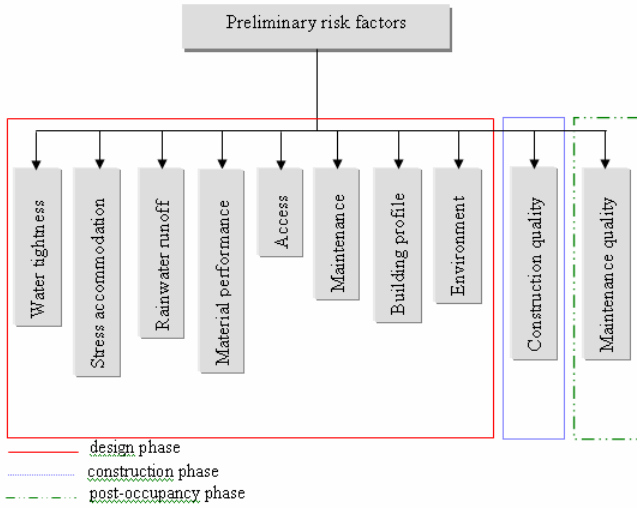


Figure 12. Maintainability risk factors.

The LCC associated with maintenance cost which includes routine cleaning, repair and replacement is used to work out the level of maintainability. With the total number of defects at a given base period, the following normalization can then be set to assign the grading of the maintainability (Maintainability Score, MS),

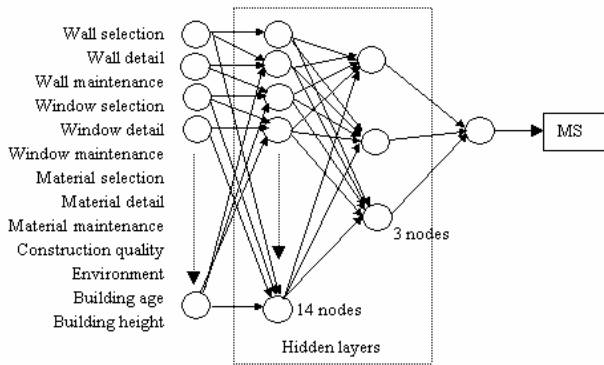


Figure 13. Network architecture for façade.

$$MS = 1 - \left[\frac{\sum_{i=1}^d RRDC_i + CC}{\sum_{i=1}^D RRDC_i + BCC} \right] \quad (2)$$

where d = the current number of defects in a building,

D = total number of defects in the building at the base period,

$RRDC_i$ = the respective repair replacement and down-time cost of i th defect,

CC = actual cleaning cost,

BCC = the basic cleaning cost derived from required cleaning cycles.

The neural network model is designed to compute the level of maintainability as an output in response to input parameters that reflect the severity of risk to the future maintainability. It can be expressed mathematically as a mapping function:

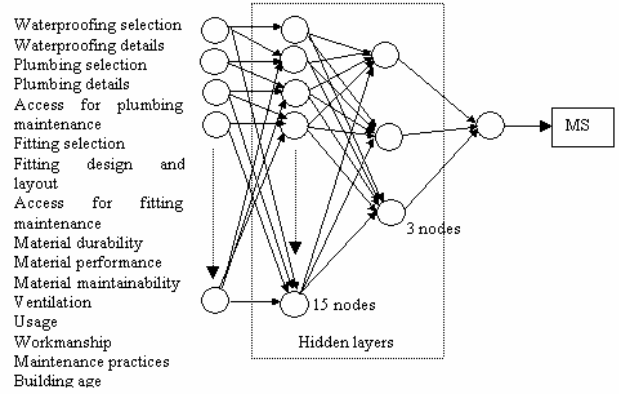


Figure 14. Network architecture for wet area.

$$f_E : \mathfrak{R} \mapsto M \quad (3)$$

where domain \mathfrak{R} is a set of n^{th} dimensional vector $[r_1, r_2, \dots, r_n]$ of risk inputs representing a risk domain of the maintainability, and M is a set of scalars providing points to the underlying maintainability function.

Figures 13 and 14 show the optimum network architecture for façade and wet areas respectively.

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