Case Definition and Holistic Model Modifications Required for Building Elements

Report No 2005-003-B No 3

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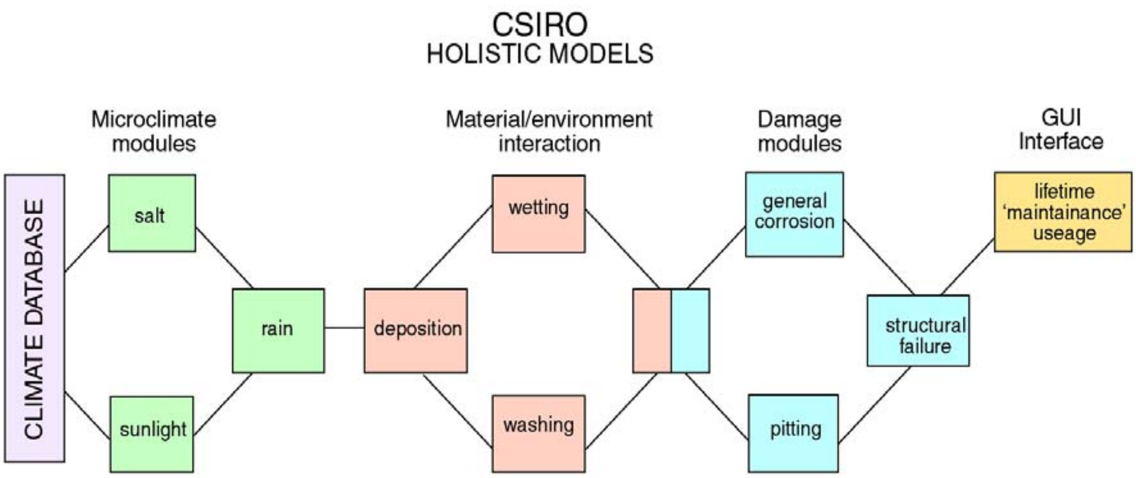
1 INTRODUCTION

This project is an extension of a previous CRC project (220-059-B) which developed a program for life prediction of gutters in Queensland schools. A number of sources of information on service life of metallic building components were formed into databases linked to a Case-Based Reasoning Engine which extracted relevant cases from each source.

1.1 Holistic Model

One of the databases was created using the CSIRO-developed holistic model of metallic corrosion which is based on an understanding of the basic corrosion processes ranging in scale from atomic electrochemical reactions to the macro scale of continental environmental factors. Figure 1 illustrates the modules of the holistic model which are divided into three broad groups: microclimate, material.environment interactions and damage modules.

Figure 1: Structure of the modules of the holistic model for predicting corrosion

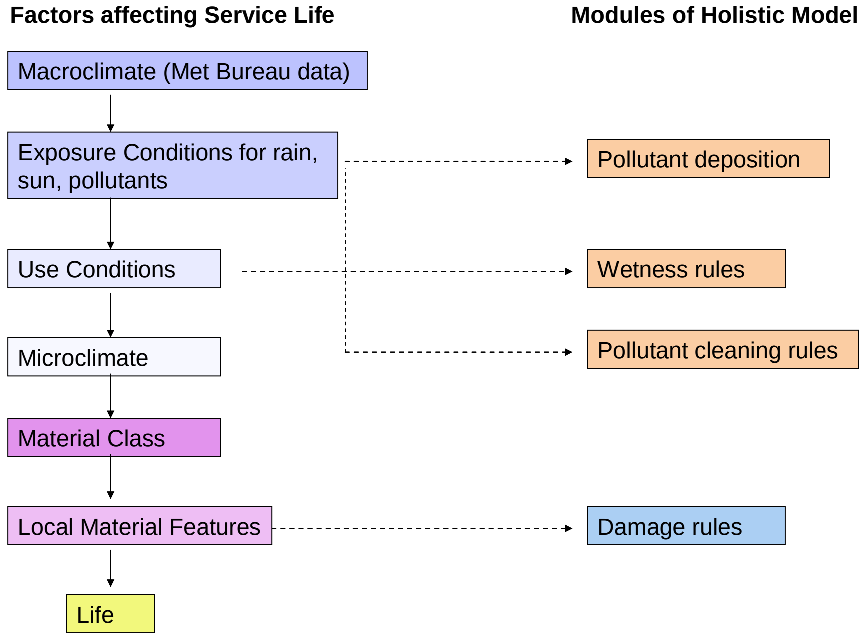


In the previous work based on gutters, modifications were made to several of the modules to tailor the calculations for the specific environments of gutters.

1.2 Case Definition

Intrinsic to the use of case-based reasoning is the definition of the attributes for cases for a particular application. Cases need to be defined such that the CBR engine can search the casebase and other databases for examples relevant to the case under consideration. Figure 2 illustrates the different factors affecting the service life of a building component. These are shown on the right hand side of the diagram. The different modules of the holistic model that may need modification for factors specific to different building components are shown on the left side of the diagram with arrows indicating which factors are likely to affect which modules.

Figure 2. Factors affecting service life of metallic components and how they relate to modules of the holistic model.



A building component will be situated on a building experiencing climate depending on its geographic location. This can be referenced from the Bureau of Meteorology. The climatic conditions experienced by the building component eg, rain, sunlight and pollutant depositions may be altered by its positioning on the building and whether it is in an open, exposed position or sheltered in some way – either from the rain, sun, or pollutant bearing winds or combinations of these. These parameters will impact on the modules in the holistic model dealing with pollutant (salt) deposition and removal (natural cleaning or washing).

The microclimate conditions experienced by a component can also be influenced by maintenance and cleaning (use conditions) especially if the component is in a dirt accumulation zone. The accumulation of dirt and leaf litter can dramatically increase the time it takes for a component to dry after rainfall. This was experimentally determined for gutters in the previous project phase (CRC Report 2002-059-B No 16) and the time-of-wetness is a significant parameter in the wetting module of the holistic model. All these factors (exposure and use conditions) determine the microclimate experienced by the building component.

How the microclimate affects the building component will depend on the material of the component eg galvanised steel, Colorbond, zincalume, aluminium, etc. and any local material features eg edge effects, material incompatibilities where components are joined etc. These factors are considered in the damage modules of the holistic model.

The ultimate outcome of how the microclimate affects the material and local features is the corrosion rate which determines the service life of the component.

This document summarises the previous work on case definition and then considers each of the building elements selected for extension of the project work with regard to special attributes which may need to be included in case definition, and which will affect the similarity rules used in comparison of cases. It also looks at how these special attributes will impact on the holistic model and changes that will need to be made to derive the database based on the holistic model for all the different building elements.

2 CASE ATTRIBUTES

The case definition starts with the building component. That building component will then have several more case attributes and in the previous phase of the project these were defined as:

- Geographic location
- Location in building
- Maintenance, and
- Cleaning.

By considering the attributes relevant to the formation of microclimate and corrosion, a range of case classes were defined for each parameter.

2.1 Location in Building

Building structures have been considered with regard to the situations that will affect the amount of aerosol deposition of pollutants. Thus building locations have been divided into twelve types and these are listed in Table 1.

Table 1. Description of building elements for case definition

Case	**Description**
Open Rooftop	The top of any surface that bridges between the tops of two or more walls and has an average slope of 45 degrees or less. This includes flat, hip, gable, monoslope, multispan, sawtooth, arched mansard and conical roofs. It includes projections and indentations of 0.3 metres or less. The roof is to have a minimum dimension of at least two metres.
Open Wall	Any flat non-sheltered surface with a slope of less than 45 degrees off vertical including any projections or indentations that depart less than one metre from planarity. The wall is to have minimum dimension of at least one metre. Also includes bridge piers.
Sheltered Wall	Any area that is covered with a covering that stops all direct sunlight when the sun is less than 45 degrees from the zenith
Edges and External corners of walls or roofs	Comprises the area within one metre of any external corner. This excludes re-entrant corners, corners on isolated steelwork, and corners on some roofs (such as saw-tooth roofs). The angle of the external corner is to be between 0 and 135 degrees. It includes corners of bulk objects projecting from roofs.
Dirt	Any area in which water, dirt, leaves or dust can accumulate. This surface usually has

Accumulation Zone	an angle of less than 3 degrees to the horizontal but as corrosion develops it can grow to encompass much steeper angles
Roof cavity	Any object lining or found within the cavity between the ceiling and roof of a building.
Wall cavity	Any object lining or found within the cavity between the inner and outer walls of a building. Also includes cavities in multistorey buildings between the false ceiling and the floor above.
Moisture Accumulation Points in Wall Cavities	e.g bottom Plates
Underfloor cavity	Any object lining or found within the space under the ground floor of a building. Excludes any such space that is artificially heated or ventilated.
Underfloor cavity in contact with soil	
Semi-enclosed space	Seem most frequently as a lower floor in a multistorey car park. Defined as any object in a space with at least one large opening to the atmosphere. Excludes any such space that is artificially heated or ventilated.
Enclosed room	Includes rooms in domestic residences, commercial establishments, factories and warehouses, and elsewhere. Estimating the corrosion in an enclosed room requires further information on heating, artificial ventilation, and local sources of aerosols, gases and moisture.

2.2 Cleaning

Corrosion is also affected by how much of any pollutant deposition can be removed by the natural cleaning of rain, condensation and wind. Classifications with regard to cleaning levels are listed in Table 2.

Table 2. Definitions of cleaning

Case	**Description**
Open Rooftop	Any area exposed to sun and rain with a slope between 3 degrees and 45 degrees (but see (6) below
Open Wall	Any area that is not sheltered with a slope of less than 45 degrees off vertical.
Sheltered	Any area that is covered with a covering that stops all direct sunlight when the sun is less than 45 degrees from the zenith.
Crevice	Any gap small enough for capillary attraction to drag water upwards
Drop-off Zone	Any area from which water will drop. This typically occurs under the edges of overhangs
Dirt Accumulation zone	Any area in which water, dirt, leaves or dust can accumulate. This surface usually has an angle of less than 3 degrees to the horizontal but as corrosion develops it can grow to encompass much steeper angles.

2.3 Maintenance

If a metallic building element is subject to a regular maintenance schedule that will pick up and deal appropriately with the first signs of corrosion, then it is likely to last longer than one that is not maintained in the same situation. Thus maintenance (or lack of) is considered an important parameter for definition of a case. It is particularly an issue for building components, such as gutters, where dirt and debris can collect over time and affect drainage and the rate of drying after rainfall or condensation.

Thus two cases are defined: Maintained and Not Maintained.

2.4 Geographic Location

The most important aspect for geographic location is considered to be whether or not the building is in a marine environment or not (benign, salinity < 15 mg/m2.day). Thus two case attributes are defined: Marine and Non-Marine.

3 SIMILARITY INDEX

In the previous project, a similarity number (S) was defined such that:

$$S = M_s \times C_s \times L_s \times G_s$$

Where:

Ms = maintenance similarity index;
Cs = cleaning similarity index,
Ls = location similarity index, and
Gs = geographic similarity index.

If two parameters match exactly, the similarity index will equal 1. If two parameters are different but have similar effects on the likely corrosion rate, then the similarity index will be close to 1 (0.8-0.9). The lower the similarity index, then the greater the difference between two situations in terms of the likely corrosion rates. Since the individual similarity indices are multiplies together to provide the overall similarity index, S, variations individual indices result in a cumulative lowering of S. The cut-off point for S at which a case is not retrieved from the casebase can be defined to broaden or narrow the cases chosen.

Tables of similarity indices relating attribute value to the others have been devised and can be found in Report 2002-059 No 16.

4 CASE DEFINITION FOR COMPONENTS

In a previous report (CRC report No 2005-003-B No 1) the building elements to be incorporated in the life prediction software were discussed. These were

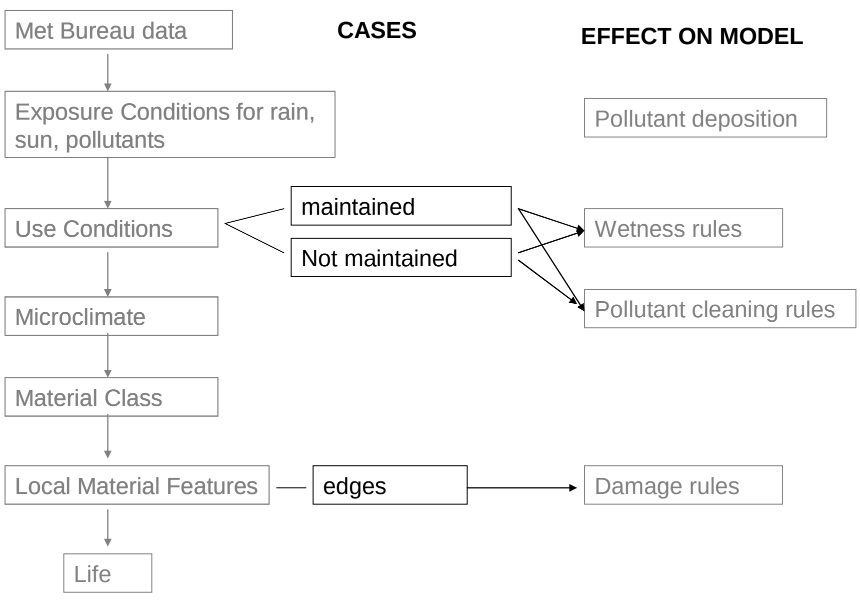
1. Gutters (already in original software)
2. downpipes
3. roof sheeting
4. fasteners
5. ridge capping
6. flashing
7. window frames
8. steel supports
9. sub-floor members
10. gang nail plates and strapping

These additional components will be considered individually to determine what factors are pertinent to the case definition for each.

4.1 Downpipes

The important parameters for downpipes are similar to those for gutters and are illustrated in Figure 3. Downpipes are a component where dirt can accumulate so maintenance (or lack of it) can strongly influence the service life. Edge effects may also be observed.

Figure 3: Parameters of importance to downpipes for case definition

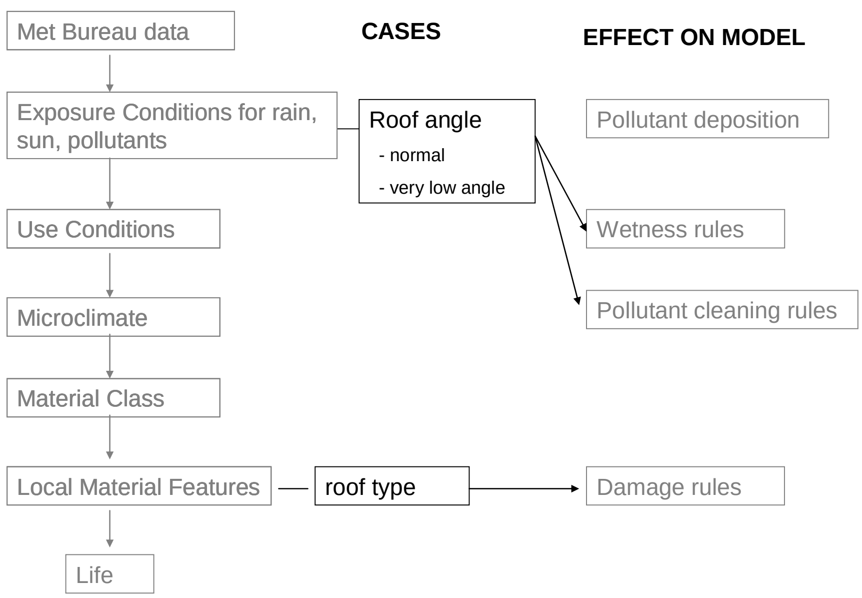


Work will be carried out (similar to that done for gutters) to instrument a downpipe to gain experimental data about the effects of leaf litter and blockage on drying times after rain, for inclusion in the holistic model.

4.2 Roof Sheeting

Figure 4 illustrates parameters important to roof sheeting degradation. The most relevant is the angle of the roof which will determine the drainage of water. Two cases will be defined: normal (any roof at an angle > 1°) and very low angle (≤1°). The roof type eg. corrugated, Cliplock etc may affect the corrosion rate and this will be incorporated.

Figure 4. Parameters of importance to roof sheeting for case definition

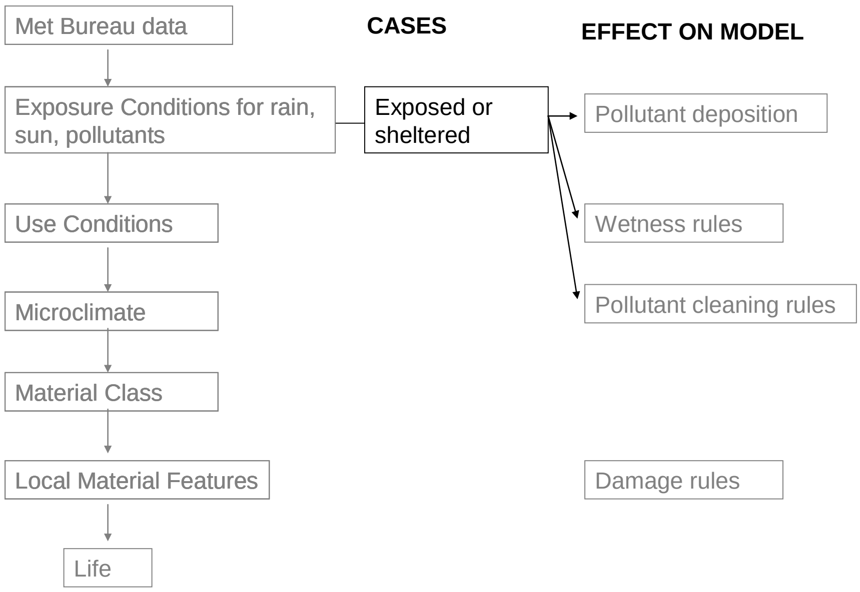


The effect of a very low roof angle will be modelled to consider how this will impact on the time-of-wetness. The possible chemical effect of leaf litter will also be evaluated by measuring the pH generated in wet conditions by leaves from a range of tree species.

4.3 Fasteners

Fasteners, eg. nails, bolts, can be in a range of positions on a building structure and the most pertinent parameter is likely to be whether they are in an exposed or sheltered position (see Figure 5).

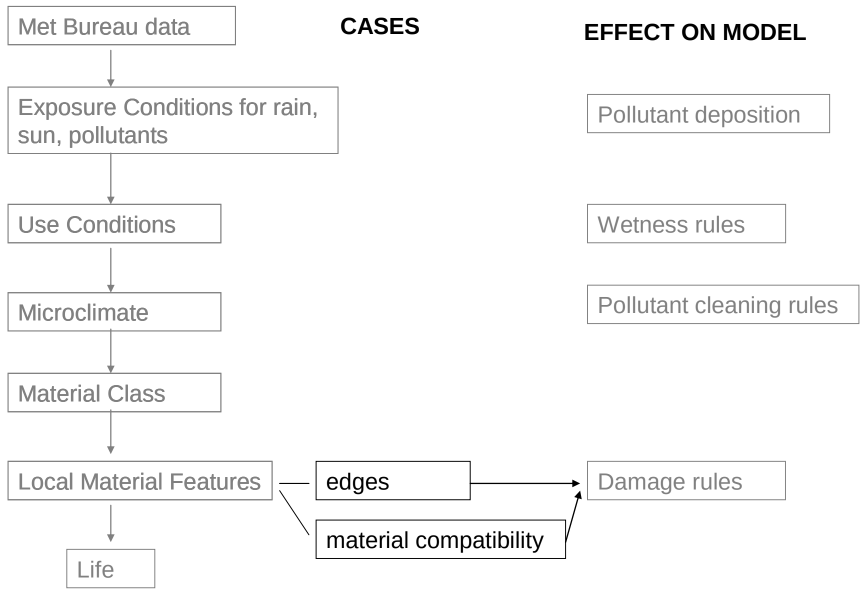
Figure 5. Parameters of importance to fasteners for case definition



4.4 Ridge Capping

Ridge capping is considered to be in an open exposed position (rooftop). There are likely to be edge effects and there is the possibility that ridge capping of a material incompatible with the roof material may be used and corrosion enhanced (see Figure 6). These instances will require modification of the damage modules of the holistic model.

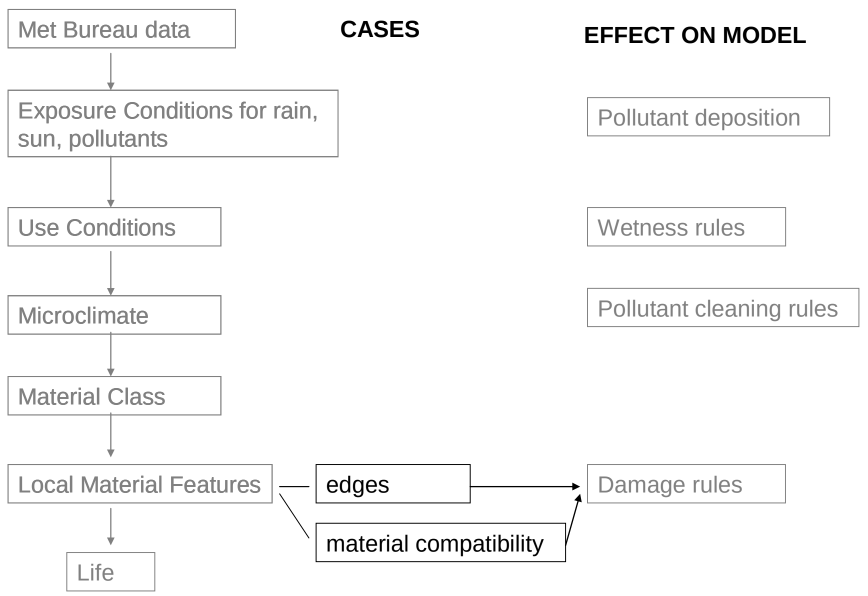
Figure 6. Parameters of importance to ridge capping for case definition



4.5 Flashing

The situations for flashing are similar to those for ridge capping (Figure 7).

Figure 7. Parameters of importance to flashing for case definition

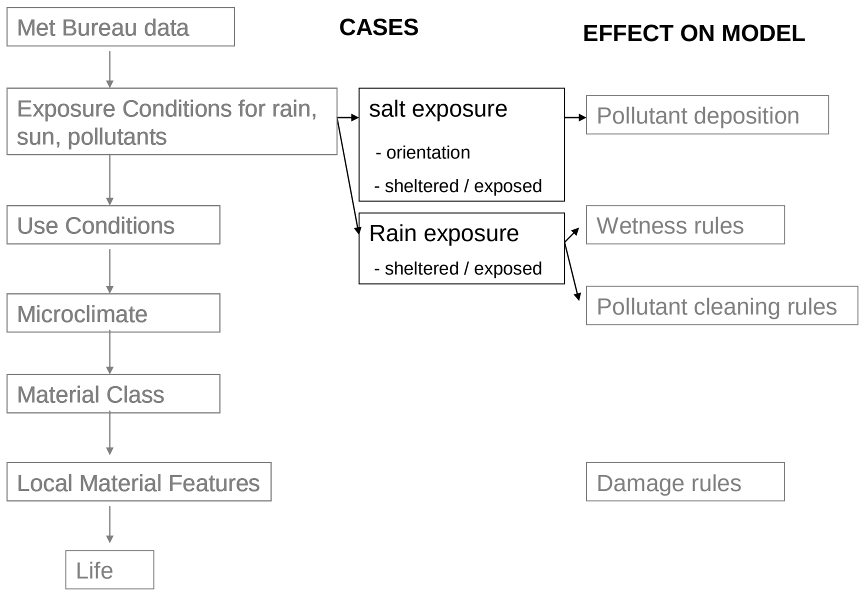


4.6 Window Frames

The positioning of windows on a building could have a large effect on the rate of corrosion of the window frames. (Figure 8) In particular the orientation and exposure of the window with respect to salt-bearing winds, and whether the windows are sheltered from salt-removing rain will determine the levels of salt and moisture. An orientation parameter will be designated for window frames and is relevant also for roofs and exposed walls:

- High – facing salt-bearing winds ±30°.
- Medium – angle to salt-bearing winds between 30 and 60°.
- Low – facing away from salt-bearing winds, ±30°.

Figure 8. Parameters of importance to window frames for case definition

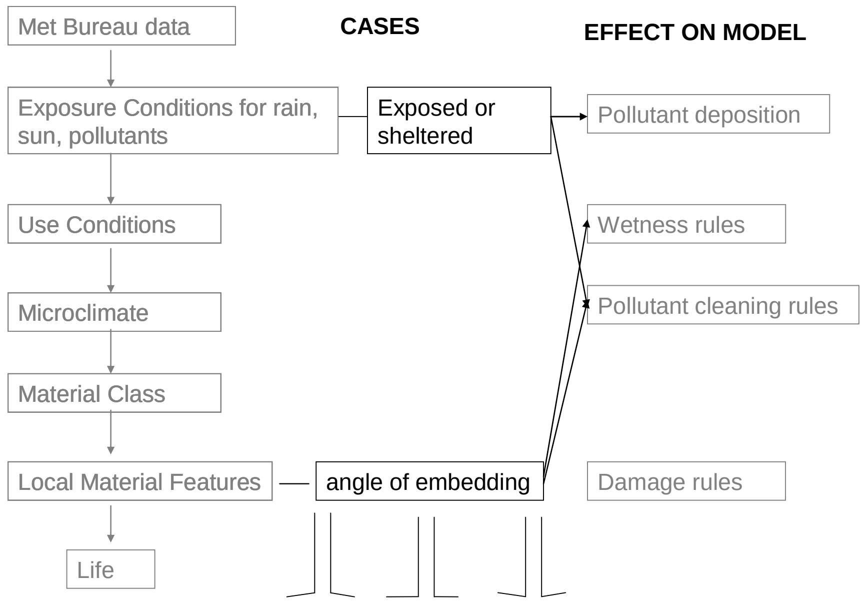


The main material for window frames is painted aluminium 6060 which is a material not covered by previous work with the holistic model. Experimental work will be carried out to formulate relevant damage rules.

4.7 Steel Supports

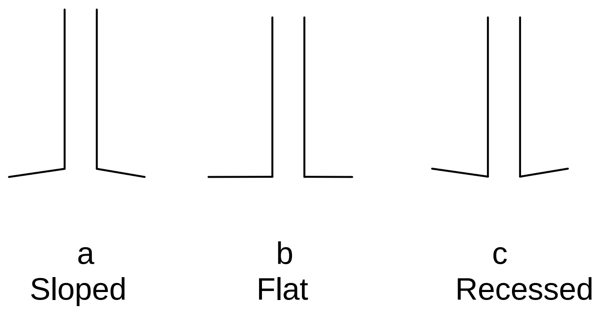
Steel supports can be in an exposed or sheltered position (see Figure 9).

Figure 9. Parameters of importance to steel supports for case definition



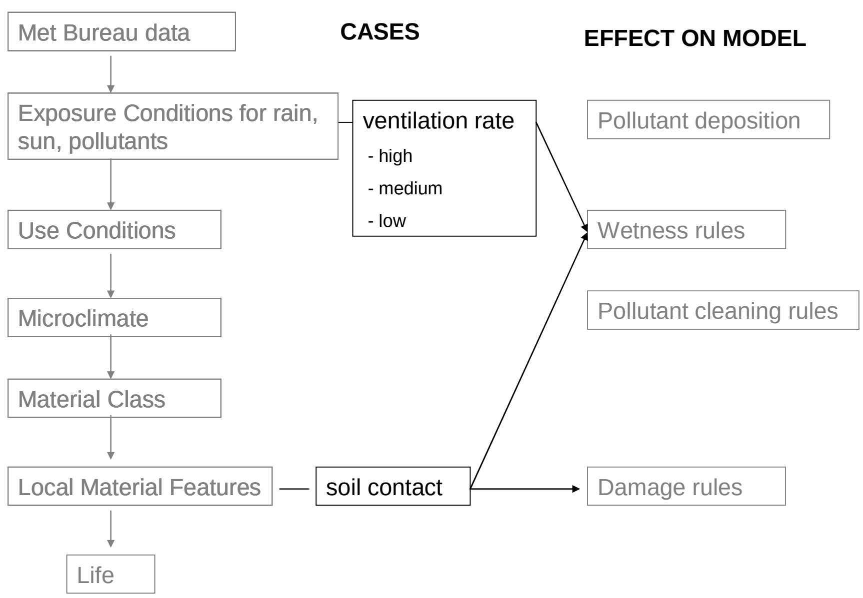
The workmanship on installation can significantly impact on the likely corrosion of the base of steel supports embedded in concrete. The recommended practice would have the concrete sloping away from the base to provide good drainage. In practice, the concrete may be level or even sloping up which will promote pooling of rainwater around the base of the support. These are illustrated in Figure 10 a, b and c respectively. These three cases will be included in the definition of steel supports and modelled separately.

Figure 10. The three cases for embedding of steel supports in concrete



4.8 Sub-floor Members

Figure 11. Parameters of importance to sub-floor members for case definition



The sub-floor area will be dominated by the ventilation rate which determines how long building components in this area stay wet. (Figure 11) Three cases have been defined for the ventilation rate:

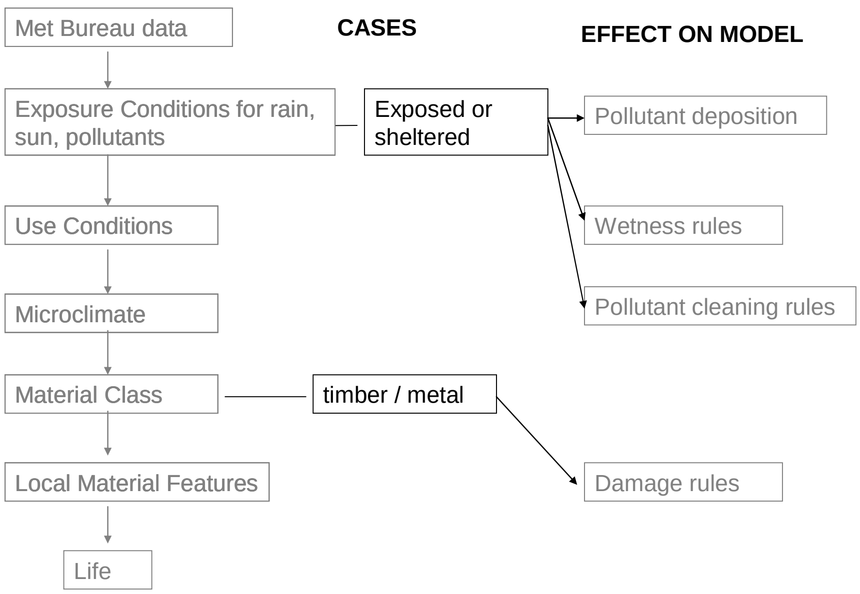
- Low – it takes more than 12 hours for a hygroscopic wetted surface to dry at “typical” humidity conditions, i.e. 70%RH, 20°C.
- Medium - it takes 3 -12 hours for a hygroscopic wetted surface to dry at “typical” humidity conditions, i.e. 70%RH, 20°C.
- High - it takes <3 hours for a hygroscopic wetted surface to dry at “typical” humidity conditions, i.e. 70%RH, 20°C.

Soil contact will also affect corrosion rate and a separate case was designated for sub-floor areas in contact with the soil. Modifications will be made to the damage modules of the holistic model to account for effects of soil contact.

4.9 Gang nail Plates

Gang nail plates can also be in an exposed or sheltered situation (Figure 12) leading to modifications in the holistic model modules. The rate of corrosion of a gang nail plate will also be affected by the metal-type and the timber type to which it is connected. Modifications to the damage rules will be required.

Figure 12. Parameters of importance to gang nail plates for case definition



4.10 Summary

The analysis of the new elements leads to the definition of a new similarity index designated D_s. This will vary depending on the element concerned and the overall similarity index becomes:

$$S = M_s \times C_s \times L_s \times G_s \times D_s$$

Thus Ds can relate to:

- Ventilation rate (for sub-floor members)
- Drainage rate (vertical steel supports)
- Orientation factor (window frames, exposed walls and roofs), and
- Roof angle (roofs)

5. REFERENCES

Cole I., Ball M., Carse A., Chan W.Y., Corrigan P., Ganther W., Muster T., Paterson D., Trinidad G., Maher M.L., and Liew P.S., CRC for Construction Innovation, Final Report 2002-059-B No 16. Case-Based Reasoning in Construction and Infrastructure Projects, 2005.

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