Thermal Performance of the Exterior Envelopes of Whole Buildings XIII
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A SYSTEMATIC METHOD OF ASSESSING THE DURABILITY OF "WOOD-FRAME" WALL ASSEMBLIES:

TOWARDS THE LIMIT-STATES DESIGN APPROACH

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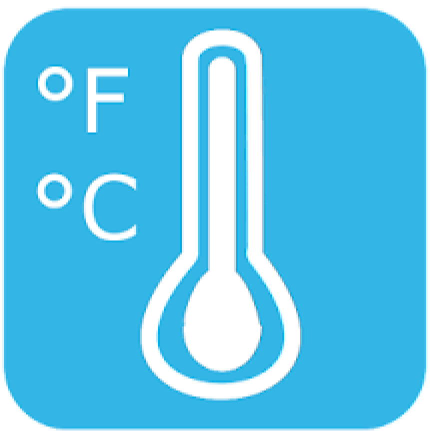
Background

In constructions, water must not reduce the durability of the structure!

The long-term performance of a building component depends on the hygrothermal response of the component when subjected to interior environmental and exterior climatic loads.



Relative humidity	Wood moisture content
0 %	0 %
25 %	5 %
50 %	9 %
75 %	14 %
87 %	20 %
99 %	23-30 %

The MEWS-project

Moisture Management for Exterior Wall Systems (MEWS)

The main emphasis of the MEWS project was to estimate the hygrothermal responses of several different wall assemblies that were exposed to various climate loads as occur in North America and that engendered a range of rain penetration loads within the wall; such estimates of response were derived from the outputs of a hygrothermal simulation model.

MEWS has resulted in an integrated methodology for assessing and predicting the long-term performance of any wall assembly at any location in North America. The methodology has been applied to stucco-clad wood-frame construction and several design considerations followed.

Intent of presented work

This work is intended to demonstrate that the approach used in the MEWS project, in which the RHT index is applied as a measure of the response of the wall to hygrothermal effects, is consistent with the broad precepts described in ISO 13823.

Example of stucco-clad wood-frame wall assembly

INTERNATIONAL STANDARD **ISO 13823**

First edition
2008-06-15

General principles on the design of structures for durability

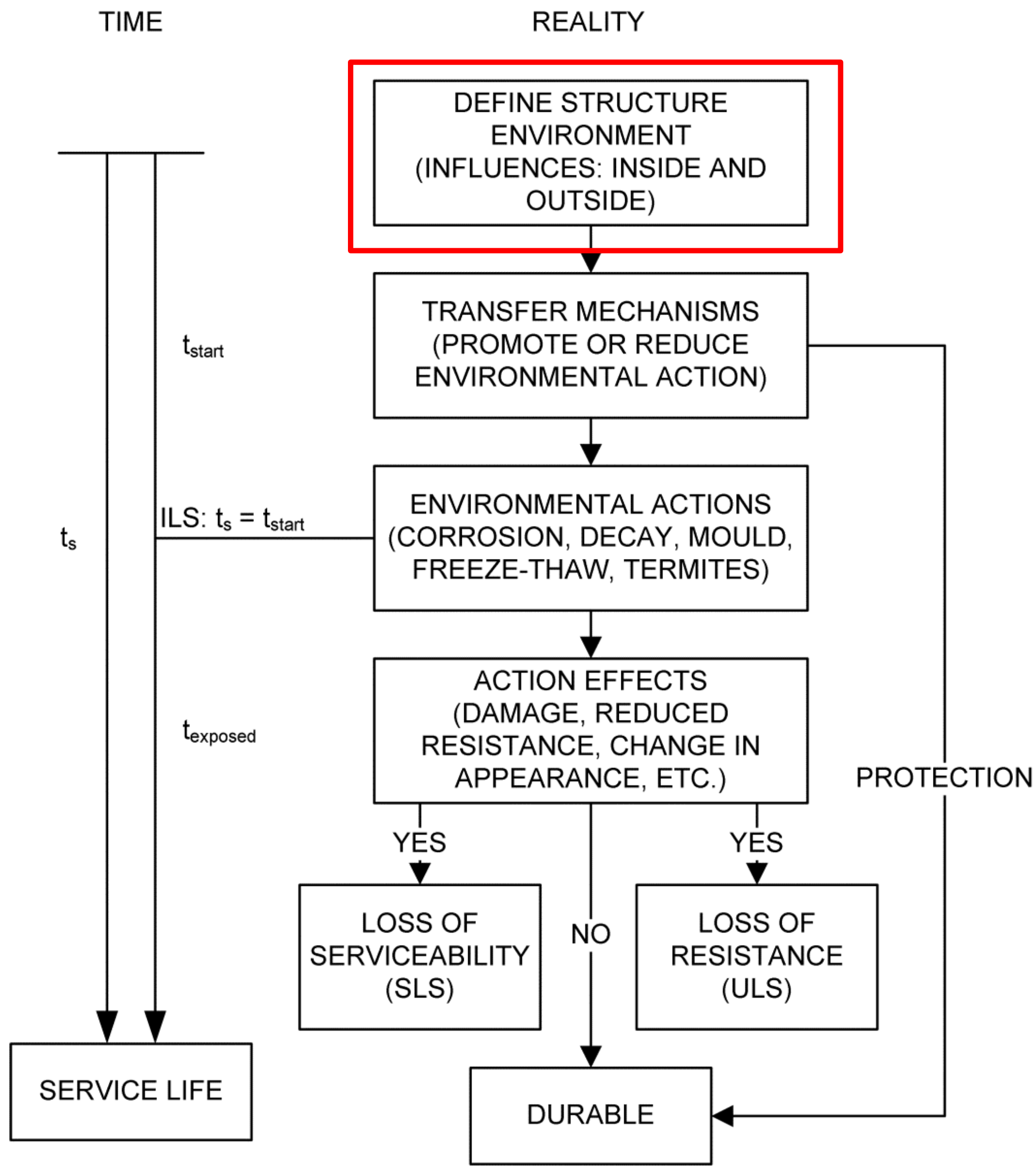
Principes généraux du calcul des constructions pour la durabilité

Limit State Design

The concept of the limit-states method is to verify the performance against a threshold value

Define structure environment (influences inside and outside)

ISO 13823,
General Principles on the Design of Structures for Durability



Limit State Design

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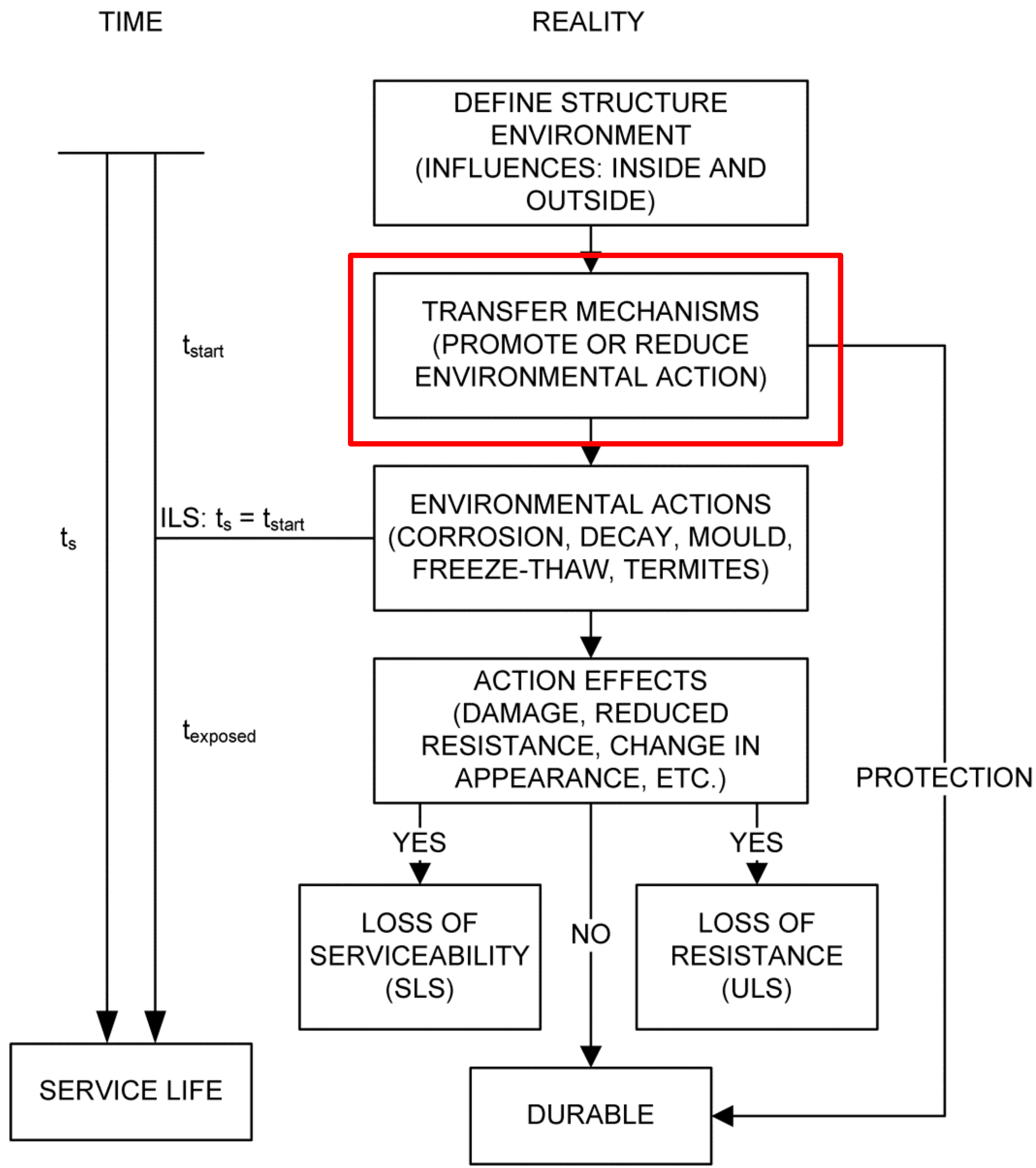
Transfer mechanisms (promote or reduce environ. action)

ISO 13823,
General Principles on the Design of Structures for Durability



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Environmental actions (corrosion, decay, mould, freeze-thaw,…)

ISO 13823,
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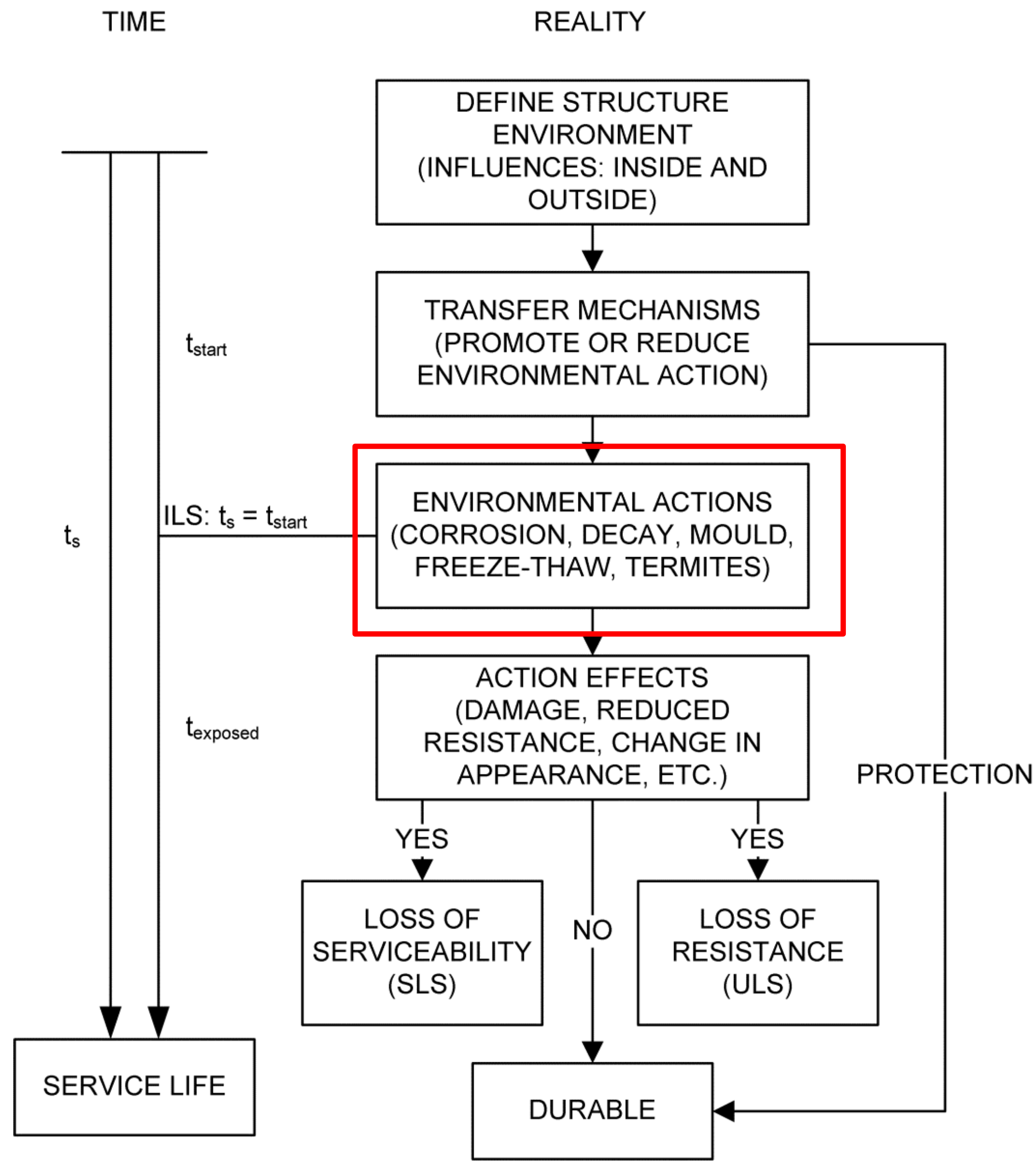

Limit State Design

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Action effects (damage, reduced resistance, change in appearance)

ISO 13823,
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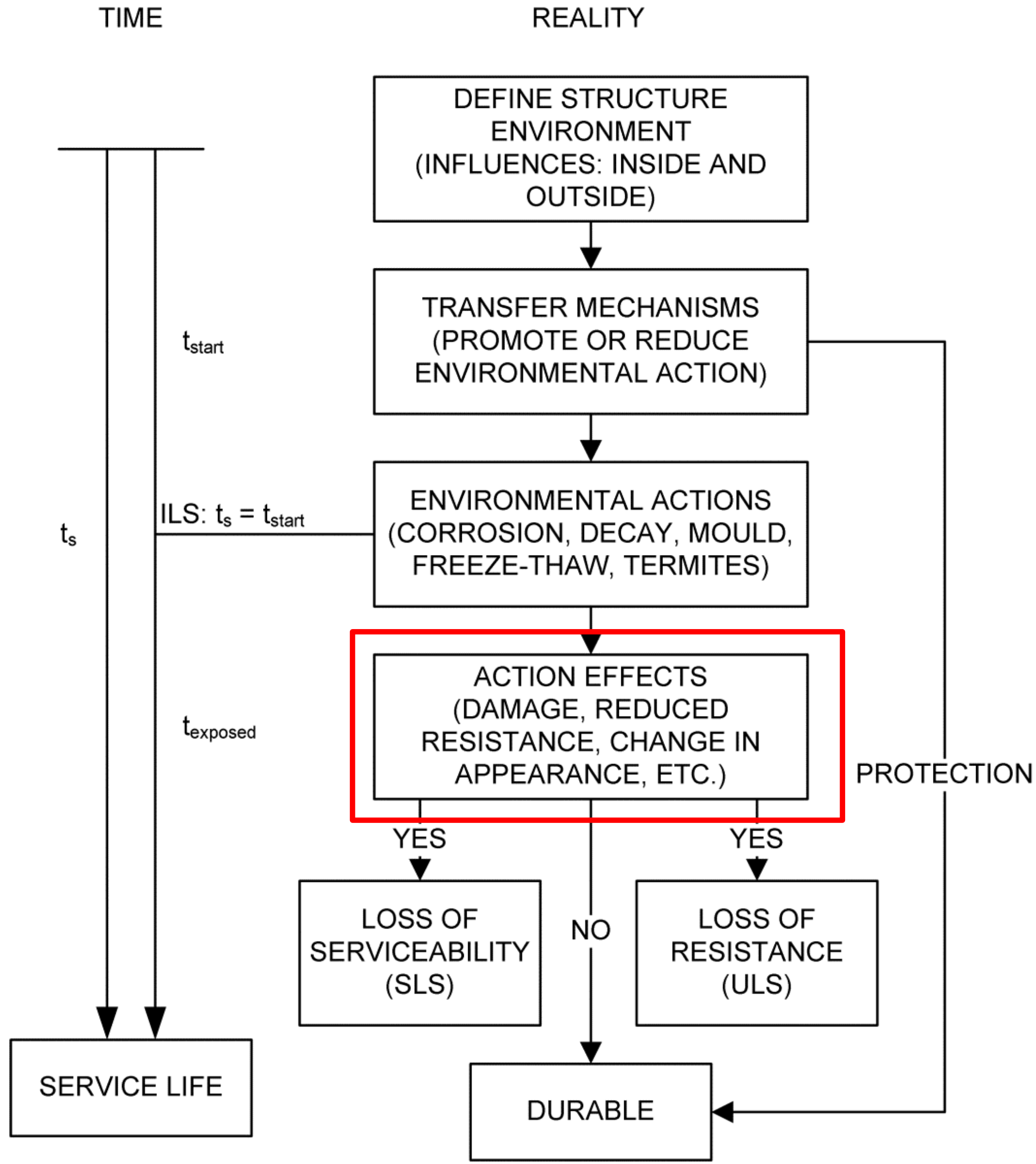
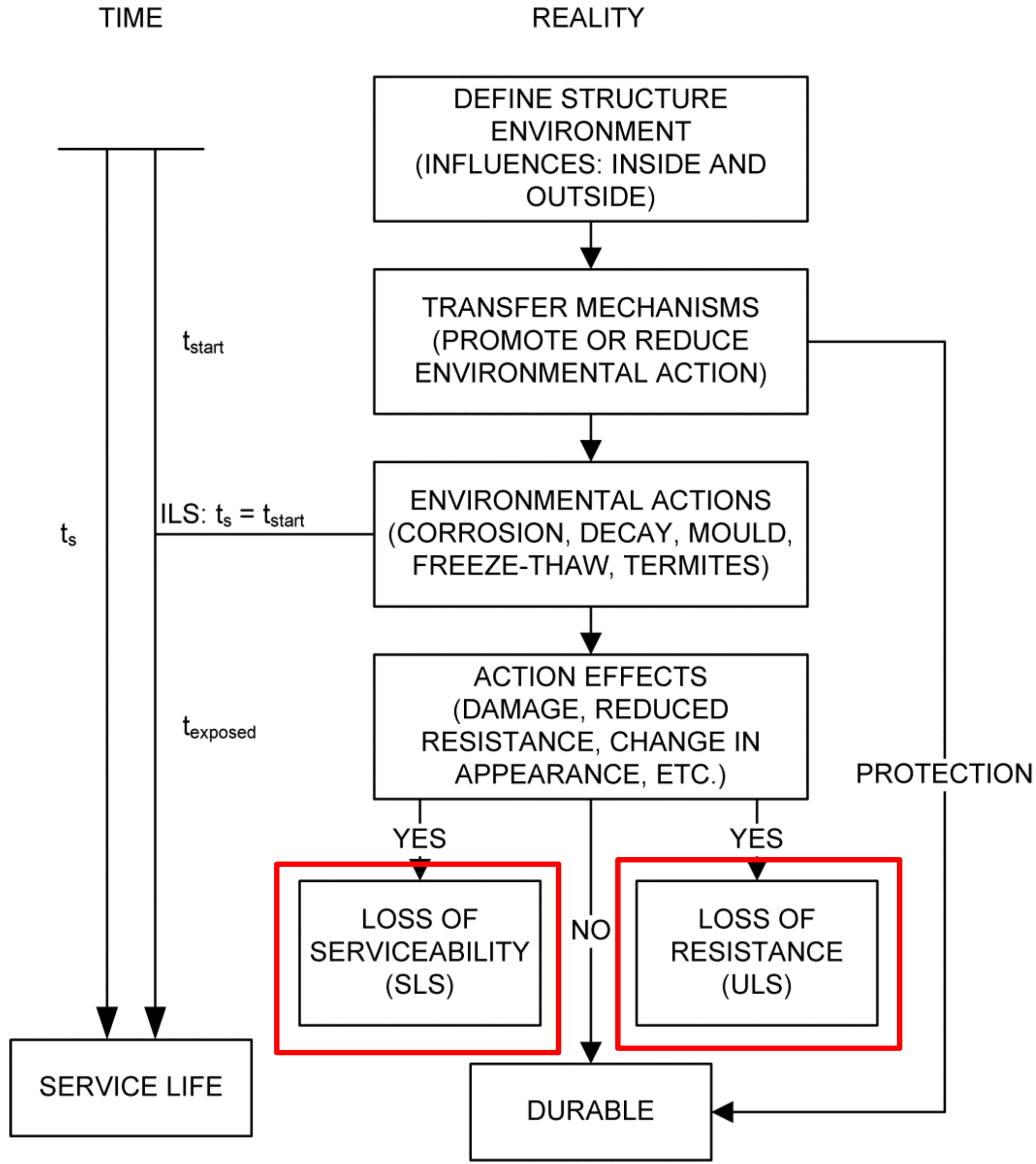


Limit State Design

SLS:
changes in material appearance or local damage due to mold growth

ULS:
material deterioration relates to the onset of wood rot

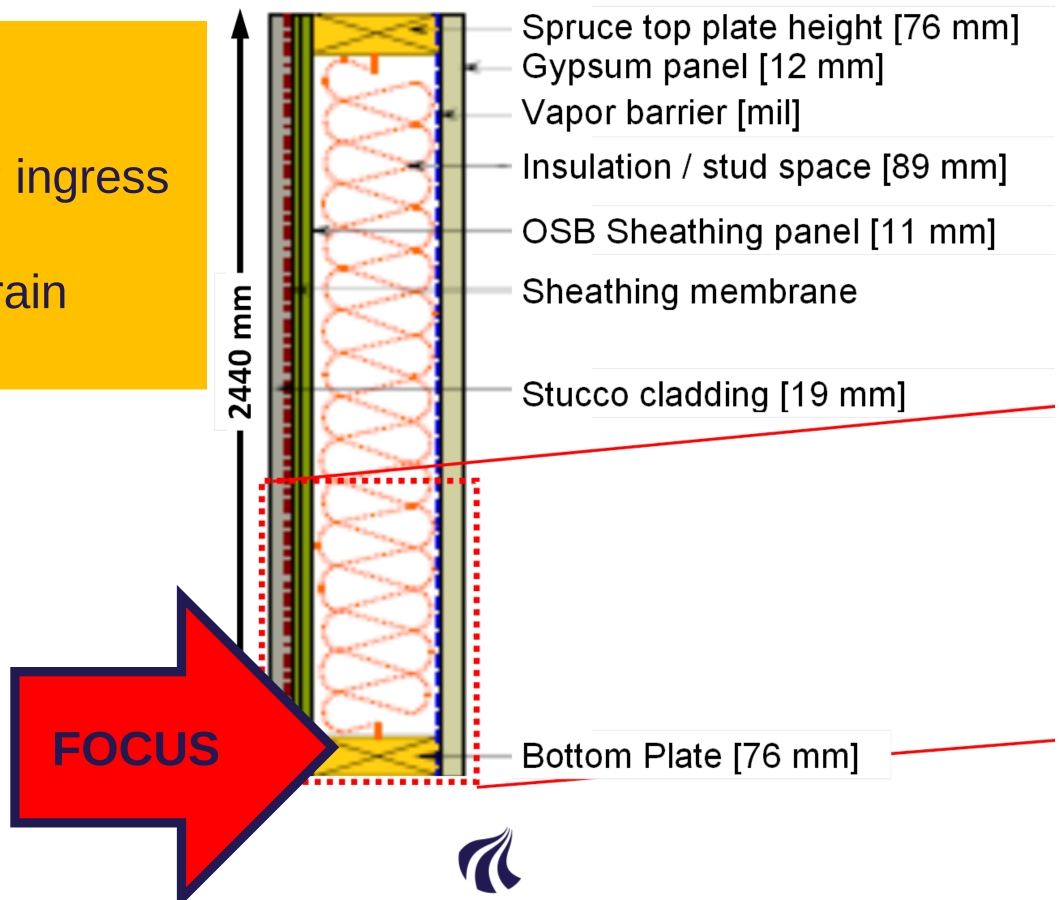


Structure - Stucco-Clad Wood-Frame Wall Assembly

Two models

1) Without water ingress

2) Well-defined rain ingress

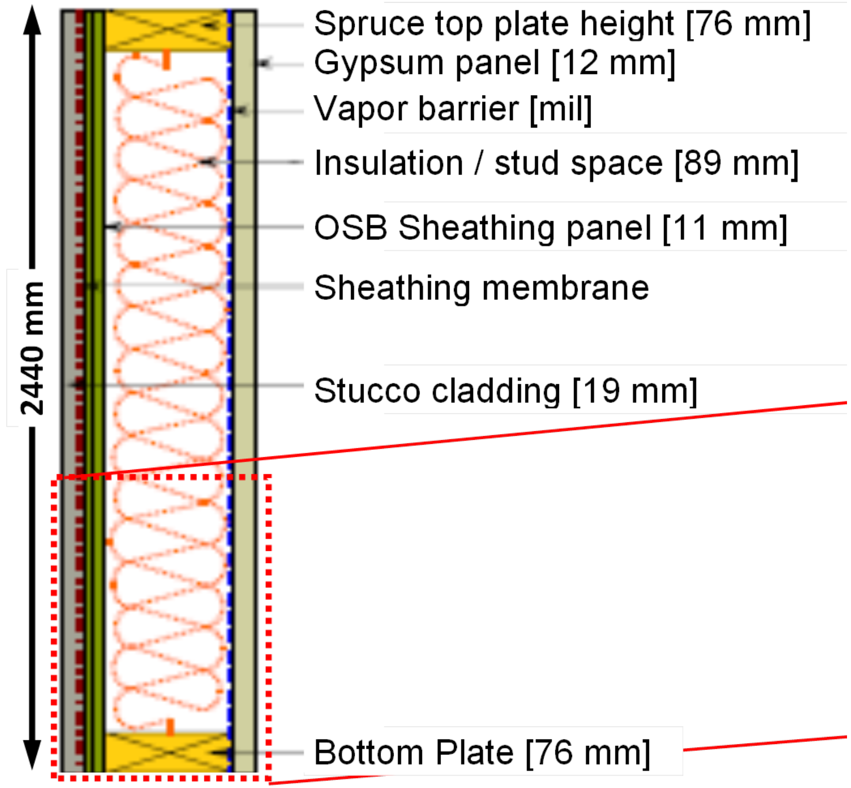


Environment – Boundary Conditions

Outside:

Hourly values
- Temperature
- RH
- Solar radiation
- Wind driven rain
- Cloud index

Weather data cycle:
wet-wet-average



Inside:

Vinter:
22 °C
25 % RH

Summer :
25 °C
55 % RH

mean monthly outdoor temperature was less than 11°C

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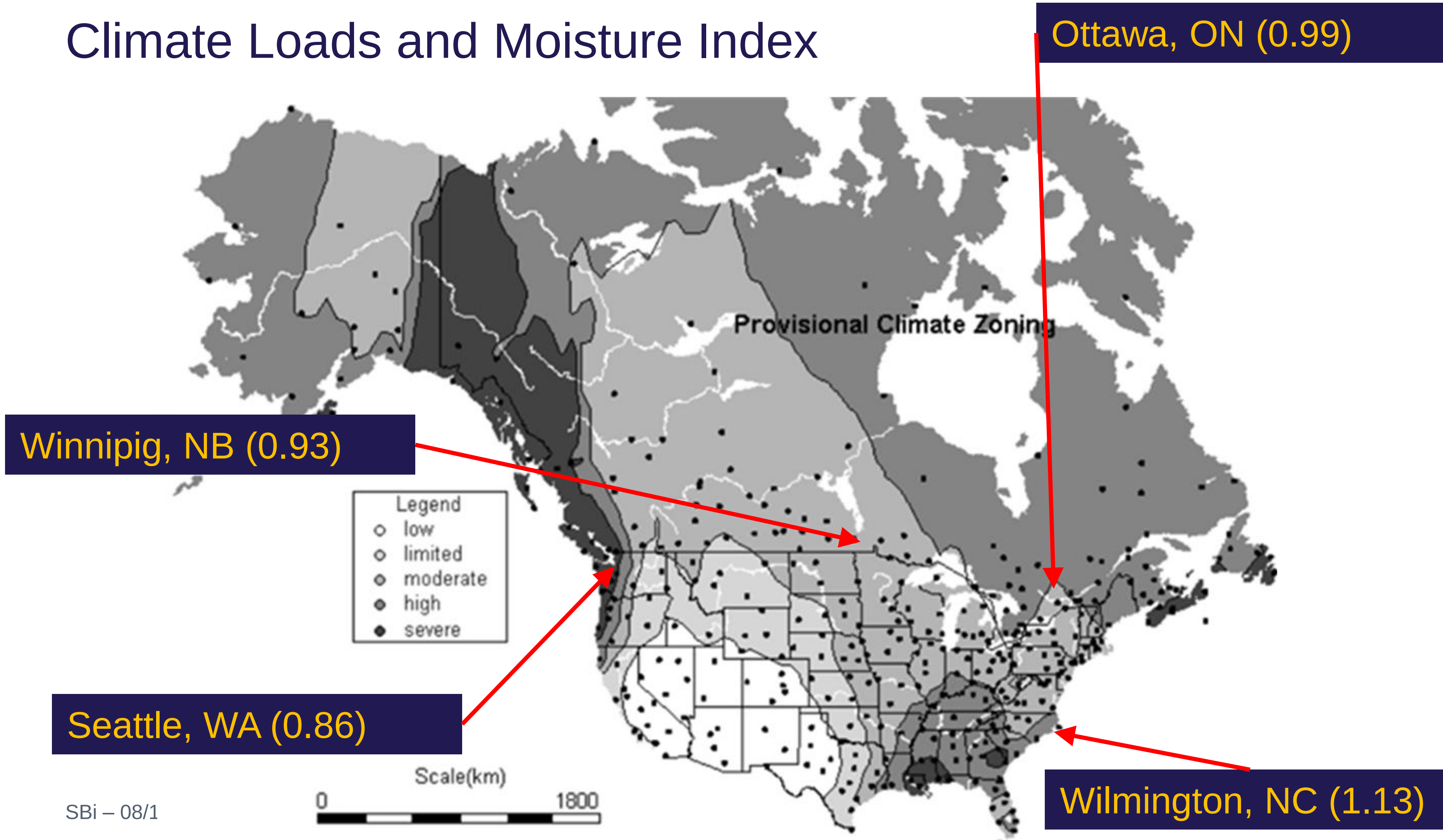
Climate Loads and Moisture Index



Transfer Mechanisms (1)

(i) Wind driven rain converted to a rain load on vertical wall surface

$$\mathbf{WDR = RAF \times DRF(}\boldsymbol{r_h}\mathbf{) \times \cos(\theta) \times }\boldsymbol{V(h)}\mathbf{ \times }\boldsymbol{r_h}$$

WDR = wind-driven rain load, L/m2·h

RAF = rain admittance factor

DRF = driving rain factor

r_h = horizontal rainfall intensity, mm/m2·h

$V(h)$ = wind speed at the height of interest, m/s

θ = angle of the wind to the wall normal

Transfer Mechanisms (2)

(ii) Proportion of water ingress entering wall assembly

$$\boldsymbol{Q}\ \textbf{(L/h)} = R_w \times f(\Delta P)$$
$$= R_w \times \{0.0314 + 7.74 \times 10^{-5}\,\Delta P - 8.14 \times 10^{-8}\,\Delta P^2\}$$

where

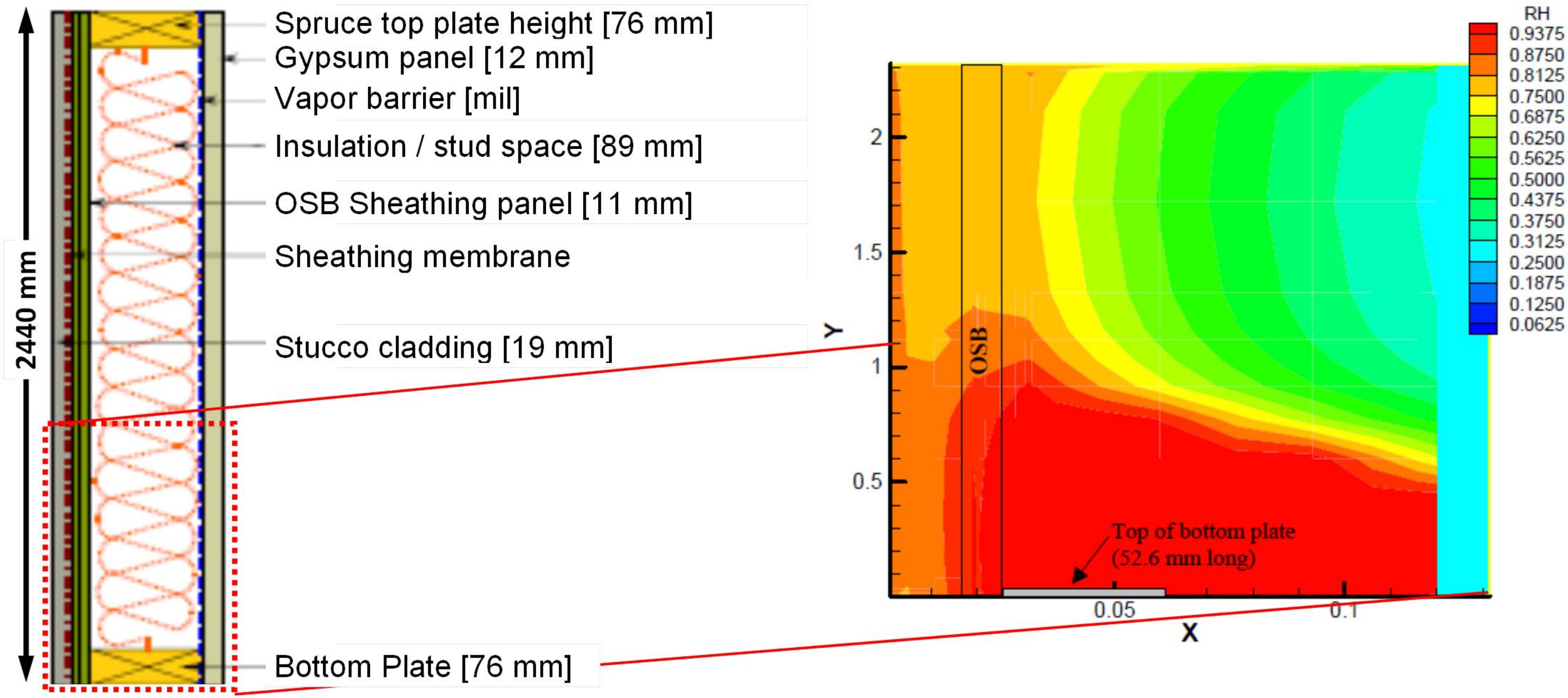
Q = rate of water entry to the wall

R_w = rate of water striking the wall

ΔP = pressure difference across the wall assembly

Transfer Mechanisms (3)

(iii) Location of water deposition in the wall



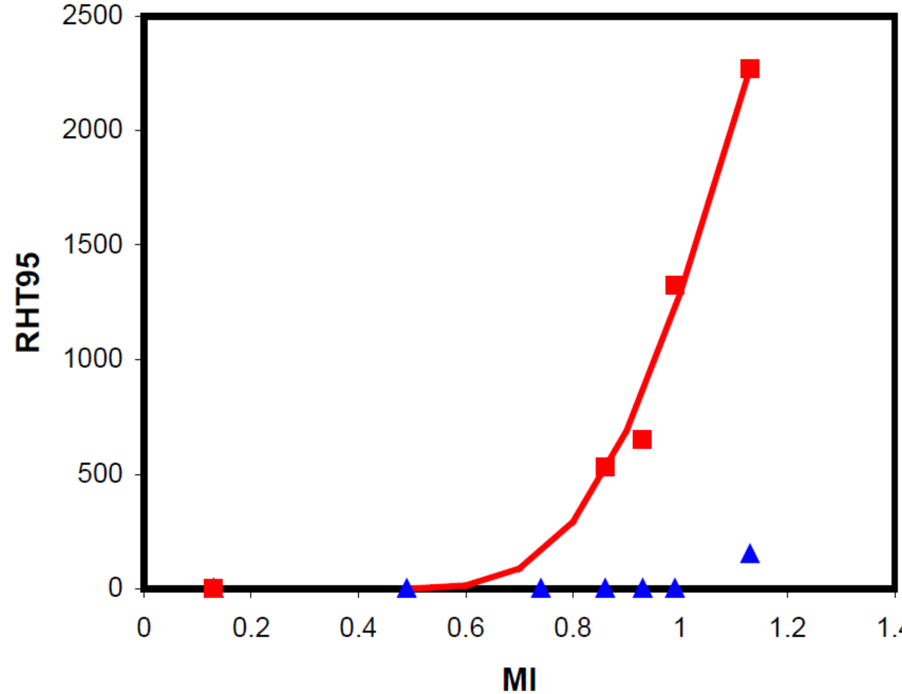
Environmental Action

Wall Moisture Response Indicator - RHT Index

RHT (Cumulative value, second and third years of simulation)
= SUM (RH – RH*x*) × (*T* – *Tx*)

where RH > RH*x* (%) and *T* > *Tx* (°C)
are values averaged over
10-day intervals of simulation.

Rot: RH*x* = 95% and *Tx* = 5°C
Mold: RH*x* = 80% and *Tx* = 5°C



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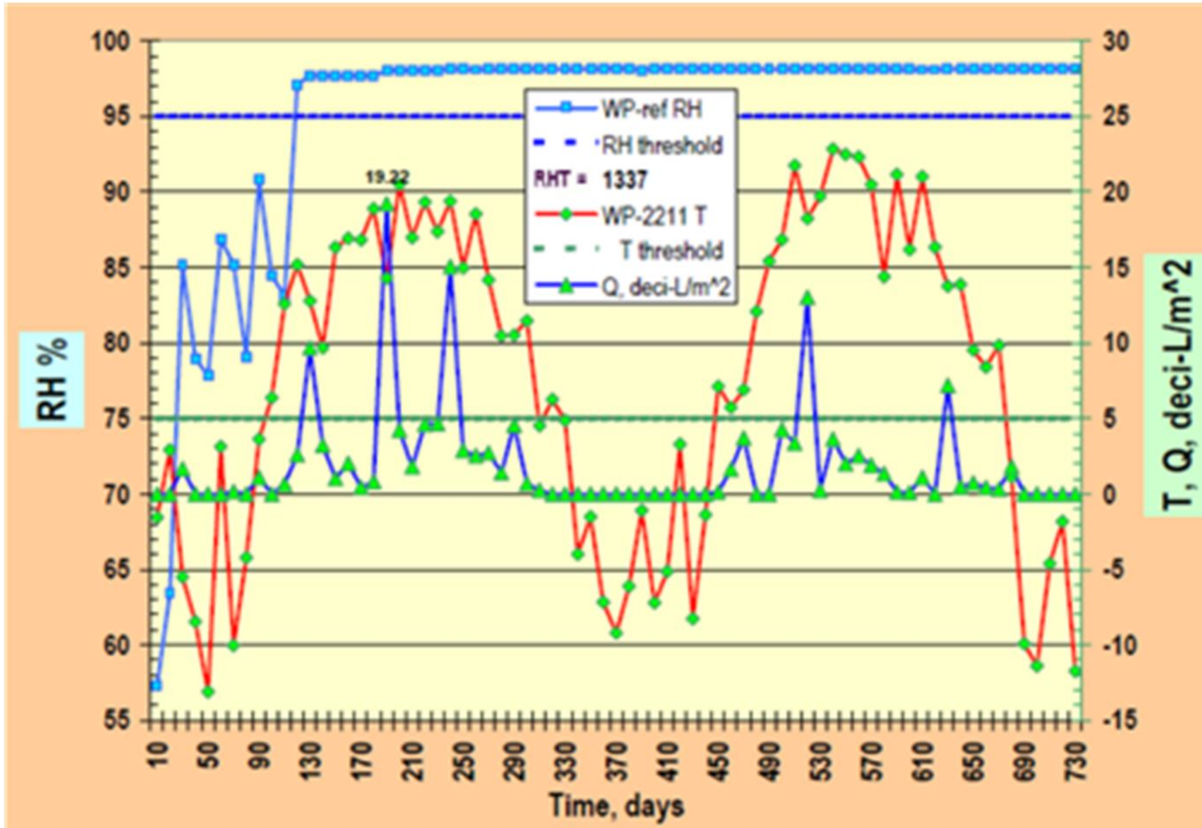
Hygrothermal Simulation (Winnipeg, MB)



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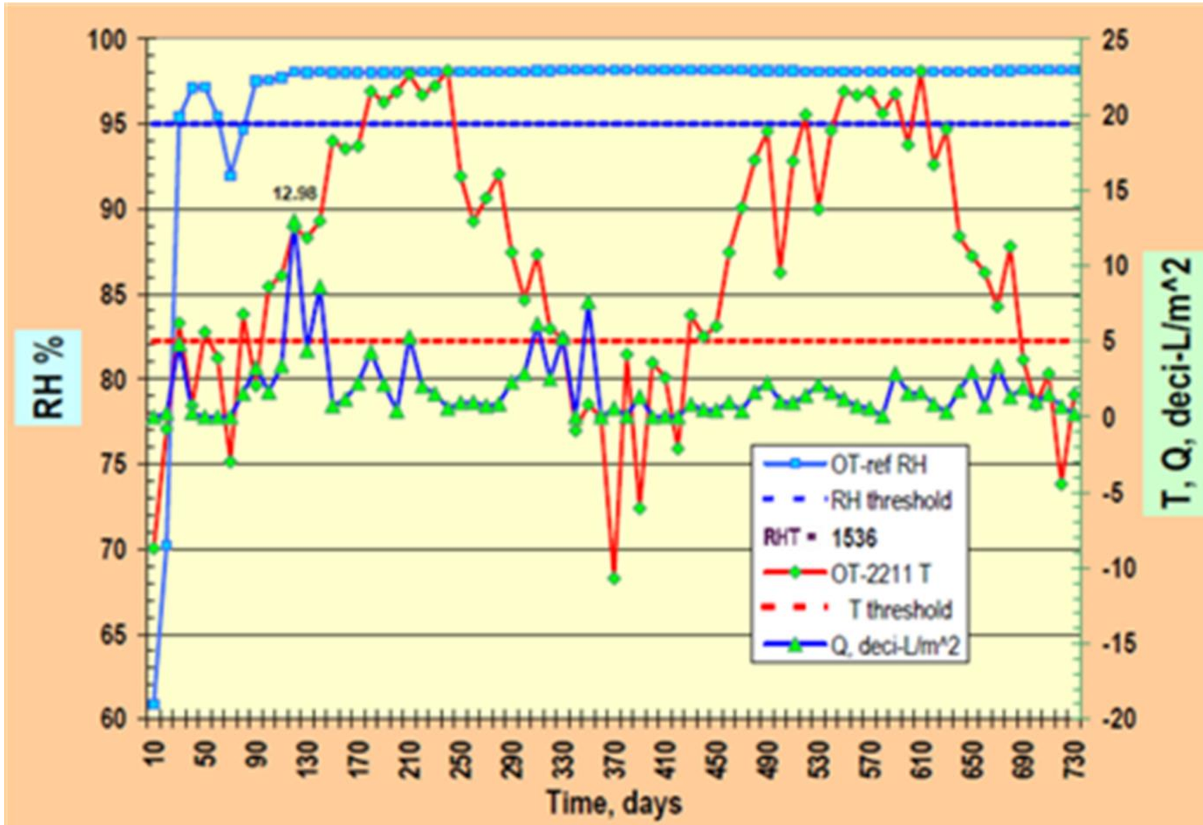
Hygrothermal Simulation (Ottawa, ON)



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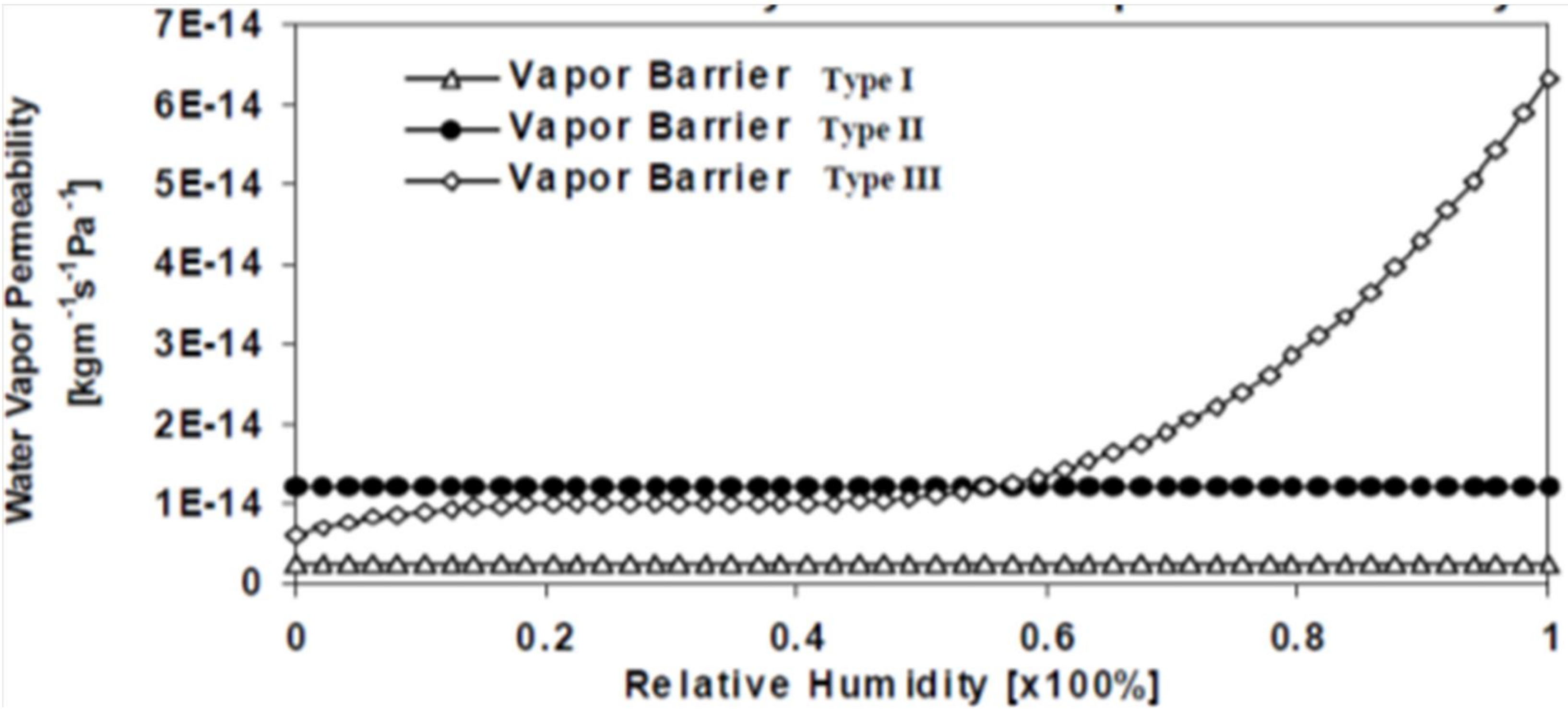
Vapor Barriers

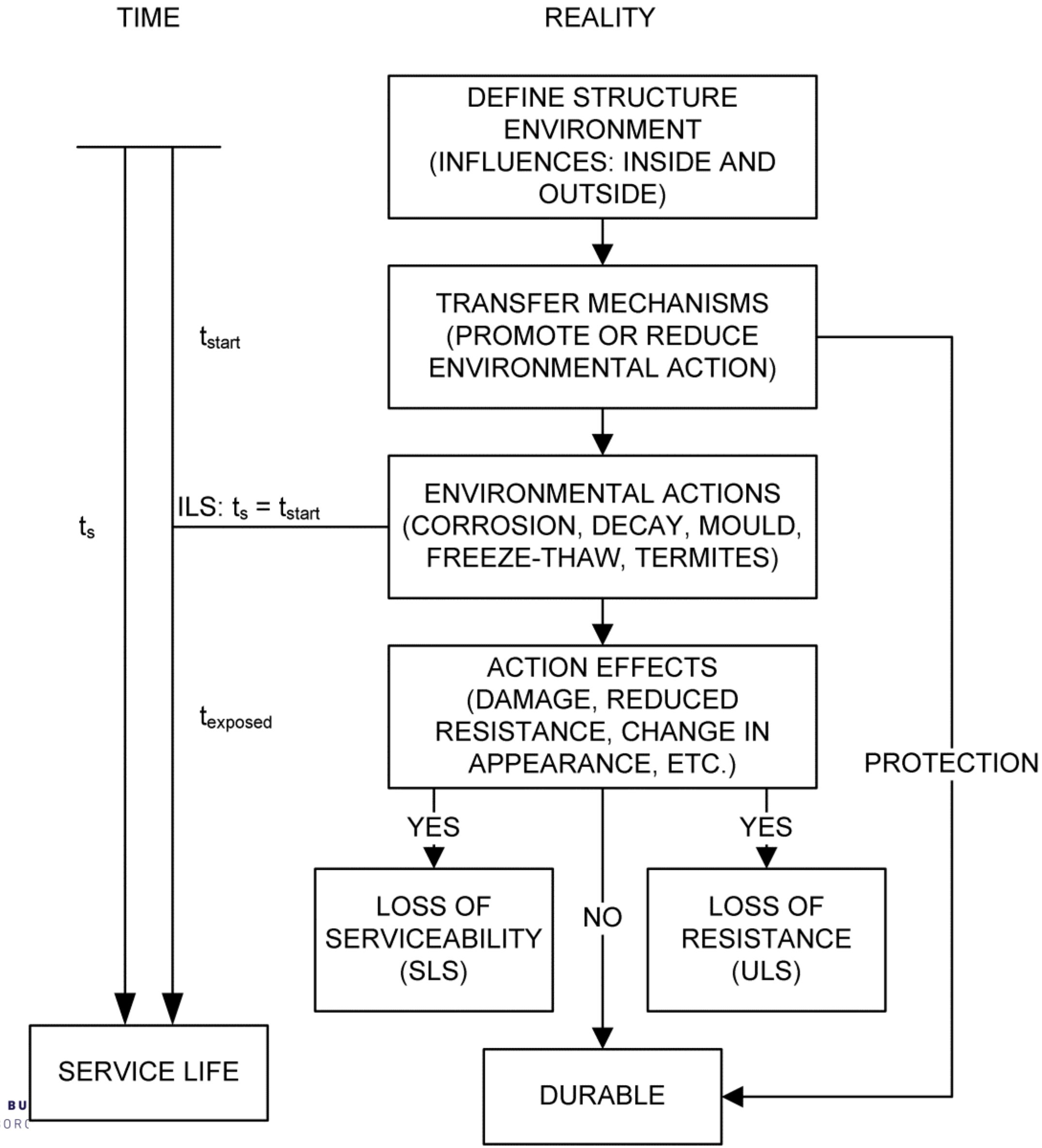


Varying Moisture Load and Vapor Barrier

Location	Wilmington, NC	Seattle, WA	Ottawa, ON	Winnipeg, MB
MI*	1.13	0.99	0.93	0.86
Dose fraction	RHT(95)	RHT(95)	RHT(95)	RHT(95)
0	9	0	0	0
¼ Q	2841	1979	864	697
½ Q	3008	2177	1434	1190
1 Q (VB1)	3213	2290	1536	1337
1 Q (VB2)	3261	2245	1517	1321
1 Q (VB3)	3080	2148	1482	1295

*MI = moisture index; VB1–3 = difference vapor barrier

Concluding Remarks



The Intent was …

- to demonstrate that the proposed approach is consistent with the broad precepts described in ISO 13823

- to provide a systematic method of assessing the long-term performance of wall assemblies

It is acknowledged …

- that the limit-states method is based on the estimation of the probability of failure, which is a function of the loads imposed on the components and the probability of occurrence of these loads.

- that the proposed approach, does not currently provide a means to determine whether the ULS is attained – can be implemented in HT simulations
  - Damage function or Wood decay models

- that the approach as currently developed more appropriately relates to assessing the SLS of components in the wall assembly.
  - How is the long-term performance determined on the basis of the proposed approach?

(i) Determination of long-term performance

by demonstrating performance of a wall assembly equivalent to that of a wall having known or accepted long-term performance as obtained from observations of in-service performance in the field

- currently being used at NRC as the basis for assessing the performance of wall assemblies when technical opinions are rendered on new construction products to demonstrate compliance to the *National Building Code of Canada* in respect to hygrothermal performance of the assembly as a whole.

- provided the performance of the wall being evaluated is equal or better than the reference wall, the “evaluated” wall is deemed to have met the minimum level of conformance to the building code.

(ii) Determination of long-term performance

by subjecting the wall assemblies to climate loads of a specified return period

- not yet been fully explored, but it nonetheless has merit, as structural loads that arise from the effects of climate (e.g., wind loads, snow loads) are typically based on a given return period. Clearly for a given climate location, the greater the return period the more severe the climate loads.

- The severity of climate loads in respect to their return period and as regards the water-tightness performance of wall assemblies has been explored by several authors. This indicates that the SLS can be adapted to the proposed approach in the context of an adequate in-service hygrothermal performance.

Thank you

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