Fire safety and humidity control
30.4.2019

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Intensive training course

Fire and humidity control

- Fire safety
- Moisture performances

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Fire safety of wooden buildings

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Fire safety of wooden buildings

Fire testing and classification of fire safety has just harmonised in EU. **But**, requirements are governed by national legistlation.

Fire safety of wooden buildings

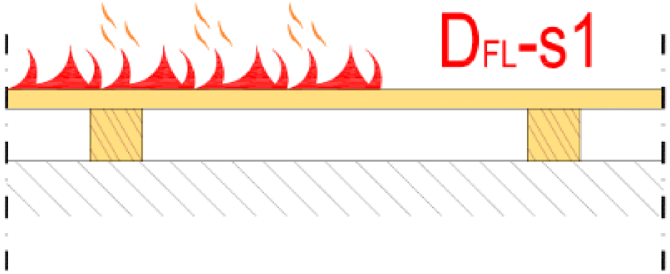
Östman Birgit, Fire Safety in timber buildings, Technical guidelines for Europe, SP Technical Institute of Sweden, SE-114 86 Stockholm Sweden, SP Report 2010:19, ISBN 978-91-86319-60-1

Objective in fire safety

1. Occupants shall be able to leave building or be rescued
2. The safety of the rescued team shall be taken into account
3. Load bearing structures shall resist fire for the required duration
4. The generation and spread of fire and smoke shall be limited
5. The spread of fire to neighbouring buildings shall be limited

1.

3.



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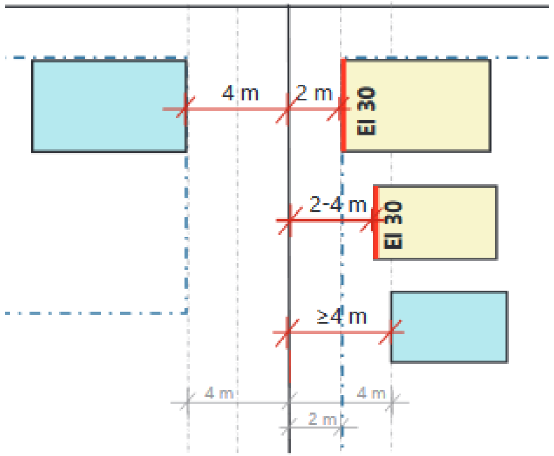

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Fire safety wooden buildings

Objective in fire safety

- Safety of life (in national standards)
- Loss prevention
- Environmental protection

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Fire safety wooden buildings

Means to fulfilling fire safety objectives

- The use of fire safety consepts
  - Tabulated values from national building codes
- Performance based codes and design tools
  - Fire risk assesment

Table 3. Class requirements of load-bearing and bracing structures in P1 and P2 fire class buildings.

Building	Building's fire class and fire load categories MJ/m²			
	P1			P2
	more than 1,200	600-1,200	less than 600	-
one- or two-storey building, general	R 120 (R60 *)	R 90 (R60 *)	R 60	R 30
- institutions, accommodation premises	R 120, A2 (R60 *, A2)	R 90, A2 (R60 *, A2)	R 60, A2	R 30
- uppermost basement storey	R 120, A2 (R90 *, A2)	R 90, A2 (R60 *, A2)	R 60, A2	R 60, A2
- uppermost floor in a building where there is no attic and the structure is an essential part of the structural body 1)	R 60	R 60	R 60	R 30
- single-storey production and storage building	R 60 (R30 *) (R15, A2 *)	R 60 (R30 *) (R15, A2 *)	R 60 (R30 *) (R15, A2 *)	R 30 (R15 *) (R15, A2)
- uppermost floor in a building where there is no attic and the structure is not an essential part of the structural body 1)	R 15	R 15	R 15	R 15
Building of over two storeys with a height not exceeding 28 m, general	R 180, A2 (R90 *, A2)	R 120, A2 (R60 *, A2)	R 60, A2	R 60 * # 3) 4)
- uppermost basement storey	R 180, A2 (R90 *, A2)	R 120, A2 (R60 *, A2)	R 60, A2	R 60 * A2
- residential building, dwelling, uppermost storey	R 60 +	R 60 +	R 60 +	R 60 * # 3)
- residential building, dwelling, two uppermost storeys 2)	R60 * #	R60 * #	R60 * #	R 60 * # 3)
- a residential building of more than two storeys, with a height not exceeding 14 m and where all the storeys of each housing unit belong to one and the same apartment	R 45, A2 (R30, A2 *)	R 45, A2 (R30, A2 *)	R 45, A2 (R30, A2 *)	R 45 # (R30 * #)
Building of over two storeys with a height greater than 28 m but not exceeding 56 m	R 240, A2 (R180 *, A2)	R 180, A2 (R120 *, A2)	R 120, A2 (R90 *, A2)	not possible
Building of over two storeys with a height exceeding 56 m	R180 *, A2	R120*, A2	R 120 *, A2	not possible
Basement storeys below uppermost basement storey	R 240, A2 (R180 *, A2)	R 180, A2 (R120 *, A2)	R 120, A2	R 120, A2 (R90 *, A2)

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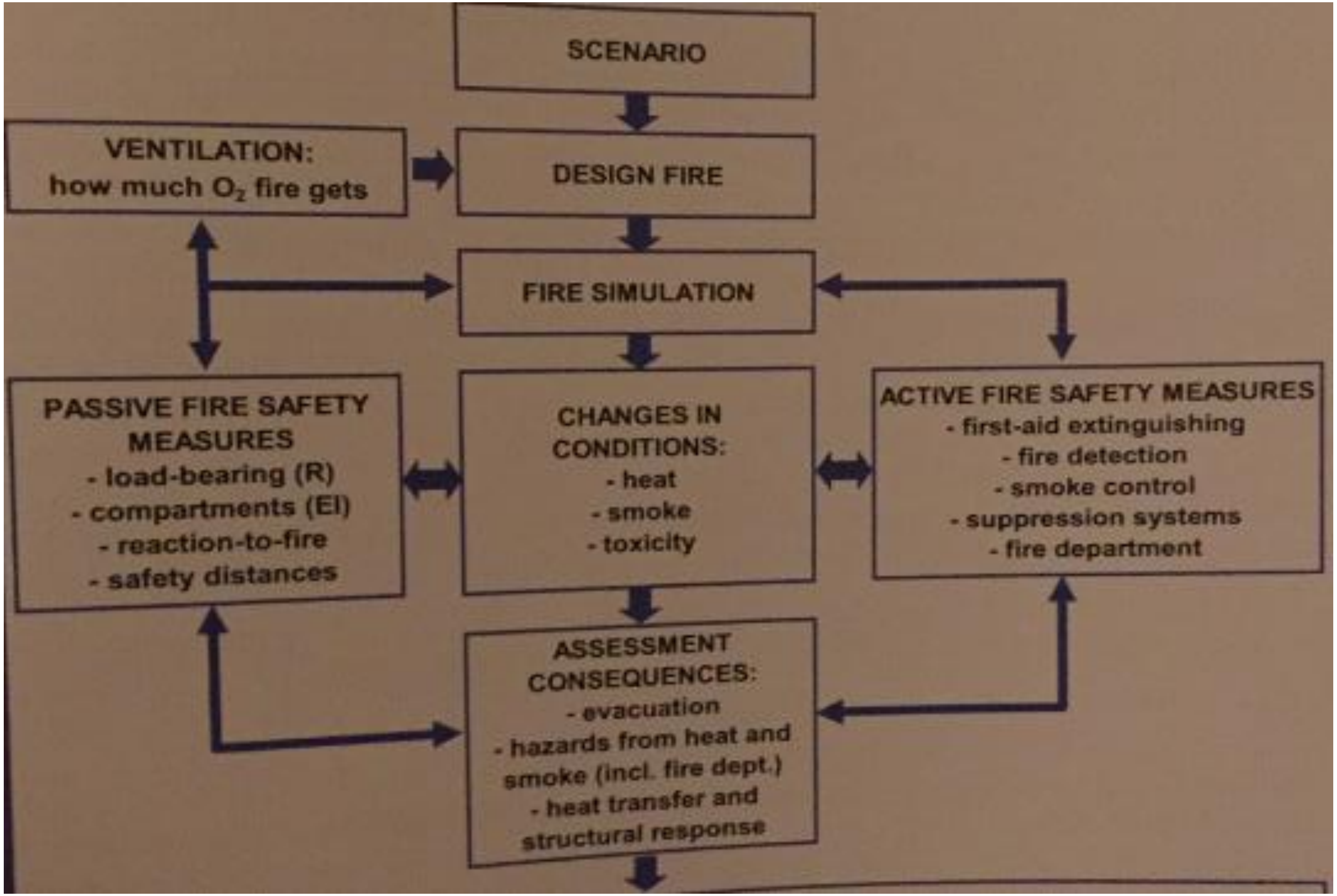
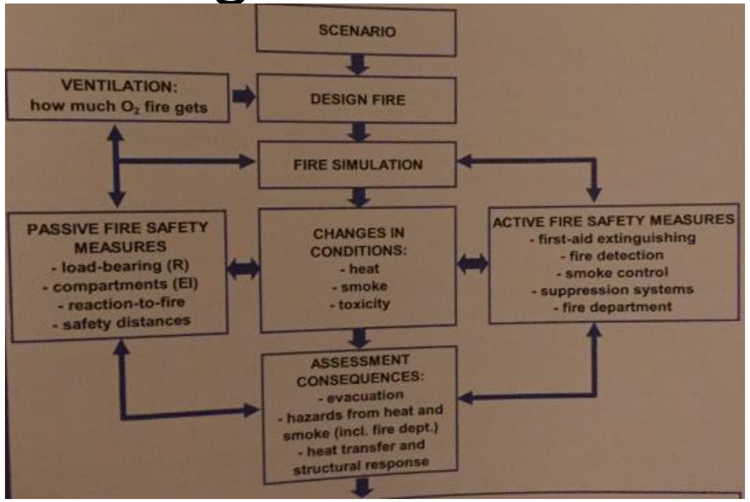
Performance based codes and design tools



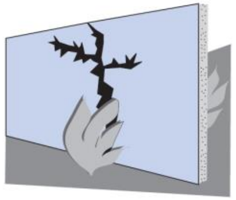
- Performance based codes and design tools
  - Fire risk assesment



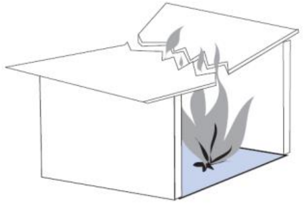
Passive fire safety

- Structural fire safety with building elements,
- fire compartments
- Material fire class in building element

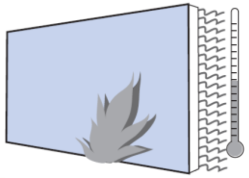
Tiiviys – E
Rakennusosan tulee säilyttää tiiviys palon aikana siten, etteivät kuumat palokaasut tai liekit pääse tunkeutumaan sen läpi halkeamien, rakojen tai muiden aukkojen kautta.



Kantavuus – R
Kantavat rakennusosat on mitoitettava ja toteutettava siten, että ne kestävät palonaikaiset kuormat.



Eristävyys – I
Rakennusosan tulen vastakkaisella puolella lämpötilat eivät saa nousta vaatimustasoa korkeammaksi.



Evacuation safety

- Evacuation plans
- Maximum lengt of evacuation path
- Multiple exits
- Dimension of exits
- Alarm/guidanse system
- Door opens to escaping direction

Active fire safety

- Fire detection and alarm system
- Initial fire fighting
- Water sprinklers
- Smoke extraction system
- Closing of smoke dampers in ducts, closing firedoors

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- Performance based codes and design tools
  - Fire risk assesment

FIRE SCENARIOS

- What burns where & when
- Operation/operation failures of safety system
- How many people are threatened
- What is the percentage of children, elderly people, disabled

Think fire scenarios in your case building !

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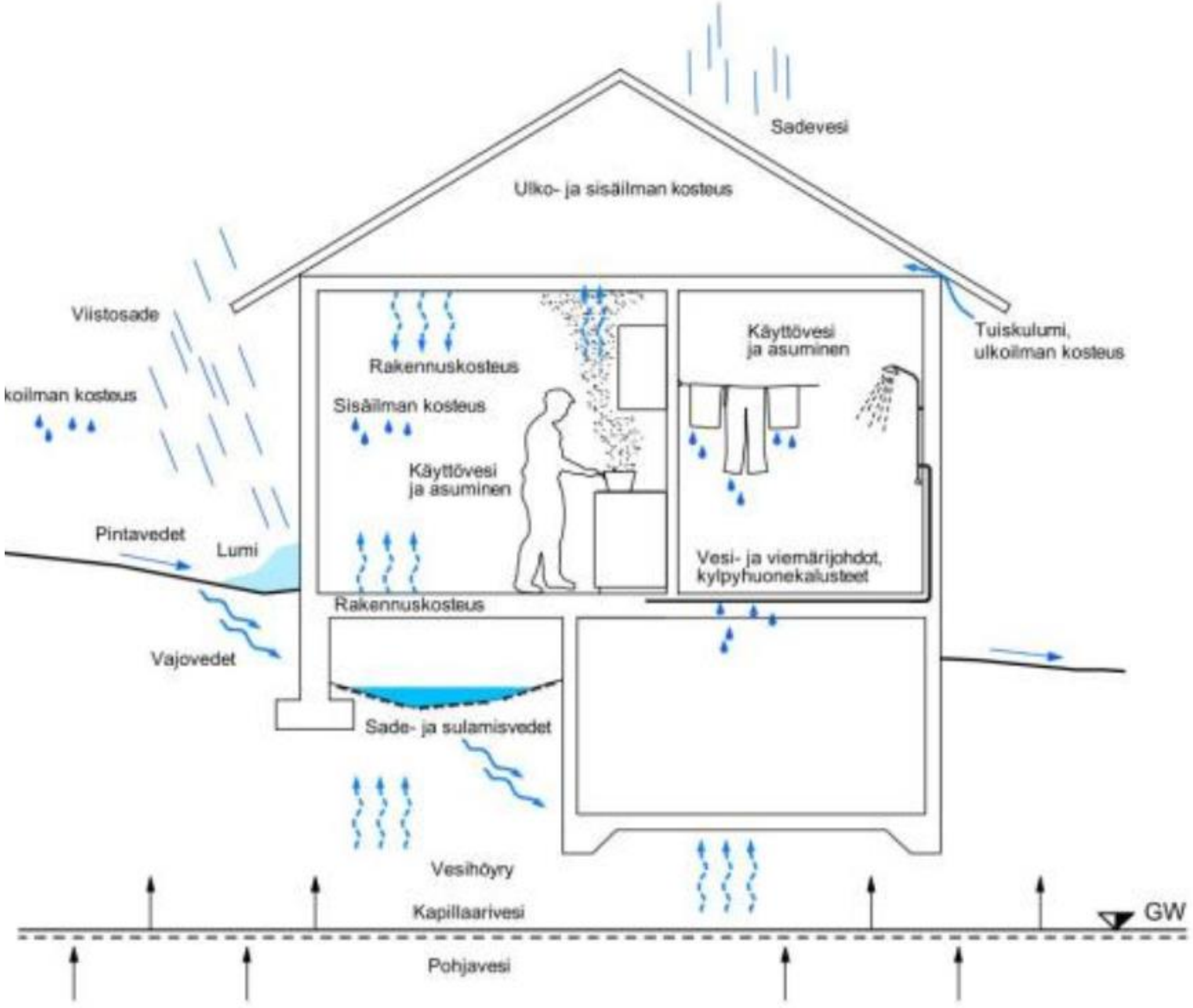
Moisture control

Moisture sources:

- Ground water
- Building moisture
- Rain water
- Shower
- Cooking
- Drying clothes



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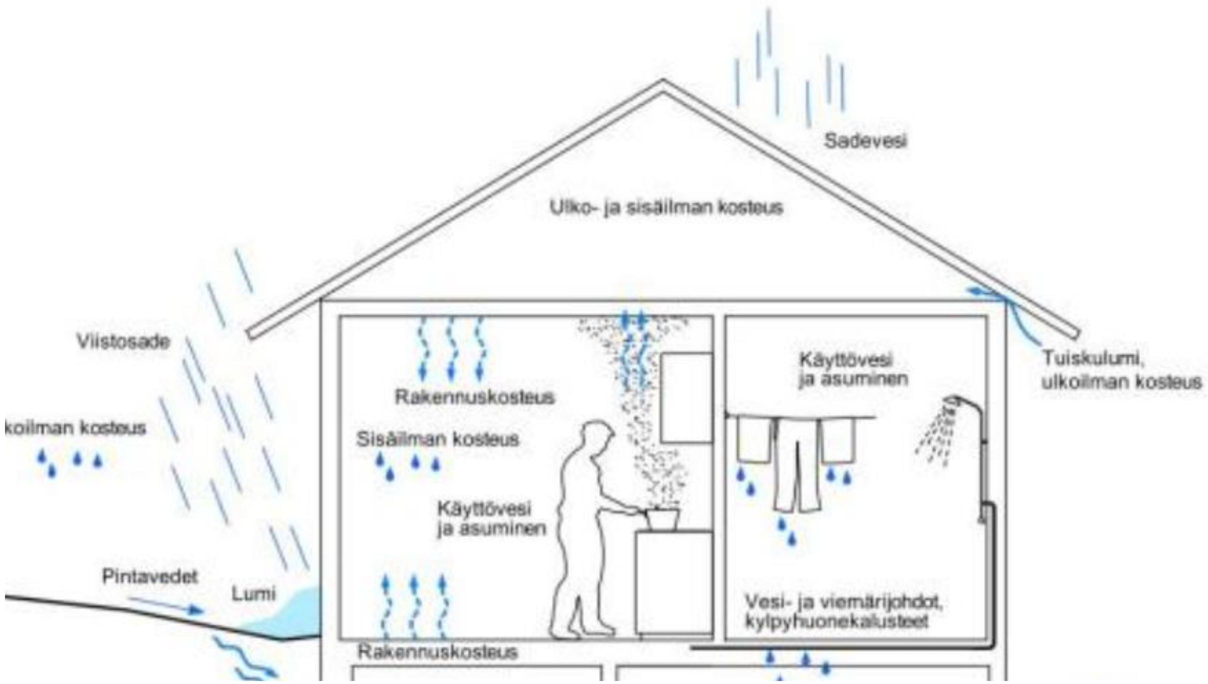
Essential requirements for a building moisture performance (national)

Considering the internal and external moisture stresses…
… must not damage the building or cause health hazard to the occupants.



The principal designer, building designer and special designer shall, in accordance with their respective duties, design the building so that it meets the essential technical requirements for moisture performance in accordance with its intended use. For alteration and repair work or alteration of the intended use, the designer shall determine the building's initial construction method and moisture performance.

Considering the internal and external moisture stresses, the building, structures and building elements must be functional in terms of their moisture performance through their planned technical service life. The building's excessive moisture content or moisture accumulation in the building's parts or interior surfaces must not damage the building or cause health hazard to the occupants.

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Moisture in museum

Stop time!

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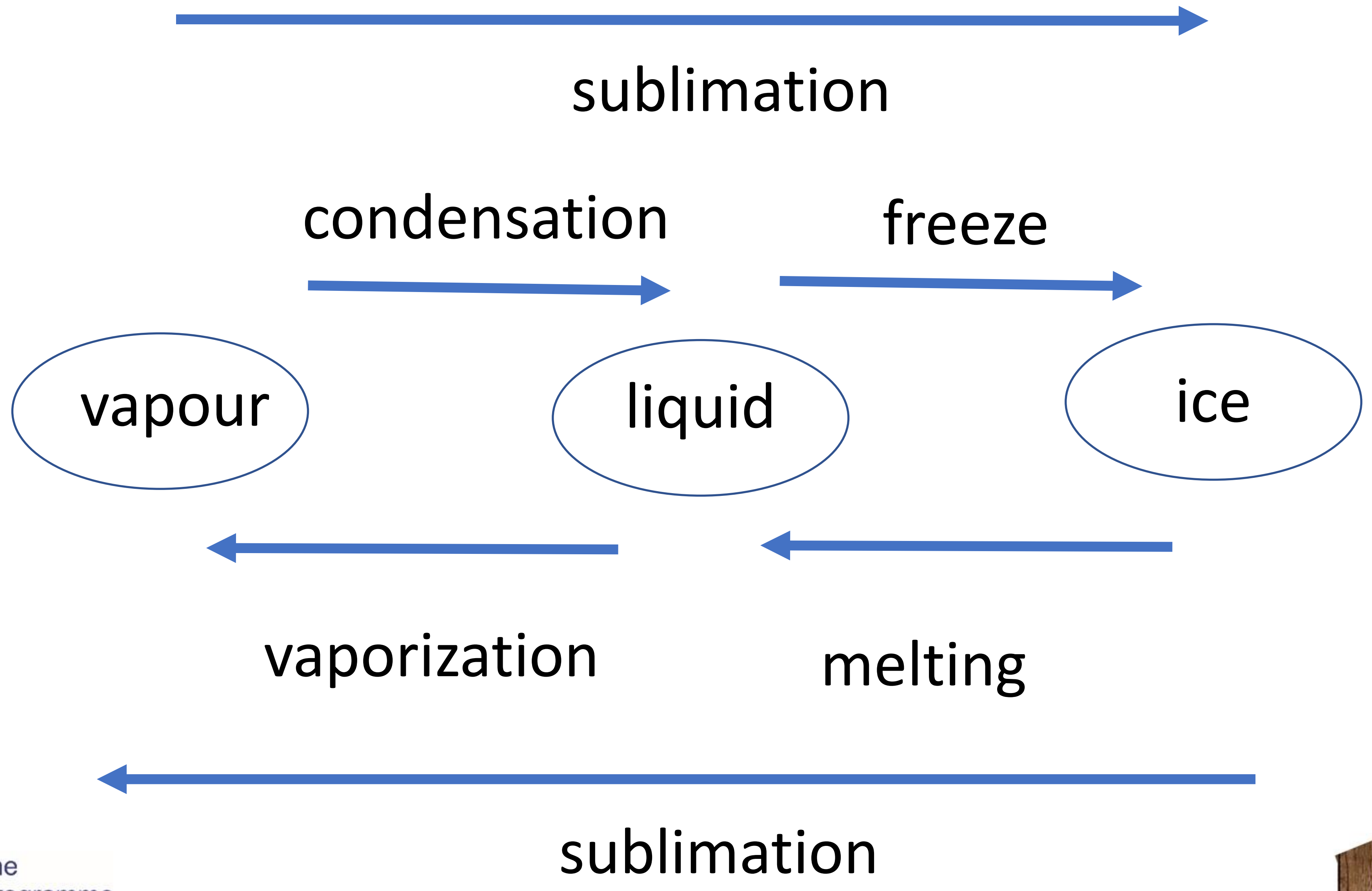
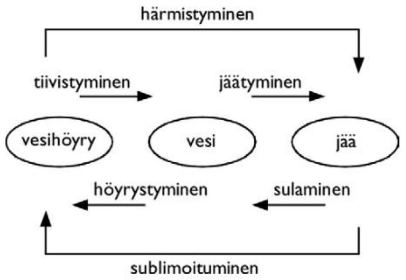
Building physics

-design

- Standard requirements
    - Well known structures with guidelines
- Demanding requirements
    - Building physical analysis

Phases of water and phase change





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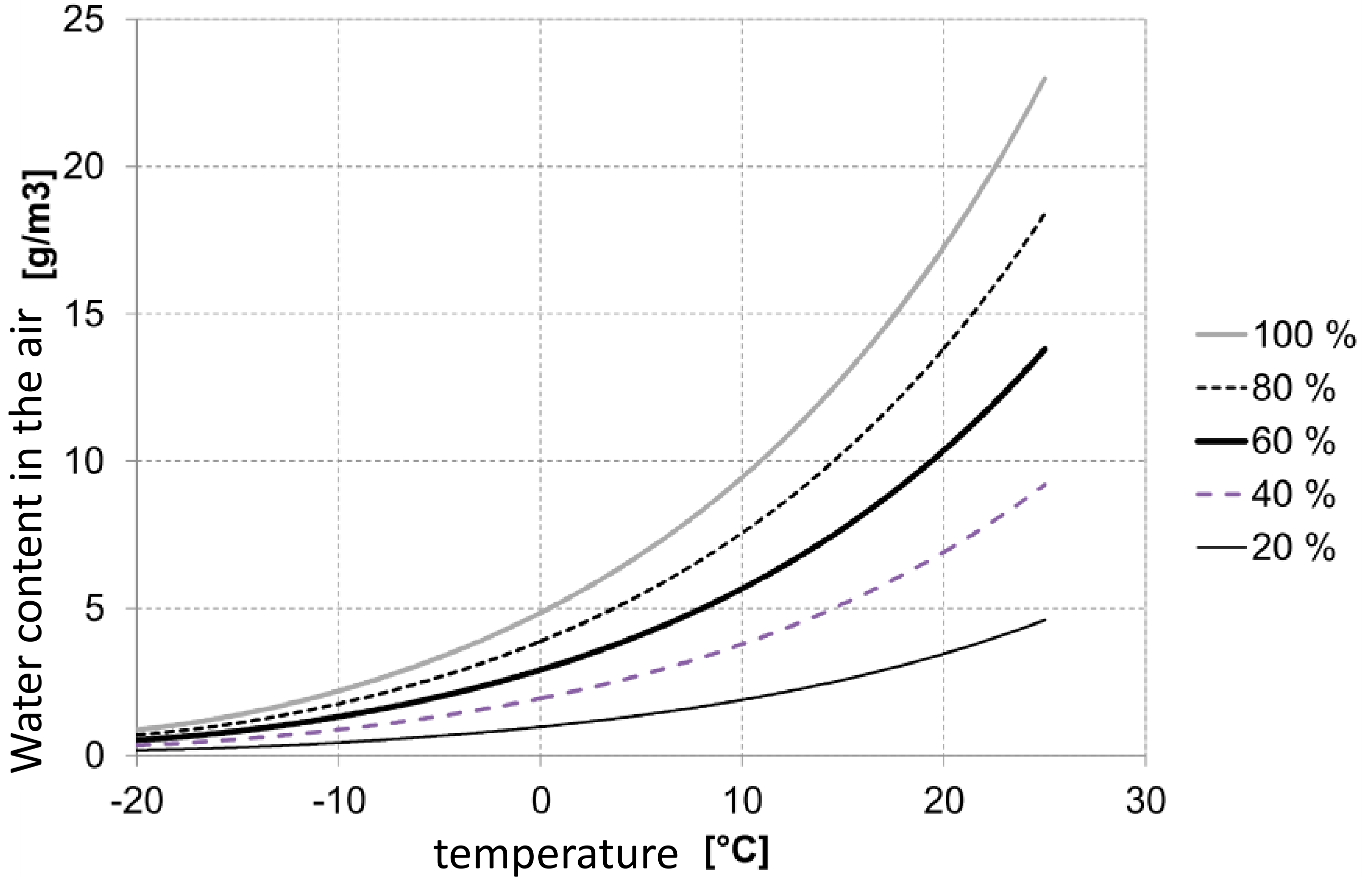
Water vapour in the air



Amount of water vapour (water content g/m3) is dependent on air temperature and relative humidity

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Water in the air

Therms

Relative humidity	RH	[%]
water content of air	ν	$\left[\frac{kg}{m^3}\right]$
partial pressure of water in air	p	[Pa]
dew point	T_d	[°C]

temperature

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Water in the air

Relative humidity

$$RH = \frac{\nu}{\nu_k} = \frac{p}{p_k}$$

water content of air	ν	$\left[\frac{kg}{m^3}\right]$
saturation water content	ν_k	$\left[\frac{kg}{m^3}\right]$
partial pressure of water in air	p	[Pa]
saturation partial pressure (water in air)	p_k	[Pa]

temperature

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Water in the air

saturation water content

T (°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
-20	0.89	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.82	0.82
-19	0.97	0.96	0.95	0.94	0.94	0.93	0.92	0.91	0.90	0.89
-18	1.06	1.05	1.04	1.03	1.02	1.02	1.01	1.00	0.99	0.98
-17	1.16	1.15	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07
-16	1.27	1.26	1.25	1.24	1.23	1.22	1.20	1.19	1.18	1.17
-15	1.39	1.38	1.36	1.35	1.34	1.33	1.32	1.31	1.29	1.28
-14	1.52	1.50	1.49	1.48	1.46	1.45	1.44	1.43	1.41	1.40
-13	1.65	1.64	1.63	1.61	1.60	1.58	1.57	1.56	1.54	1.53
-12	1.80	1.79	1.77	1.76	1.74	1.73	1.71	1.70	1.68	1.67
-11	1.97	1.95	1.93	1.92	1.90	1.88	1.87	1.85	1.84	1.82
-10	2.14	2.12	2.10	2.09	2.07	2.05	2.03	2.02	2.00	1.98
-9	2.33	2.31	2.29	2.27	2.25	2.23	2.21	2.20	2.18	2.16
-8	2.53	2.51	2.49	2.47	2.45	2.43	2.41	2.39	2.37	2.35
-7	2.75	2.73	2.71	2.69	2.66	2.64	2.62	2.60	2.58	2.55
-6	2.99	2.97	2.94	2.92	2.89	2.87	2.85	2.82	2.80	2.78
-5	3.25	3.22	3.20	3.17	3.14	3.12	3.09	3.07	3.04	3.02
-4	3.52	3.50	3.47	3.44	3.41	3.38	3.36	3.33	3.30	3.27
-3	3.82	3.79	3.76	3.73	3.70	3.67	3.64	3.61	3.58	3.55
-2	4.14	4.11	4.08	4.04	4.01	3.98	3.95	3.92	3.88	3.85
-1	4.49	4.45	4.42	4.38	4.35	4.31	4.28	4.24	4.21	4.18
-0	4.85	4.82	4.78	4.74	4.71	4.67	4.63	4.60	4.56	4.52
0	4.85	4.88	4.92	4.95	4.98	5.02	5.05	5.09	5.12	5.16
1	5.19	5.23	5.27	5.30	5.34	5.38	5.41	5.45	5.49	5.52
2	5.56	5.60	5.64	5.68	5.72	5.75	5.79	5.83	5.87	5.91
3	5.95	5.99	6.03	6.07	6.12	6.16	6.20	6.24	6.28	6.32
4	6.37	6.41	6.45	6.50	6.54	6.58	6.63	6.67	6.71	6.76
5	6.80	6.85	6.90	6.94	6.99	7.03	7.08	7.13	7.17	7.22
6	7.27	7.32	7.36	7.41	7.46	7.51	7.56	7.61	7.66	7.71
7	7.76	7.81	7.86	7.91	7.96	8.02	8.07	8.12	8.17	8.23
8	8.28	8.33	8.39	8.44	8.50	8.55	8.61	8.66	8.72	8.77
9	8.83	8.89	8.94	9.00	9.06	9.11	9.17	9.23	9.29	9.35
10	9.41	9.47	9.53	9.59	9.65	9.71	9.77	9.83	9.90	9.96
11	10.02	10.09	10.15	10.21	10.28	10.34	10.41	10.47	10.54	10.60
12	10.67	10.74	10.80	10.87	10.94	11.01	11.08	11.14	11.21	11.28
13	11.35	11.42	11.49	11.57	11.64	11.71	11.78	11.85	11.93	12.00
14	12.07	12.15	12.22	12.30	12.37	12.45	12.53	12.60	12.68	12.76
15	12.83	12.91	12.99	13.07	13.15	13.23	13.31	13.39	13.47	13.55
16	13.63	13.72	13.80	13.88	13.97	14.05	14.14	14.22	14.31	14.39
17	14.48	14.57	14.65	14.74	14.83	14.92	15.01	15.10	15.19	15.28
18	15.37	15.46	15.55	15.64	15.74	15.83	15.92	16.02	16.11	16.21
19	16.30	16.40	16.50	16.59	16.69	16.79	16.89	16.99	17.09	17.19
20	17.28	17.39	17.49	17.59	17.69	17.80	17.90	18.01	18.11	18.22
21	18.32	18.43	18.53	18.64	18.75	18.86	18.97	19.08	19.19	19.30
22	19.41	19.52	19.63	19.75	19.86	19.97	20.09	20.20	20.32	20.44
23	20.55	20.67	20.79	20.91	21.03	21.15	21.27	21.39	21.51	21.63
24	21.75	21.88	22.00	22.13	22.25	22.38	22.50	22.63	22.76	22.89
25	23.02	23.14	23.28	23.41	23.54	23.67	23.80	23.94	24.07	24.20
26	24.34	24.48	24.61	24.75	24.89	25.03	25.16	25.30	25.45	25.59
			26.01	26.16	26.30	26.45	26.59	26.74	26.89	27.04
			27.49	27.64	27.79	27.94	28.09	28.25	28.40	28.56
			29.03	29.19	29.34	29.50	29.66	29.83	29.99	30.15
			30.64	30.81	30.98	31.14	31.31	31.48	31.65	31.82

temperature

Water content in the air

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Can be presented in the two different unit

Vapour pressure p $[Pa]$

Vapour content c $\left[\frac{kg}{m^3}\right]$

vapour pressure can be changed to vapour content using **ideal gas law**

$$p \cdot V = n \cdot R \cdot T$$

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Moisture in the air

Units

Vapour pressure p $[Pa]$

Vapour content $\nu \left[\frac{kg}{m^3}\right]$

Ideal gas law

$$p \cdot V = n \cdot R \cdot T$$

$where$ p is total pressure

V is volumetric

R is universal gas constant 8,314

T is temperature

n is amound of moles

$$n = \frac{m}{M_v}$$

where m is mass

M_v is molemass of water $0{,}018 \frac{kg}{mol}$

$$p = \frac{m}{M_v \cdot V} \cdot R \cdot T = \nu \cdot \frac{R \cdot T}{M_v} = \nu \cdot \frac{8{,}314 \cdot \frac{J}{K \cdot mol}}{0{,}018 \cdot \frac{kg}{mol}} \cdot T = \nu \cdot 463 \cdot \frac{J}{K}$$

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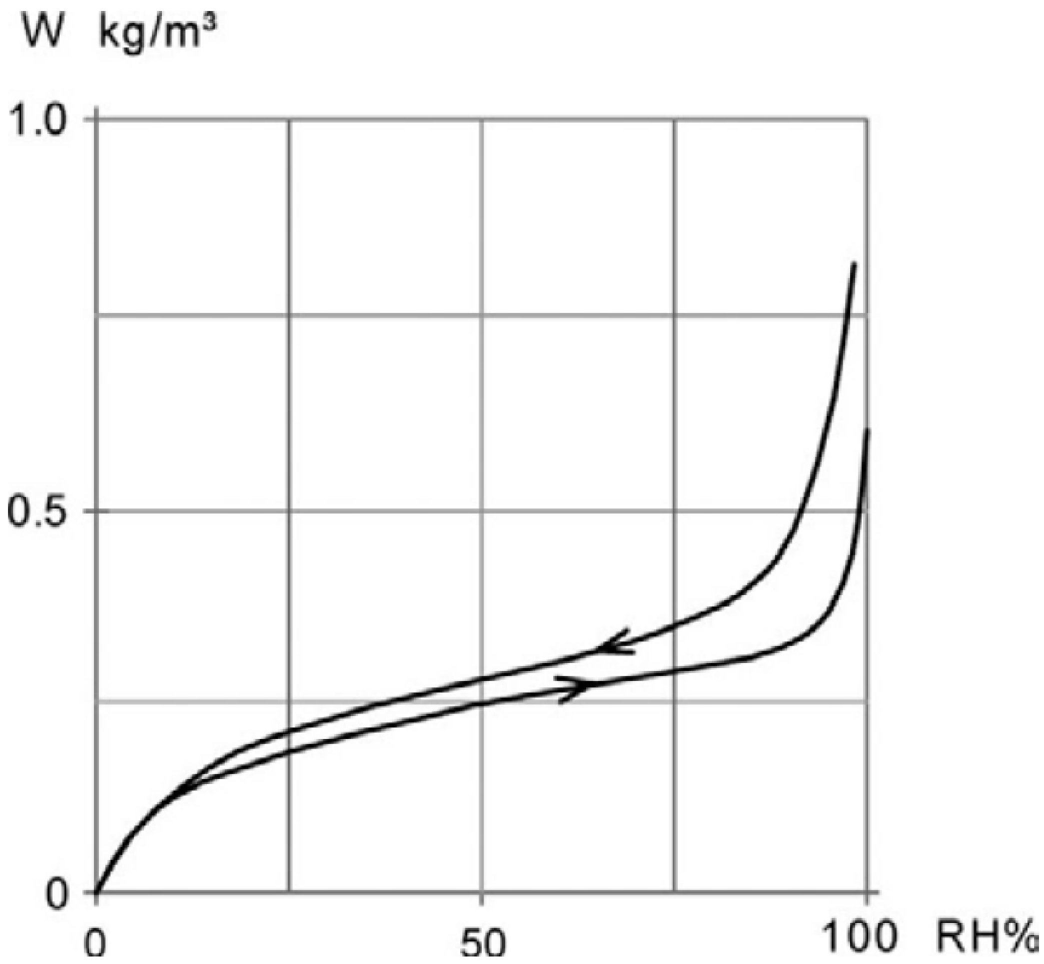
Moisture in material, hygroscopic moisture



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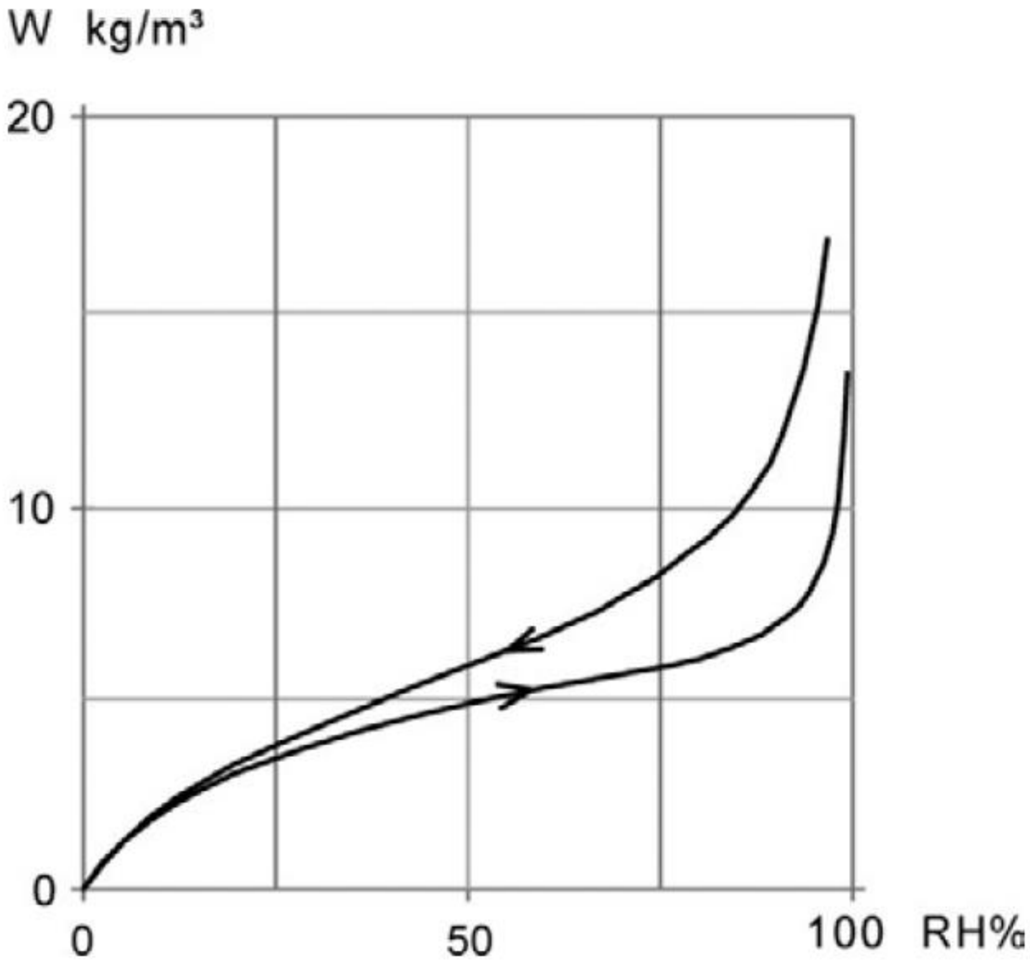

Brick

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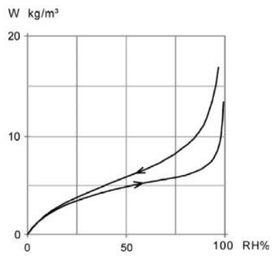
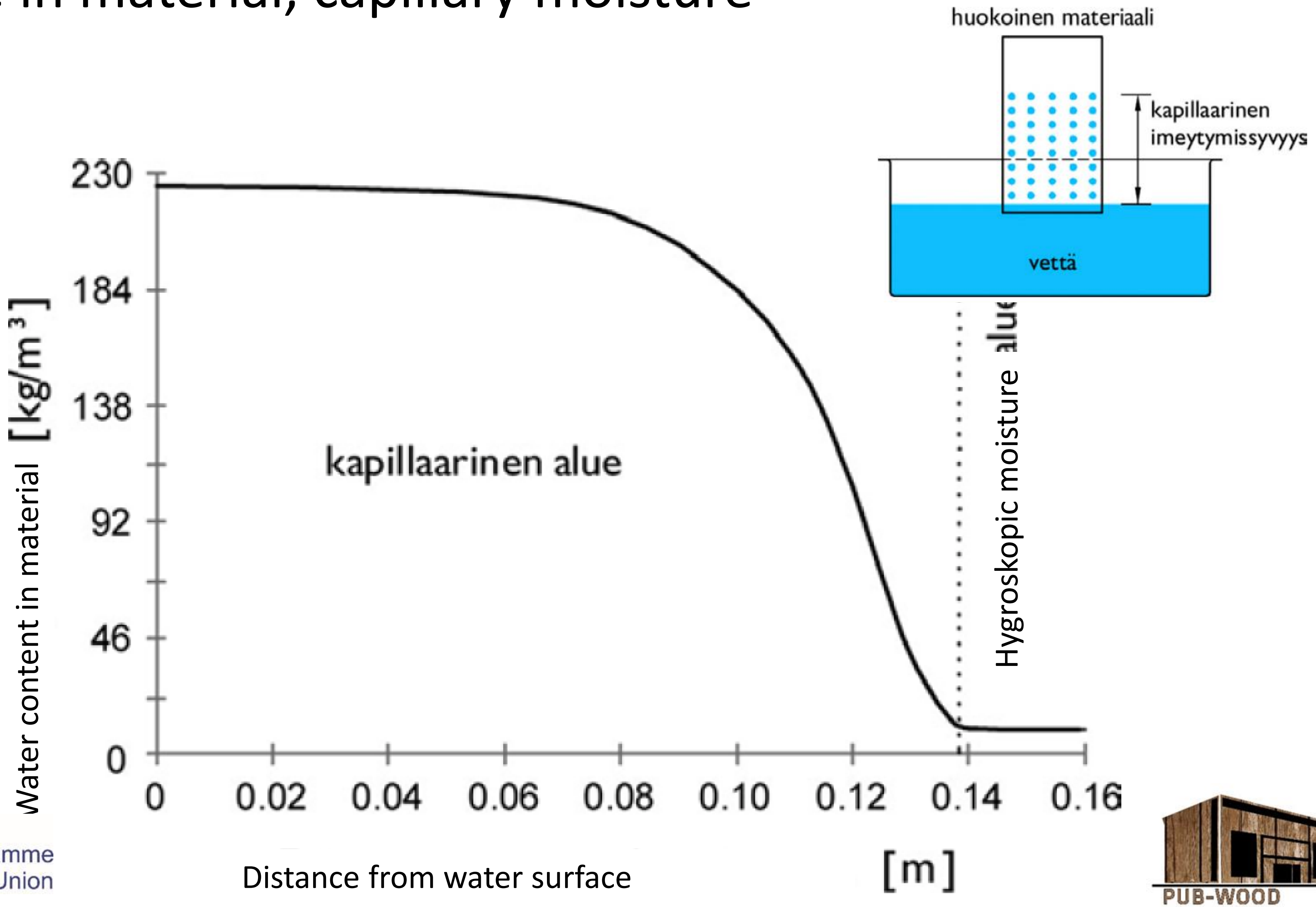
Moisture in material, capillary moisture





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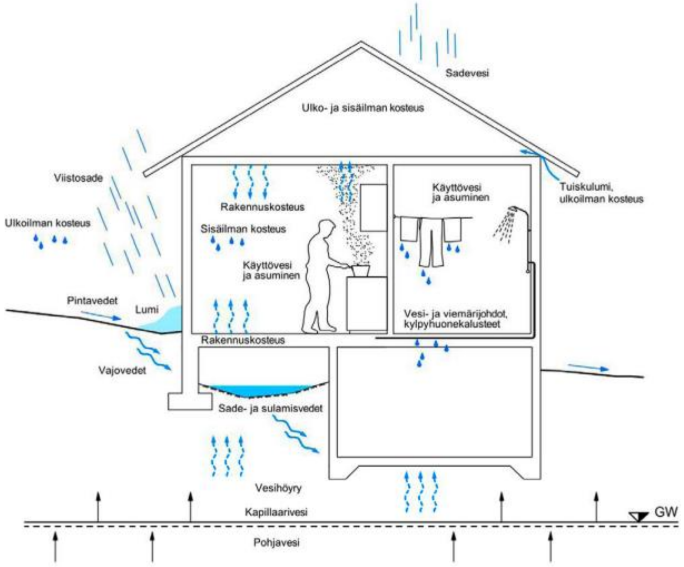
Moisture,
outdoor and indoor air



Outdoor air

weather data

Indoor air

result of:

- outdoor weather data
- moisture sources
- ventilation
- air conditioning

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Weather data

Average outdoor air temperatures in Finland

Ilman keskimääräiset lämpötilat T_m 1961…1990.(RIL 107-2000 Taulukko 1.5)

Paikkakunta	Kuukausi												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	vuosi
Helsinki-Vantaa	-6.9	-6.8	-2.9	2.9	9.9	14.9	16.6	15	10	5.4	0.1	-4.1	4.5
Turku	-6	-6.2	-2.6	3	9.8	14.6	13.5	15.2	10.3	5.7	0.6	-3.6	4.8
Tampere	-8	-7.9	-3.6	2.4	9.5	14.6	16.3	14.5	9.5	4.8	-0.5	-5.3	3.9
Lappeenranta	-9.4	-8.8	-3.8	2.3	9.8	14.8	16.7	14.8	9.5	4.2	-1.2	-6.2	3.6
Joensuu	-11.6	-10.7	-5.4	0.7	8.3	14.2	16.4	14	8.6	3.2	-2.7	-8.2	2.2
Jyväskylä	-10	-9.5	-4.7	1.3	8.7	14.1	15.7	13.6	8.3	3.4	-2.2	-7.2	2.6
Vaasa	-7.8	-7.8	-3.9	1.7	8.3	13.7	15.7	13.9	9.2	4.6	-0.9	-5.5	3.4
Oulu	-11.1	-10.4	-5.8	0.5	7.5	13.5	16	13.7	8.4	3	-3.1	-8.2	2
Sodankylä	-15.1	-13.6	-8.5	-2.1	5	11.6	14.1	11.2	5.9	-0.2	-7.4	-13.1	-1

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Weather data

Average outdoor air relative humidities in Finland

Ilman keskimääräiset suhteelliset kosteudet ϕ [%] 1961…1990.(RIL 107-2000 Taulukko 1.3)

Paikkakunta	Kuukausi											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Helsinki-Vantaa	88	86	82	74	65	66	72	78	84	86	89	89
Turku	89	87	82	75	66	64	71	76	83	86	89	90
Tampere	86	84	78	71	62	62	69	76	82	83	88	87
Lappeenranta	88	87	82	73	64	65	70	78	84	87	91	90
Joensuu	87	85	82	73	64	65	70	78	84	86	90	89
Jyväskylä	88	87	81	73	64	65	70	80	85	87	91	89
Vaasa	88	87	84	77	69	67	73	79	84	87	90	89
Oulu	86	85	82	74	67	65	70	77	82	85	88	88
Sodankylä	85	84	80	72	66	65	69	77	84	87	[illegible]	[illegible]

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Weather data

Average outdoor air water content in Finland

Ilman keskimääräiset vesihöyrynpitoisuudet v_m [g/ m^3] 1961…1990. (RIL 107-2000 Taulukko 1.2)

Paikkakunta	Kuukausi											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Helsinki-Vantaa	2.45	2.41	3.16	4.37	6.08	8.42	10.2	10	7.9	6.01	4.34	3.11
Turku	2.66	2.55	3.24	4.46	6.13	8.16	9.98	9.87	7.96	6.12	4.49	3.28
Tampere	2.18	2.14	2.84	4.05	5.65	7.76	9.58	9.46	7.47	5.57	4.11	2.76
Lappeenranta	1.98	2.06	3.18	4.15	5.94	8.24	9.95	9.89	7.85	5.61	4.01	2.65
Joensuu	1.63	1.72	2.57	3.72	5.4	7.94	9.77	9.41	7.22	5.19	3.52	2.22
Jyväskylä	1.88	1.94	2.7	3.87	5.63	7.9	9.64	9.42	7.17	5.32	3.71	2.41
Vaasa	2.27	2.24	2.98	4.2	5.82	7.94	9.77	9.48	7.51	5.76	4.07	2.78
Oulu	1.68	1.76	2.49	3.71	5.37	7.61	9.54	9.12	6.96	5.06	3.33	2.19
Sodankylä	1.17	1.32	1.94	2.96	4.49	6.76	8.38	7.82	6.28	4.02	[illegible]	[illegible]

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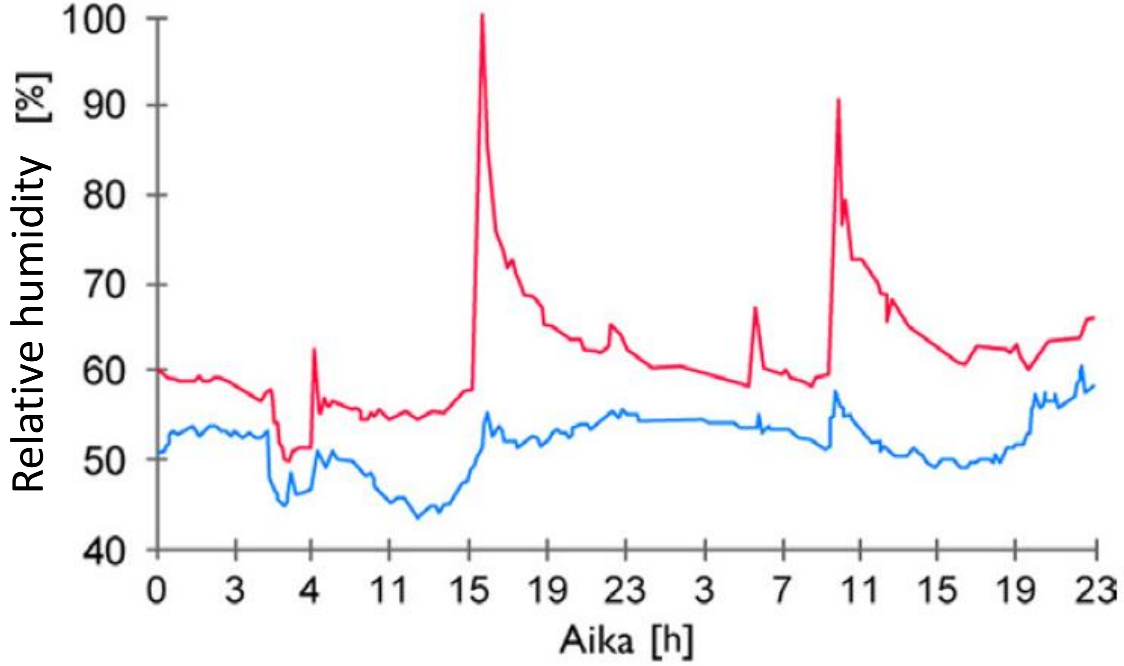
Moisture content , indoor air

Equation of mixing

$$v_i = v_e + \frac{G}{n \cdot V}$$

v_i	water content, indoor air	$\left[\frac{g}{m^3}\right]$
v_e	water content, outdoor air	$\left[\frac{g}{m^3}\right]$
G	Moisture product	$\left[\frac{g}{h}\right]$
n	ventilation rate	$\left[\frac{1}{h}\right]$
V	Volume of room or space	$[m^3]$



moisture source	G moisture product
Bath	700 g/h
Shower	2 600 g/h
Cooking	600–1 500 g/h
Avoin vesipinta Open surface of water	40 g/m²h
Kasvit, pienet Small plants	7–15 g/h
Kasvit, keskikokoiset Medium plants	10–20 g/h
Human, rest	40–50 g/h
Vaatteiden pesu ja kuivaus Washing the clothes	

Relative humidity

$$RH = \frac{v}{v_k} = \frac{p}{p_k}$$

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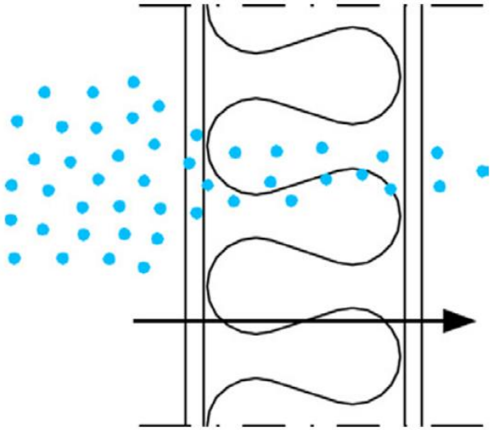
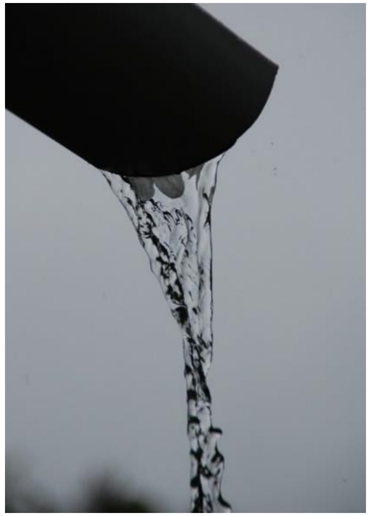
Forms of moisture transfer



Water vapour
- Diffuusio
- Moisture convection

Liquid water
- Gravitational
- Capillary force
- Pressure difference



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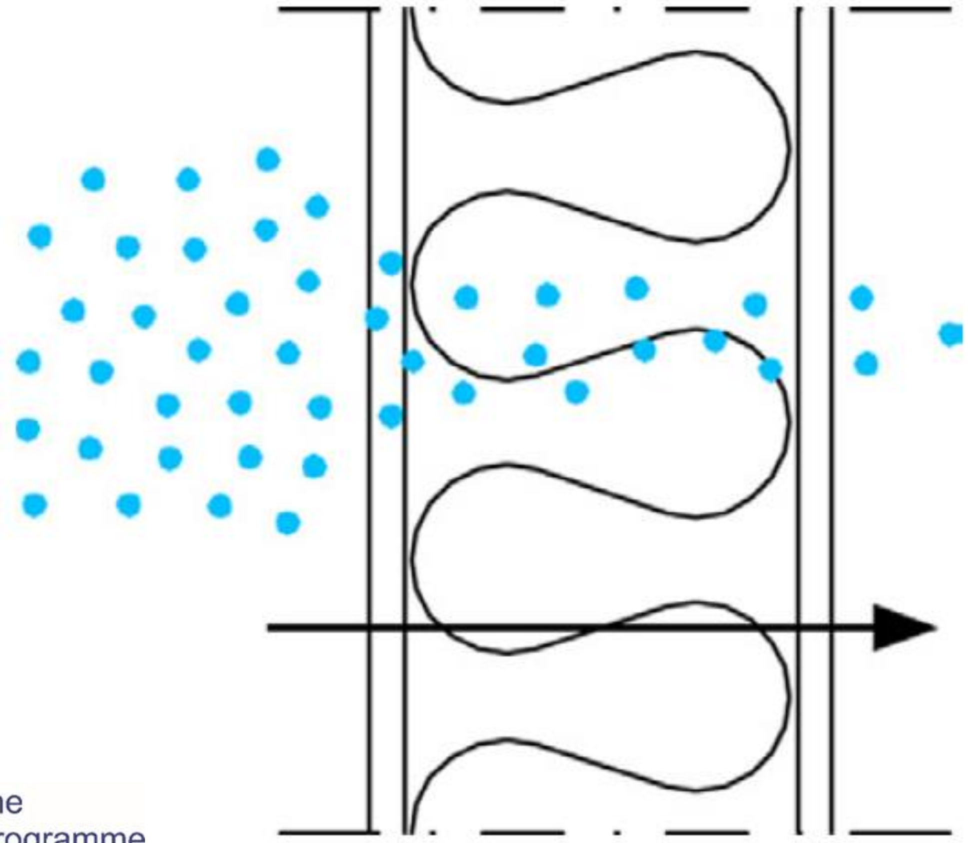
Forms of moisture transfer

- diffuusio



$$g_{dif} = \frac{p_1 - p_2}{Z_p}$$

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Hygrothermal behaviour of building element

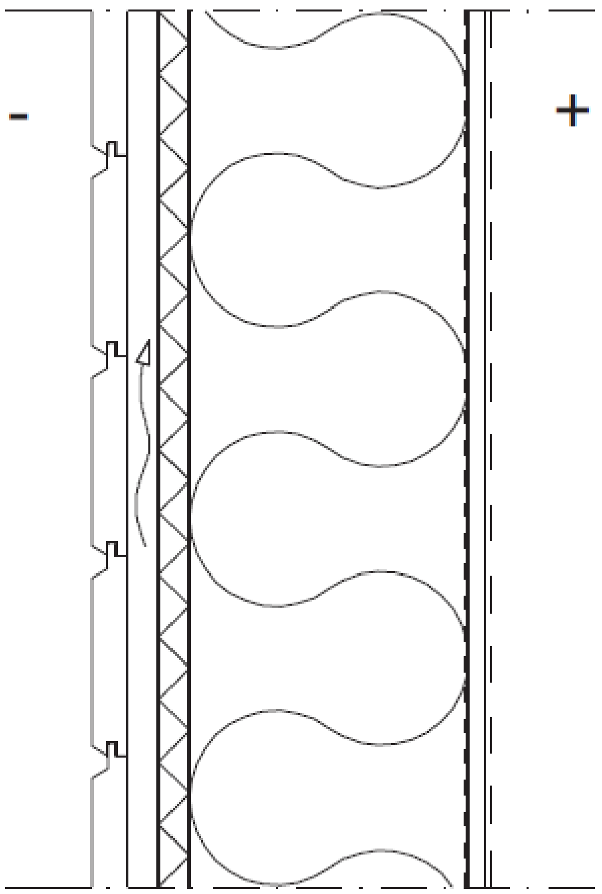
Calculation methods

Steady-state

RH distribution (constant in time)
(glaser method)

Time dependent

Numerical methods HAM-methods
(Heat, air and moisture)
Softwares:
WUFI, Delphin, COMSOL multiphysics



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Steady state hygrothermal calculation (Glaser method)

Steps

1 Calculation of temperatures distribution

2 Calculation of saturated vapour distribution

2 Calculation of water vapour distribution

3 Calculation of relative humidity distribution

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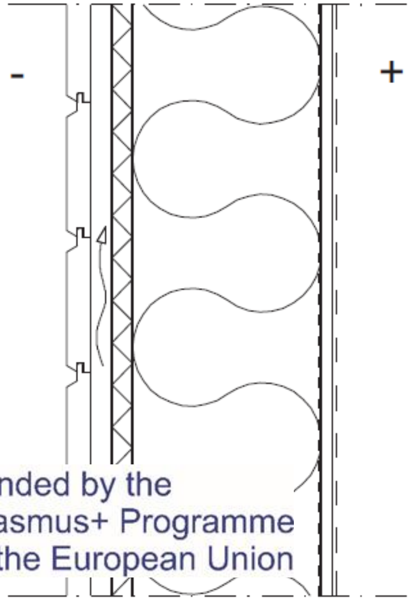
Moisture criteria for wooden building

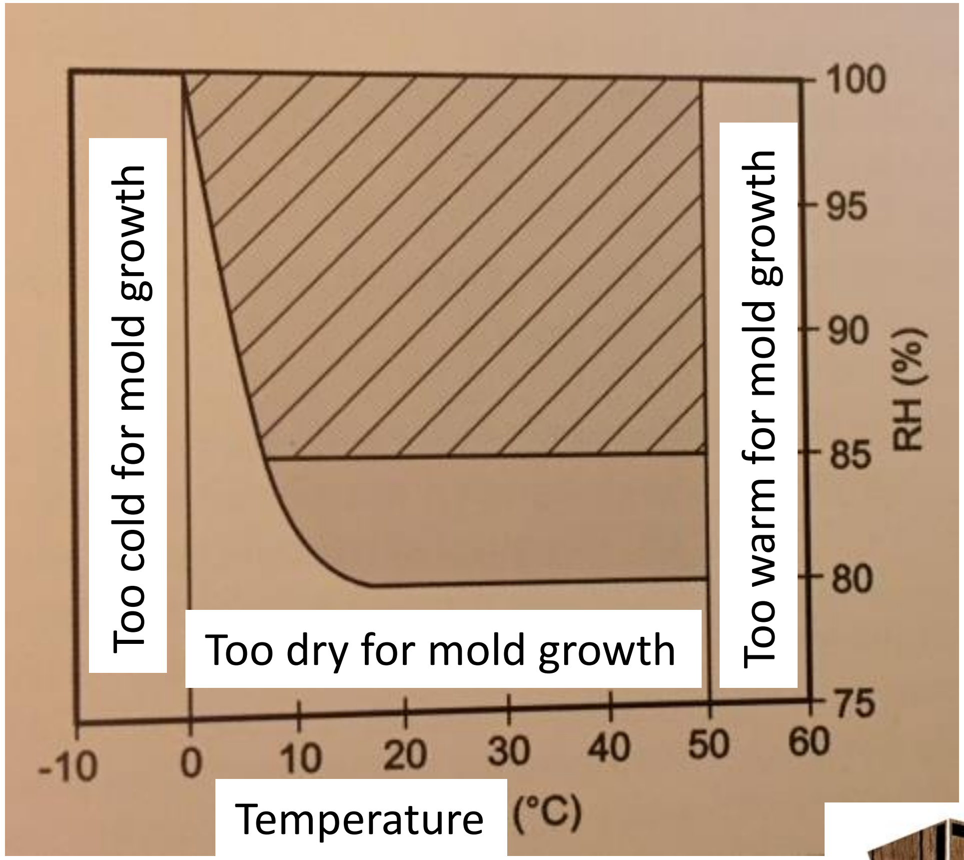
Risk assesement

Mold growth

Rot

- classification of wood





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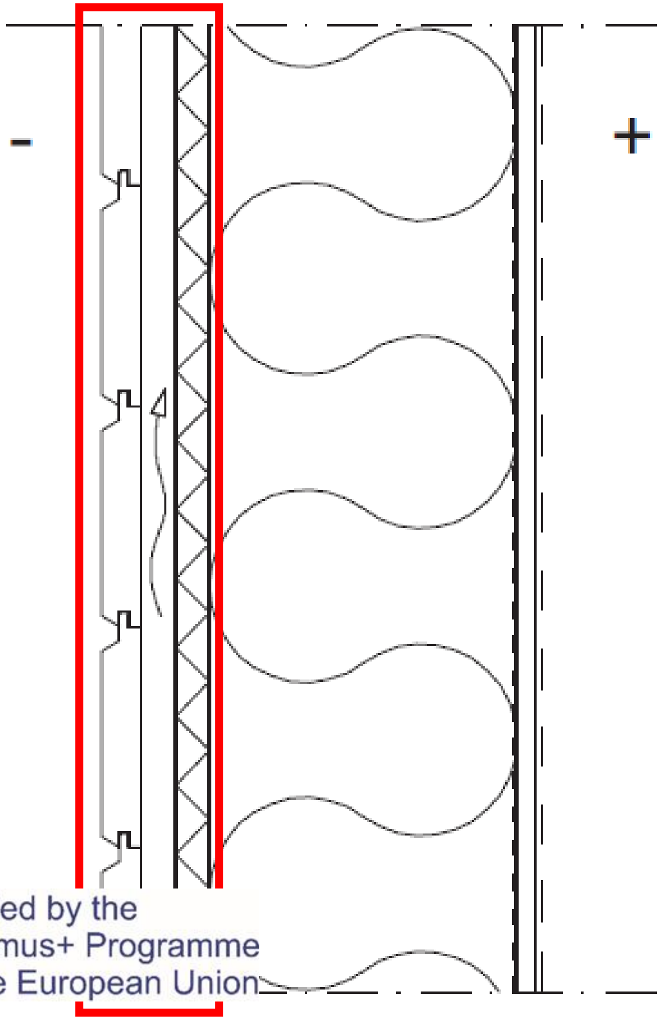

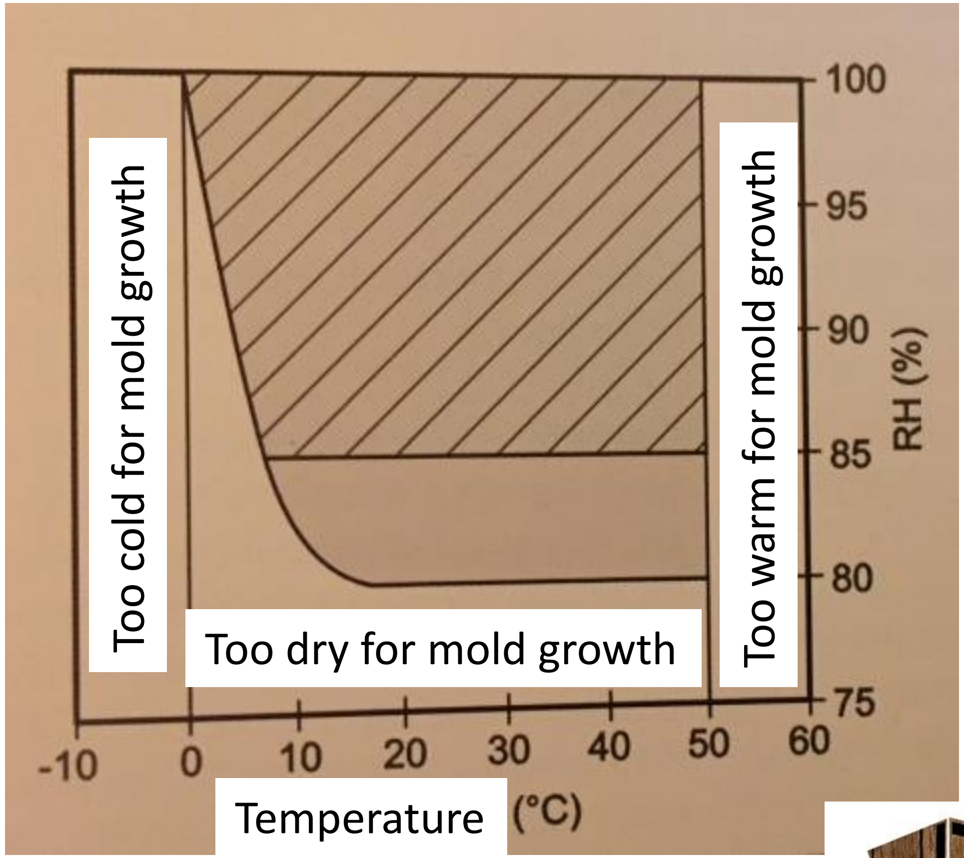

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Design prosess

Moisture control statement of a construction project

- Moisture controll requirements
- Procedures and measures for verification
- Personnel in charge of moisture control

A party engaging in a construction project shall be responsible for preparing a moisture control statement for the construction project.

The construction project's moisture control statement shall contain general construction project information, moisture control requirements at different stages of the project, procedures and measures for the verification of moisture control requirements and personnel in charge of moisture control. The construction project's moisture control statement shall also contain information regarding the person responsible for moisture control of a construction project.

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Moisture in museum

Stop time!

Corrosion of metals

RH > 55 %

Moisture deformations of wood

With variation of relative humidity

How to control moisture?

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