Prediction of Moisture Distribution in Closed Ribbed Panel for Roof

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Introduction

ANALYSIS of HYGROTHERMAL PERFORMANCE

Methodology of ISO 13788:2012

Methodology based on Fick's law

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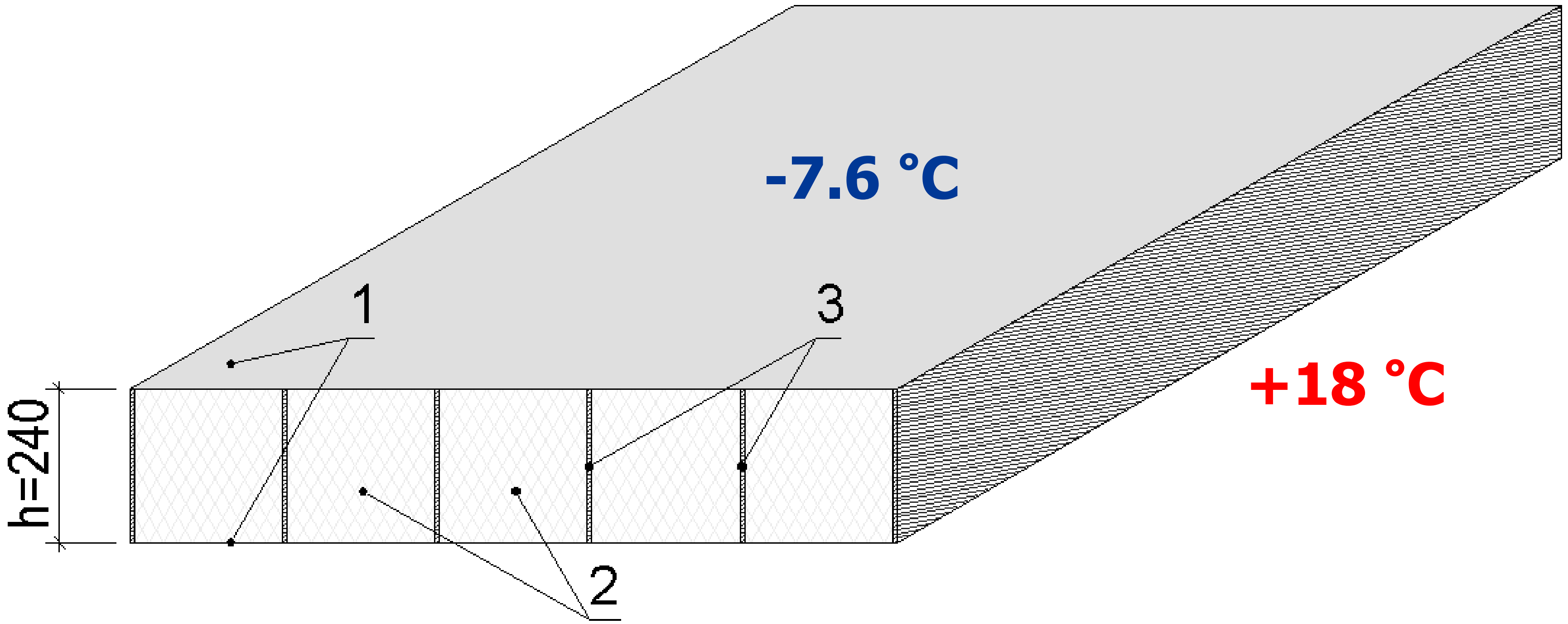
Ribbed sandwich panel



1 – steel sheeting (t = 0.5 mm)

2 – polystyrene (EPS) insulation

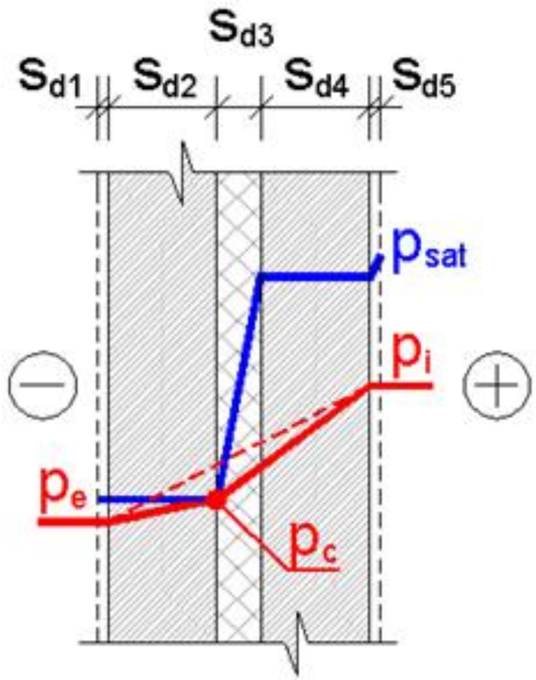
3 – birch plywood ribs (t = 6.5 mm)

Methodology of ISO 13788:2012

Assumptions:

- build-in moisture and hygroscopicity are not taken into account;
- constant and moisture independent properties of materials;
- one-dimensional moisture flux through the building envelope;
- condensation if partial water vapour pressure exceeds water vapour saturation pressure.

Methodology of ISO 13788:2012. Results



<u>Layers of sandwich panel replaced by water vapour diffusion-equivalent air layer thicknesses (rotated by 90°):</u>

$s_{d1} = s_{d5} = 0$ m – external and internal surfaces;
s_{d2}, s_{d4} – steel sheeting;
s_{d3} – plywood rib.

<u>Water vapour pressure *p*:</u>
sat – saturation; *e* – external; *c* – condensation interface; *i* – internal.

$$p_e = \varphi_e \cdot p_{sat} \qquad p_i = p_e + \Delta p$$

$$p_{sat} = 610{,}5 e^{\frac{21{,}875 T_C}{265{,}5 + T_C}} \quad if \quad T_C \geq 0\,°C$$

$$p_{sat} = 610{,}5 e^{\frac{17{,}269 T_C}{237{,}3 + T_C}} \quad if \quad T_C < 0\,°$$

T_i = +18 °C; T_e = -7.6 °C; φ_e = 0.87
Δp = 270 Pa (moisture class I)
μ = 40 (wood); μ = 10^6 (steel)

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Methodology of ISO 13788:2012 ...

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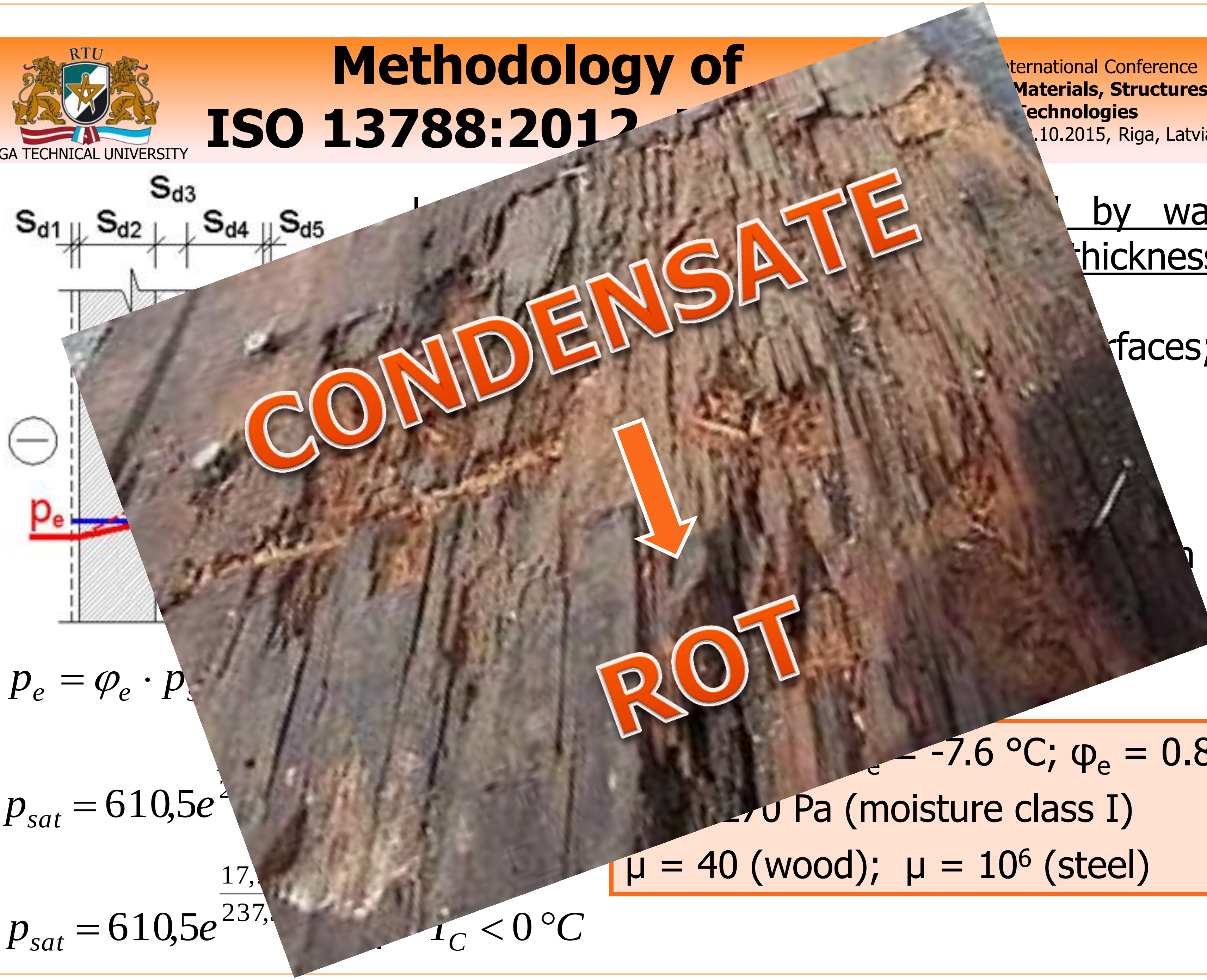


... by water ... thicknesses

...rfaces;

...n

$p_e = \varphi_e \cdot p_{s}$ ...

$p_{sat} = 610{,}5e^{...}$ ...

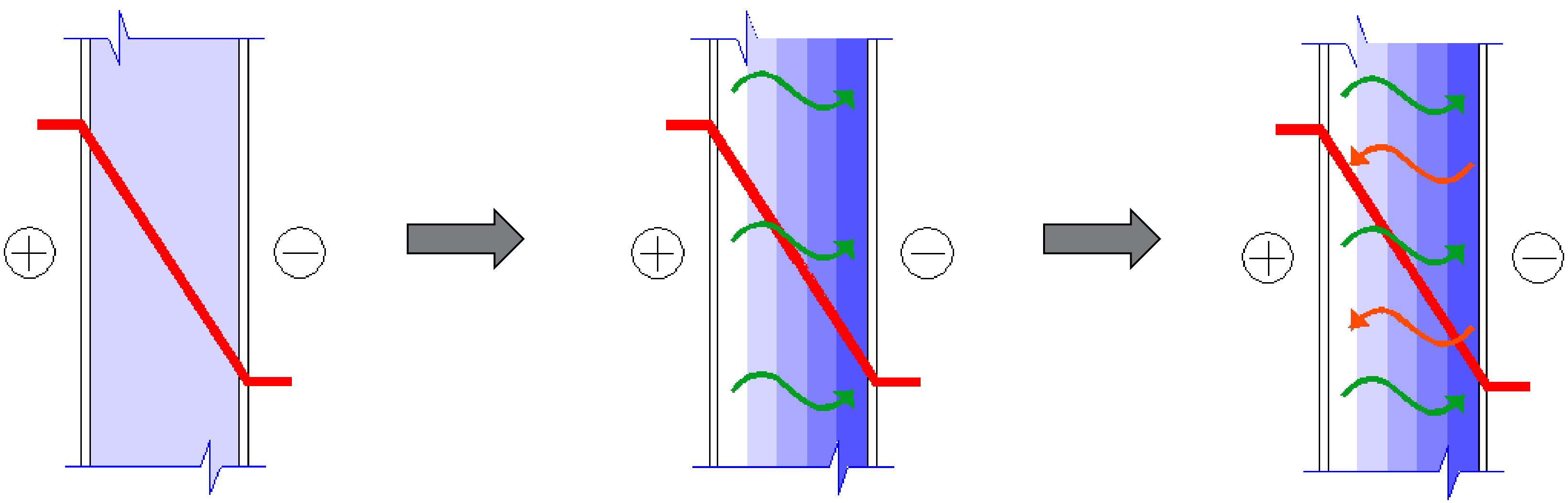
$p_{sat} = 610{,}5e^{\frac{17,...}{237,...}}$ ... $T_C < 0\,°C$

... = -7.6 °C; φ_e = 0.87
...70 Pa (moisture class I)
μ = 40 (wood); μ = 10^6 (steel)

Methodology based on Fick's law

Assumptions:

- no moisture from environment air;
- one-dimensional flux of built-in moisture;
- initially moisture is evenly distributed.



temperature gradient

moisture flux due the temperature gradient

moisture flux due the moisture gradient

Methodology based on Fick's law. Algorithm

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Devide rib into *n* layers.

Determine characteristics of wood in each layer.

Determine mean temperature in each layer.

Determine freezed layers.

<u>FREEZED LAYERS</u>

Assume that no moisture flux will occur between freezed layers.

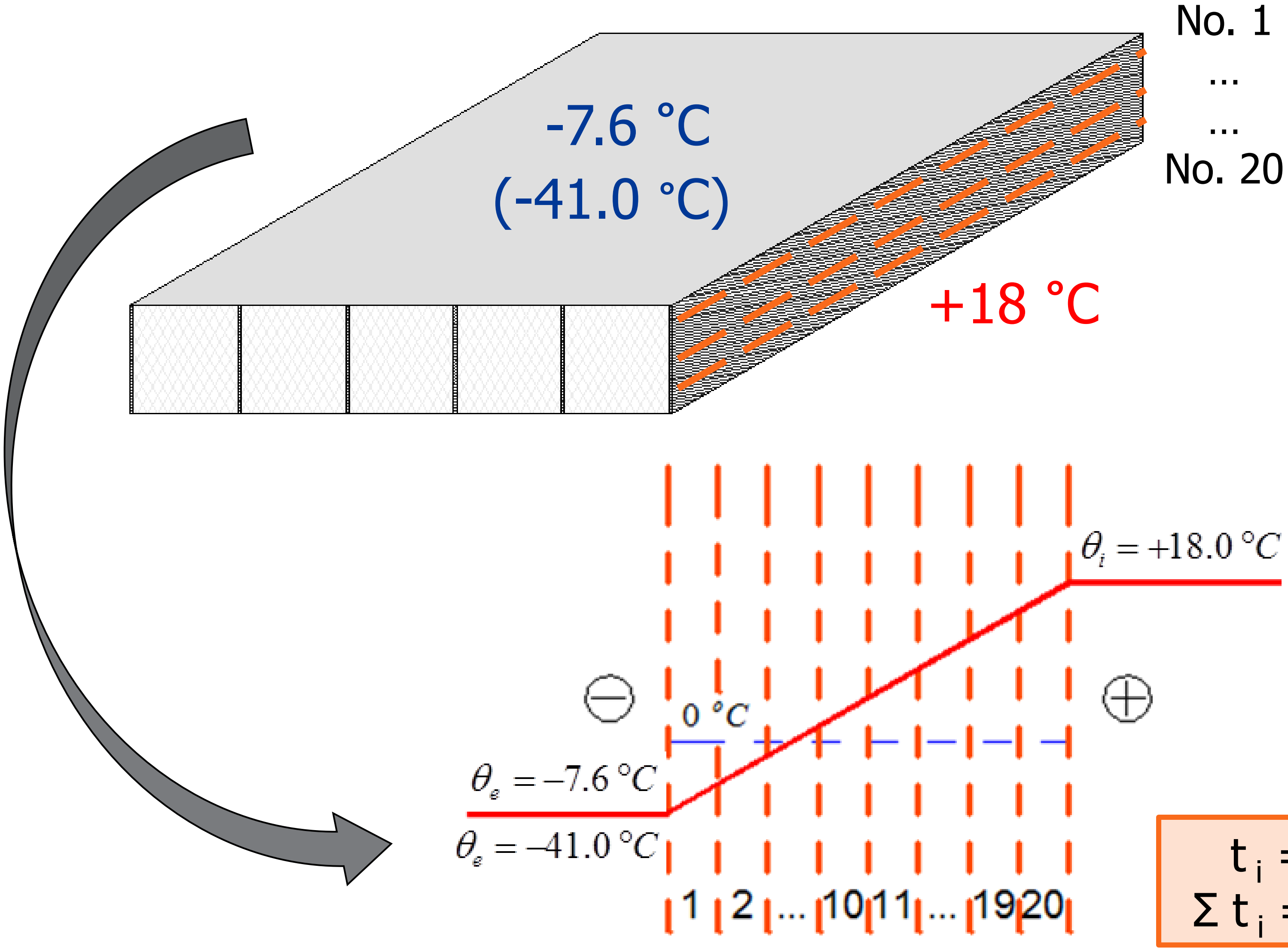
<u>NON-FREEZED LAYERS</u>

Determine bound water diffusion coefficient in each layer.

Determine moisture flux rate between adjacent layers.

Determine total moisture content in each layer after time *t*.

Methodology based on Fick's law. Ribbed panel



t_i = 1 day
$\Sigma\, t_i$ = 5 years

Methodology based on Fick's law. Properties

Properties of plywood (M_n < 30%):

- density:
  [б. Н. Уголев]
  $$\rho_n = 0{,}957\rho_{12}\frac{100 + M_n}{100 + 0{,}6M_n}$$
- specific gravity:
  [J. F. Siau]
  $$G_n = \frac{\rho_n}{\rho_w\left(1 + \frac{M_n}{100}\right)}$$
- porosity:
  [S. Avramidis]
  $$v_{a,n} = 1 - G_n\left(0{,}667 + 0{,}01M_n\right)$$
- thermal conductivity:
  [J. F. Siau]
  $$\lambda_n = 418\left[G_n\left(5{,}18 + 0{,}096M_n\right) + 0{,}57v_{a,n}\right]\cdot 10^{-4}$$
- non-freezing moisture (T_n > -50 °C):
  [Б. С. Чудинов]
  $$M^* = 12 + 19.5\exp\left(0.055T_{C,n}\right)$$

M_0 = 12%; ρ_{12} = 640 kg/m^3

Methodology based on Fick's law. Properties

Properties of layers:

- thermal resistance: [ISO 13788:2012]

$$R_n = \frac{\Delta x}{\lambda_n}$$

- mean temperature: [ISO 13788:2012]

$$T_{K,n} = 273.15 + \left[T_e + \frac{\sum_{n=1}^{n} R_n - 0.5 R_n}{R_T} \left(T_i - T_e \right) \right]$$

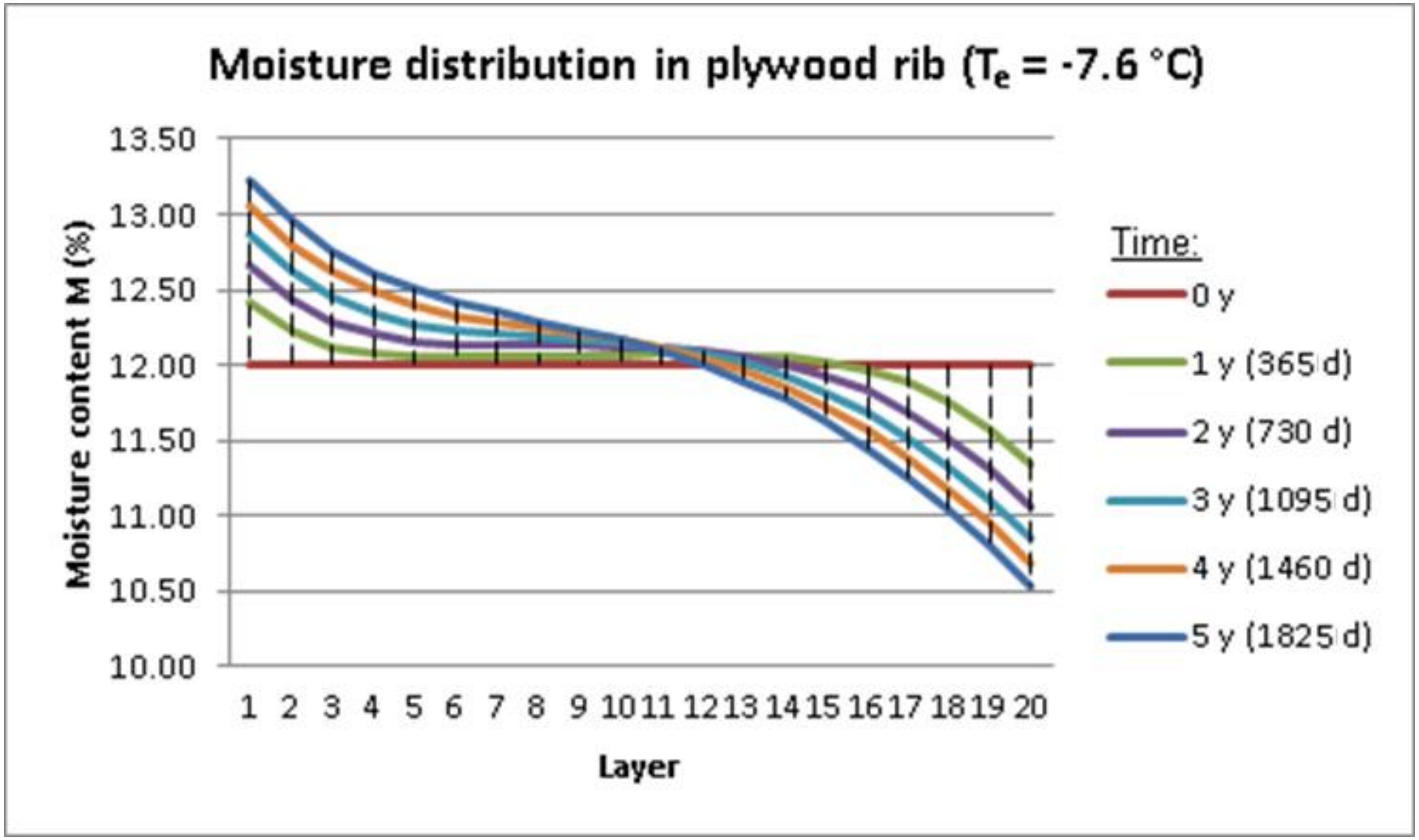
- diffusion coefficient transverse to the fibre direction: [J. F. Siau]

$$D_{T,n} = \frac{0{,}7 \cdot 10^{-5} \cdot \exp\left[-\left(\frac{9200 - 70 M_n}{R T_{K,n}} \right) \right]}{\left(1 - v_{a,n}\right)\left(1 - \sqrt{v_{a,n}}\right)}$$

- moisture flux: [J. F. Siau]

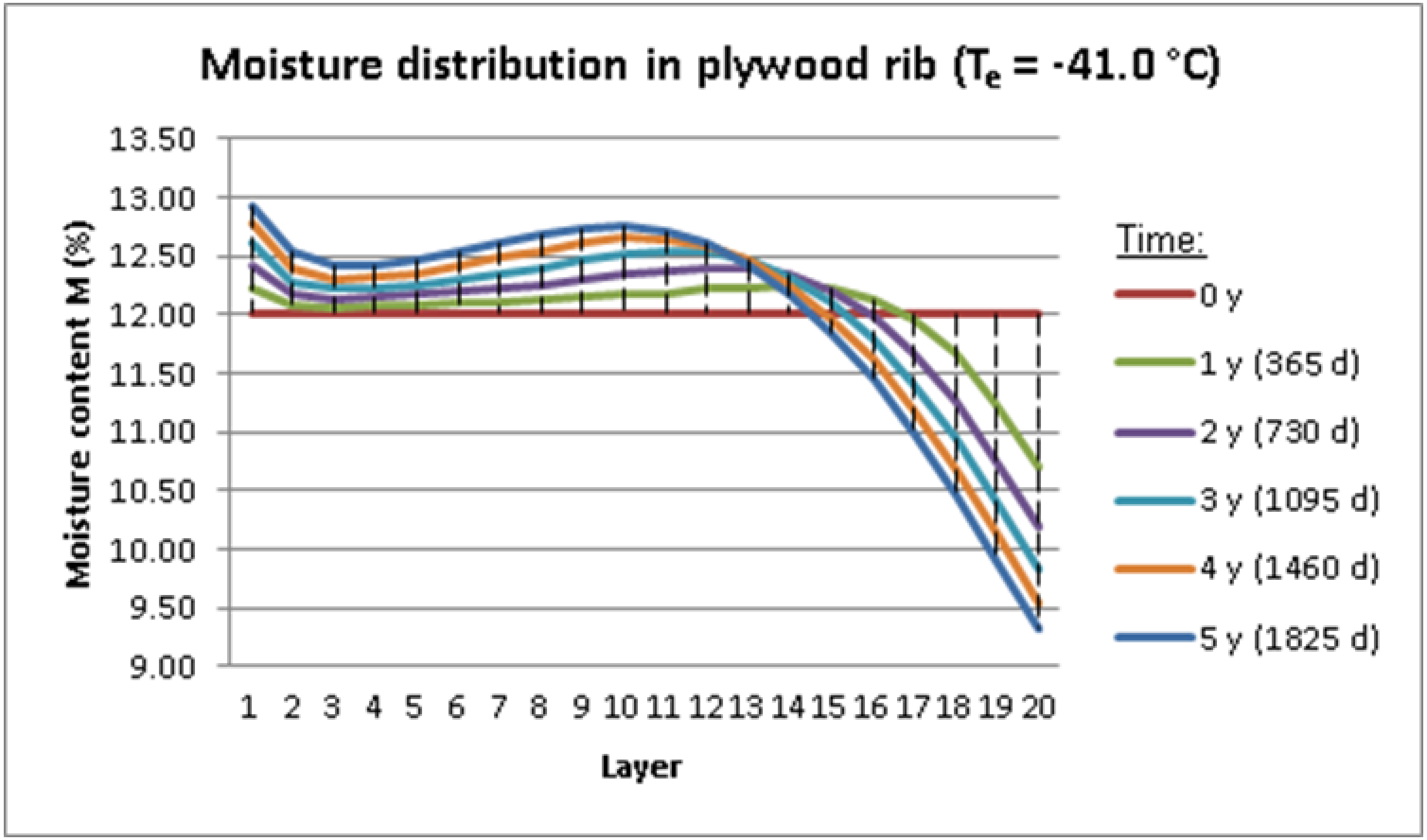
$$J = -\frac{G \rho_w}{100} \left[D_T \left(\frac{M}{R T_K + 70 M} \right) \left(\frac{E_b}{T_K} \right) \frac{\Delta T_K}{\Delta x} + D_T \frac{\Delta M}{\Delta x} \right]$$

Results. Methodology based on Fick's law. Results



M_0 = 12,00% → M_{max} =13,22%

Results. Methodology based on Fick's law. Results



M_0 = 12,00% → M_{max} =12,94%

Conclusions

- Methodology for prediction of moisture distribution in the closed building envelope is presented. An insight into prospective results obtained according to this methodology is given by analysing a ribbed sandwich panel at constant conditions.

- Results show that at moisture concentration areas moisture content of a plywood rib during 5 years at constant conditions changes from 12.00% to 13.22%. That does not exceed 30% (FSP) therefore no free water will be observed and it can be assumed that no rot is possible.

- In opposite according to the methodology of ISO 13788:2012 condensation may occur that may create favorable conditions for rot.

Thank You for attention!

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