

DTU Civil Engineering, Technical University of Denmark

Fugtberegningsmetoder

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$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$

DTU Civil Engineering
Department of Civil Engineering

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Beregningsmetoder

- Hygrotermisk
- Skimmelvurdering - temperaturfaktor
- Glasers metode
- Instationære - analytiske
- Numeriske metoder
 - 1D
 - MATCH
 - WUFI
 - 2D
 - Delphin
 - WUFIZ
 - Whole building
 - BSim
 - WUFI Plus

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Fugtberegningsmetoder

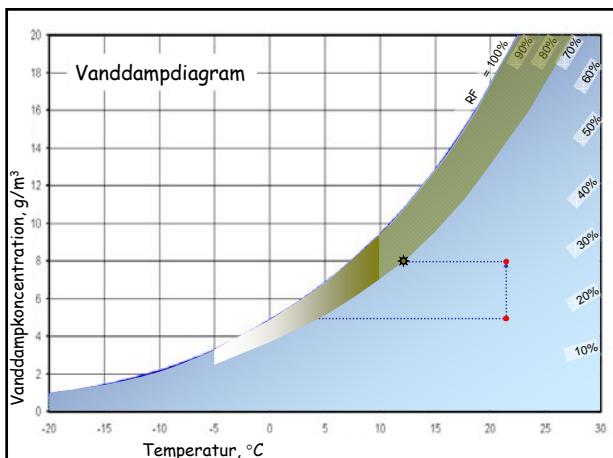
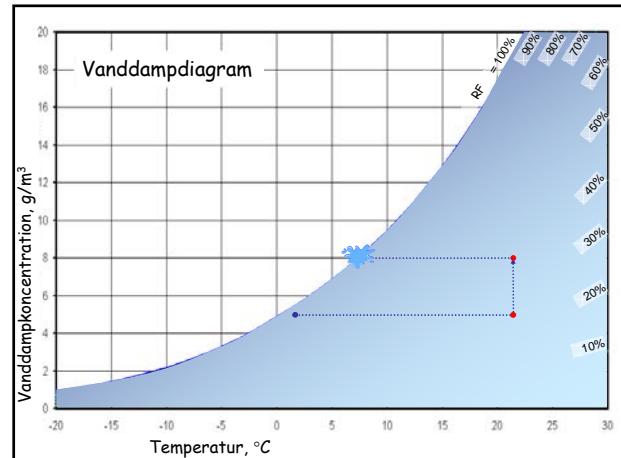
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Hygrotermik

- Mange beregningsværktøjer kan undværes - hvis bare man har lidt fornemmelse for basale hygrotermiske forhold
- Vanddampdiagrammet...

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Fugtberegningsmetoder



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Skimmelvurdering

- Temperaturfaktor:

$$f_{si} = \frac{\theta_{si} - \theta_e}{\theta_i - \theta_e}$$
- f_{si} er altid mindre end 1. Jo lavere værdier, jo større kuldebrovirkning \Rightarrow risiko for indendørs kritisk fugtighed.
- Adan, 1994 (Holland):

$$f_{si} > 0,73$$

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Fugtberegningsmetoder

Glasers metode

- Skemabaseret regnemetode
- Regneark
- Grafisk metode

Fugtberegningsmetoder

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Beregning af temperaturfordeling

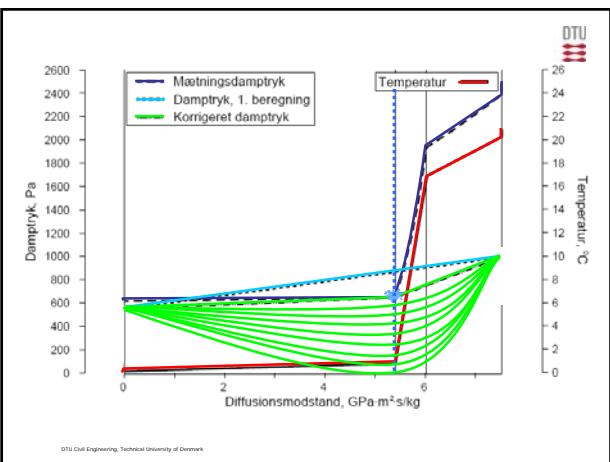
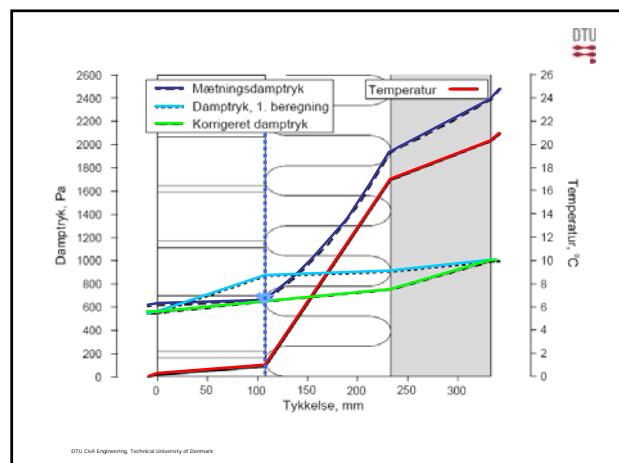
Materiale	Tykkelse, s m	Varme- lednings- evne, λ , W/m·K	Isolans, R m ² K/W	Temperatur- fald, $\Delta\theta$ °C	Temperatur, θ °C
Udv. overgang					
Tegl	0,110				
Mineraluld	0,125				
Porebeton	0,100				
Indv. overgang					
			$\Sigma R:$	$\theta_{uds} - \theta_{uds}$	

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Beregning af damptryksfordeling

Materiale	Mætnings- damptryk, p_i Pa	Damppermea- bilitet, δ μg/m·s Pa	Diffusions- modstand, Z GPa·m ² /s/kg	Damptryks- fald, Δp Pa	Damptryk, p Pa	Relativ fuglighed, RF %
Udv. overgang	611					
Tegl	620					
Mineraluld	652					
Porebeton	1937					
Indv. overgang	2398					
	2487					
			ΣZ	$p_{uds} = p_{uds}$		

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Glasers metode - ulemper

- Stationær metode
- Betruger kun vanddampdiffusion
 - ikke væskestrømning
 - ikke luftbåren fukt (konvektion)
- ...

Fugtberegningsmetoder

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Instationære - analytiske

$U(t) = \frac{w(t) - w_{\infty}}{w_0 - w_{\infty}}$ $U_w = \frac{\bar{w} - w_{\infty}}{w_0 - w_{\infty}}$

$\frac{\partial w}{\partial t} = D_w \cdot \frac{\partial^2 w}{\partial x^2}$

Metoden antager konstant D_w

Figure 14. Moisture content distributions at various times for a slab. The curves correspond to different values of the Fourier number (F_o)

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Numeriske metoder

- Differens- og finite element-metoder
 - 1D
 - 2D
 - Whole building

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Fugtberegningmetoder

1D

- MATCH (Bygge- og Miljøteknik + DTU)
- ...
- ...
- ...
- ...
- WUFI (Holzkirchen Institut für Bauphysik)

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Fugtberegningmetoder

MATCH

www.match-box.dk

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Fugtberegningmetoder

WUFI

www.wuwi.de/index_e.html

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Fugtberegningmetoder

Programmernes fordele

- MATCH
 - Tager hensyn til hysterese, latent varme og langbølget udstråling fra udvendige overflader
 - Regner hurtigt
 - Kan regne på visse konvektionsformer
- WUFI
 - Moderne program
 - Mange brugere over hele verden
 - Væsketransport og slagregn

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Fugtberegningmetoder

2D

- WUFI 2D (Holzkirchen Institut für Bauphysik)
- ...
- ...
- Delphin (TU Dresden)

Fugtberegningsmetoder

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WUFI 2D

The screenshot shows the WUFI 2D software interface. On the left is a vertical menu with options like Deutsch, English, Tour, Basics, Validation, Application, Literature, Purchase WUFI, Downloads, Service, Seminars, WUFI Forum, News, Homepage Holzkirchen, and Impress. The main area features a 3D model of a wall section with a grid overlay. To the right of the 3D model are several data plots and tables. A large blue circle highlights the 3D model. The URL www.wufi.de/index_e.html is visible at the bottom right.

www.wufi.de/index_e.html

Delphin (& CHAMPS)

The screenshot shows the Delphin software interface. It features a 3D model of a building structure on the right and a detailed material properties dialog box on the left. The dialog box contains fields for 'Lege cement producer' and 'Lege cement producer' with values '20.5 - 25.52' and 'ELEMENT'. The URL <http://bauklimatik-dresden.de/delphin/index.php> is visible at the bottom left.

<http://bauklimatik-dresden.de/delphin/index.php>

Whole Building Simulation

- BSim (Statens Byggeforskningsinstitut)
- ...
- WUFI Plus (Holzkirchen Institut für Bauphysik)

- Konstruktionernes fugtighed afhænger meget af inde- og udeklimaets fugttilstand
- Indeklimaets fugtighed afhænger (også) af konstruktionernes fugttilstand
- Der er tæt sammenhæng mellem temperatur, fugtighed og ventilation
- Simulering for hele bygningen må derfor være "rigtigst"

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Fugtberegningsmetoder

BSim

The screenshot shows the BSim software interface. It features a 3D model of a building structure on the right and two line graphs on the left. The top graph is titled 'Mean 20.2004' and shows 'RH relative %' over time. The bottom graph is also titled 'Mean 20.2004' and shows 'RH relative %' over time. The URL www.bsim.dk is visible at the bottom left.

www.bsim.dk

WUFI Plus

The screenshot shows the WUFI Plus software interface. On the left is a vertical menu with options like Deutsch, English, Tour, Basics, Validation, Application, Literature, Purchase WUFI, Downloads, Service, Seminars, WUFI Forum, News, Homepage Holzkirchen, and Impress. The main area features a 3D model of a building structure with a grid overlay. To the right of the 3D model are several data plots and tables. A large blue circle highlights the 3D model. The URL www.wufi.de/index_e.html is visible at the bottom right.

www.wufi.de/index_e.html

Torkas

- Bedømmelse af udtørringstider for nystøbt beton

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Toolbox

- International Building Physics Toolbox in Simulink (WWW.IBPT.ORG) . HAM Tools.
 - Angela Sasic Kalagasisid, Chalmers University, S.

Simulink model

- Heat and moisture balance for one calculating node

26 Figure 4: The first subsystem of the One node block.
Fugtberegningmetoder

Konklusion

- De beregningsmæssige muligheder er ved at være ganske veludviklede
- Men sund fornuft og basal bygningsfysisk viden er nu stadig nok det vigtigste...

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