Technical University of Denmark

Building thermal storage for district heating load management

EERA JP Workshop

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Benefit for DH load management

- Aviod to install expensive peak load boilers
- Improve unit partial load performance
- Reduce frequent start-up and stop of HOB
- Imcrease system redundancy and resilience
- Improve system flexibility to integrate intermittent renewable power production

Content of the analysis

- Control the heat supply to each room and make the total heating load below a certain therehold value
- The heat load control follows the fairness and quality of service principle
- The office buildings were built in 1979 – 1998*, with 3 different thermal masses
- Each building includes 6 rooms at different positions
- The analysis is simplified:
  - Ideal heater in each room
  - The control of room heat supply is not considered
  - Spatial differences between the controlled rooms are not considered.

* Sbi 2012:01 Danish building typologies

Selection of building construction

Code No	Materials	Thickness (mm)	Density ρ/(kg/m^3)	Thermal conductivity λ (W/m.K)	Specific heat c_p (J/kg.K)
C50, C100, C120, C150	Concrete	50, 100, 120, 150	2200	1.65	1000
CS15	Concrete screed	15	1200	1.15	1000
B100, B110	Brick	100, 110	1700	0.77	800
I20, I50, I100	Insulation	20, 50, 100	25	0.038	1030
L50, L100	Light weight concrete	50, 100	1200	0.4	1000
P15	Plasterboard	13, 15	900	0.25	1000

Light weight	External Wall	P15-C120-I100-B110
	Internal Wall	P15-C70-P15
	Ceiling	CS15-C50-I180-P15
	Floor	CS15-C50-I180-P15
Heavy weight	External Wall	P15-C120-I100-B110
	Internal Wall	P15-C70-P15
	Ceiling	CS15-C50-I180-P15
	Floor	CS15-C50-I180-P15
Extra heavy	External Wall	P15-C150-I100-B110
	Internal Wall	P15-C100-P15
	Ceiling	CS15-C100-I180-P15
	Floor	CS15-C100-I180-P15

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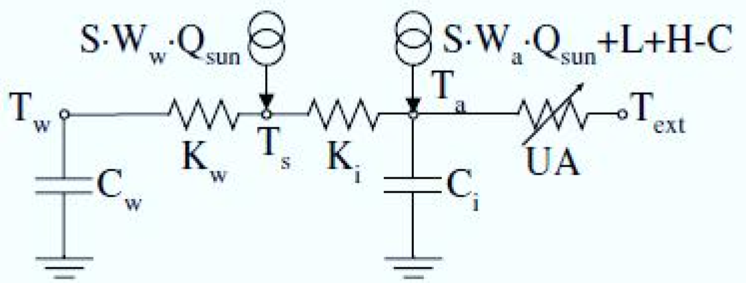
Building thermal properties calculation

	Component		Area (m2)	U-value (W/m^2. K)	Internal areal heat capacity cw,i (Wh/K.m2)	Internal areal heat capacity Cw,i (J/K)	Equivalent thermal resistance between construction and internal surface Re(m2.K/W)	Heat loss coefficient between construction and internal surface Kw [W/K]
Light weight	External Wall 0.34	P15-B110-I100-B110	6.8	0.3359	29.0226	7.105E+05	0.1469	46.29
	Internal Wall	P15-L80-P15	39.4	3.125	16.1649	2.293E+06	0.1531	257.35
	Ceiling 0.19	CS15-L60-I180-P15	24	0.2016	23.748	2.052E+06	0.1537	156.15
	Floor 0.19	CS15-L60-I180-P15	24	0.2016	23.748	2.052E+06	0.1537	156.15
Heavy weight	External Wall 0.34	P15-C120-I100-B110	6.8	0.3464	40.1846	9.837E+05	0.0961	70.76
	Internal Wall	P15-C70-P15	39.4	6.1567	23.3973	3.319E+06	0.0795	495.60
	Ceiling 0.19	CS15-C50-I180-P15	24	0.2066	35.3367	3.053E+06	0.0431	556.84
	Floor 0.19	CS15-C50-I180-P15	24	0.2066	35.3367	3.053E+06	0.0431	556.84
Extra Heavy	External Wall 0.34	P15-C150-I100-B110	6.8	0.3418	39.762	9.734E+05	0.0857	79.35
	Internal Wall	P15-C100-P15	39.4	5.5369	29.695	4.212E+06	0.0857	459.74
	Ceiling 0.19	CS15-C100-I180-P15	24	0.2053	57.6154	4.978E+06	0.0652	368.10
	Floor 0.19	CS15-C100-I180-P15	24	0.2053	57.6154	4.978E+06	0.0652	368.10

EN ISO 13789

Building simulation model

$$C_a \frac{dT_a}{dt} = \sum (U_i \cdot A_i + C_a \cdot n_{inf}) \cdot (T_{ext} - T_a) + h_i(T_s - T_a) + w_a \cdot Q_{sun} + H$$

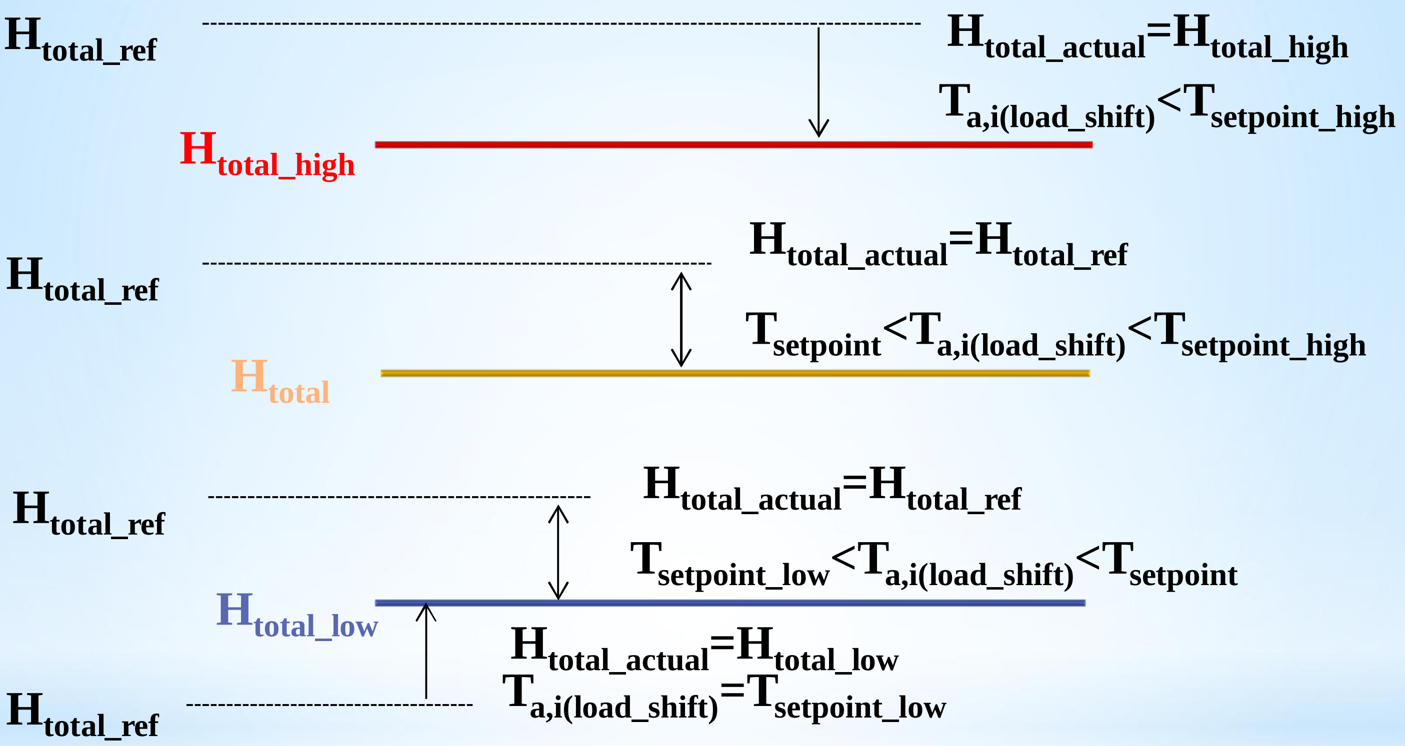


$$C_w \frac{dT_w}{dt} = h_w \cdot (T_s - T_w)$$

$$0 = h_w \cdot (T_w - T_s) + h_i \cdot (T_a - T_s) + w_w \cdot Q_{sun}$$

2-Node approach, Toke

Load control strategy



- H_{total_low} , H_{total} , H_{total_high} : Total heating load corresponding to low/medium/ and high set-point temperature ($T_{setpoint\_low}$, $T_{setpoint}$, $T_{setpoint\_high}$)
- H_{total_ref}: Reference total heating load (daily average temperature)
- H_{total_actual} : Actual total heating load after load management
- $T_{a,i(load\_shift)}$: For room which participated the load management

Time constant calculation

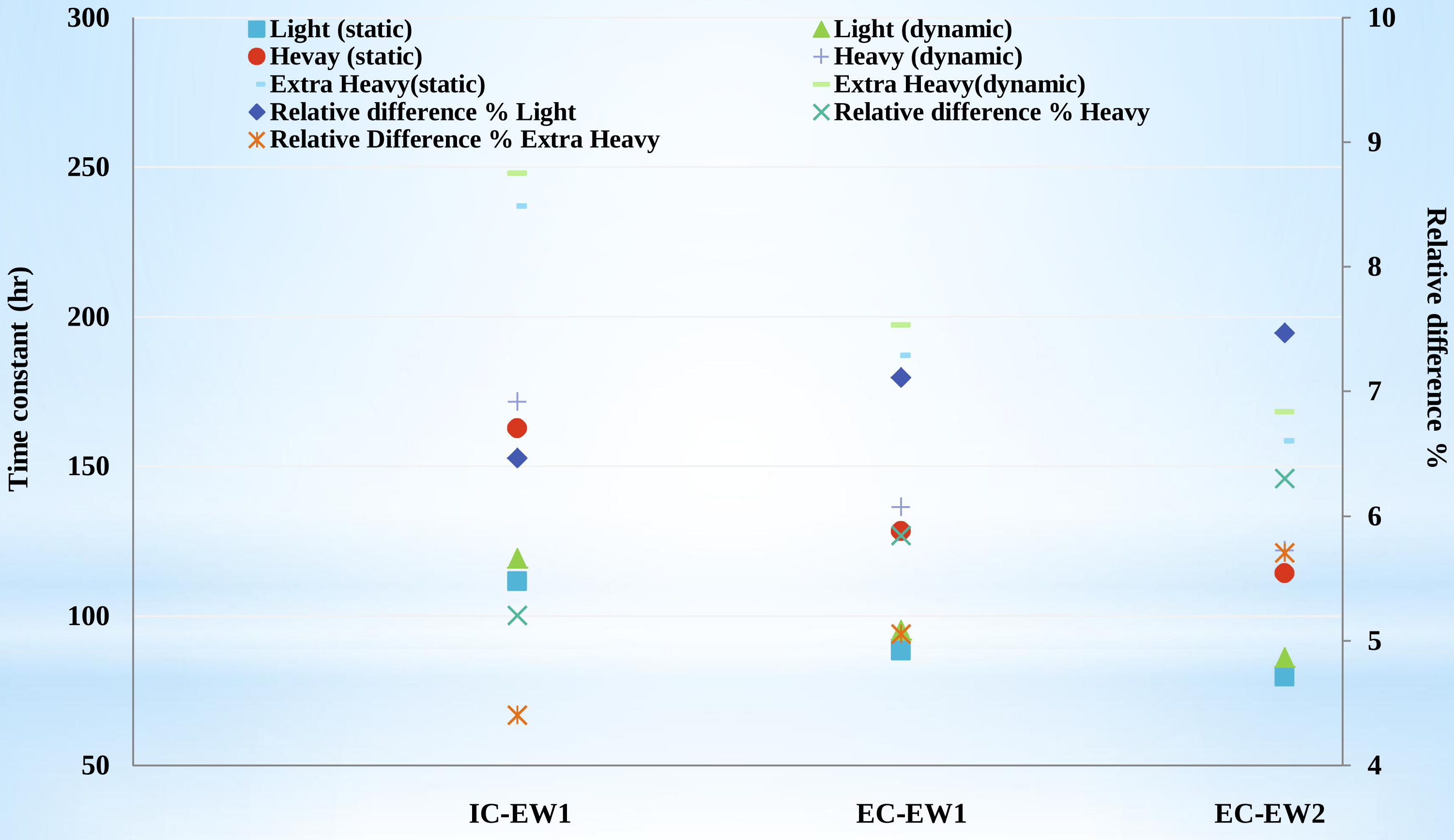
Static calculation

$$\tau = \frac{\sum_i C_w / 3600}{\sum_i U_i A_i + \rho_{air} c_{p,air} V n_{inf}}$$

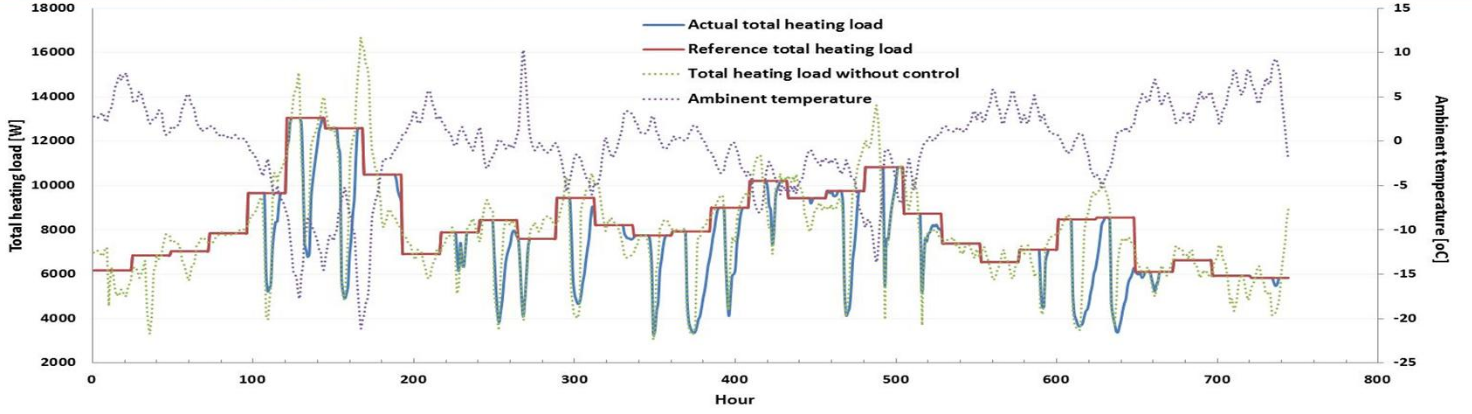
Dynamic calculation

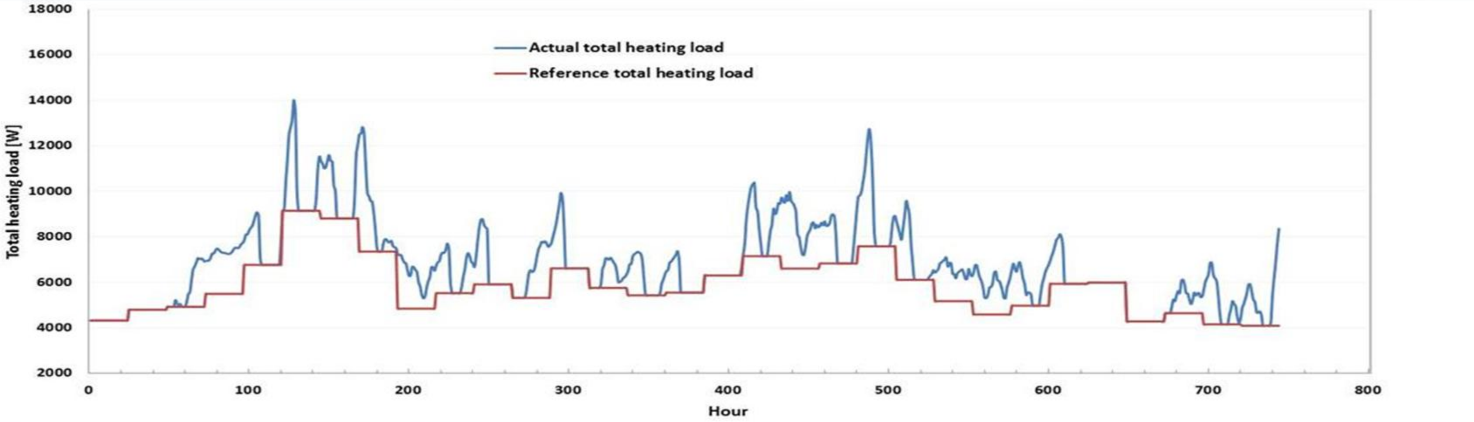
$$\tau = t / ln \left[\frac{\frac{H}{\sum_i U_i A_i + \rho_{air} c_{p,air} V n_{inf}} - (T_{ini} - T_{ext})}{\frac{H}{\sum_i U_i A_i + \rho_{air} c_{p,air} V n_{inf}} - (T_{fin} - T_{ext})} \right]$$

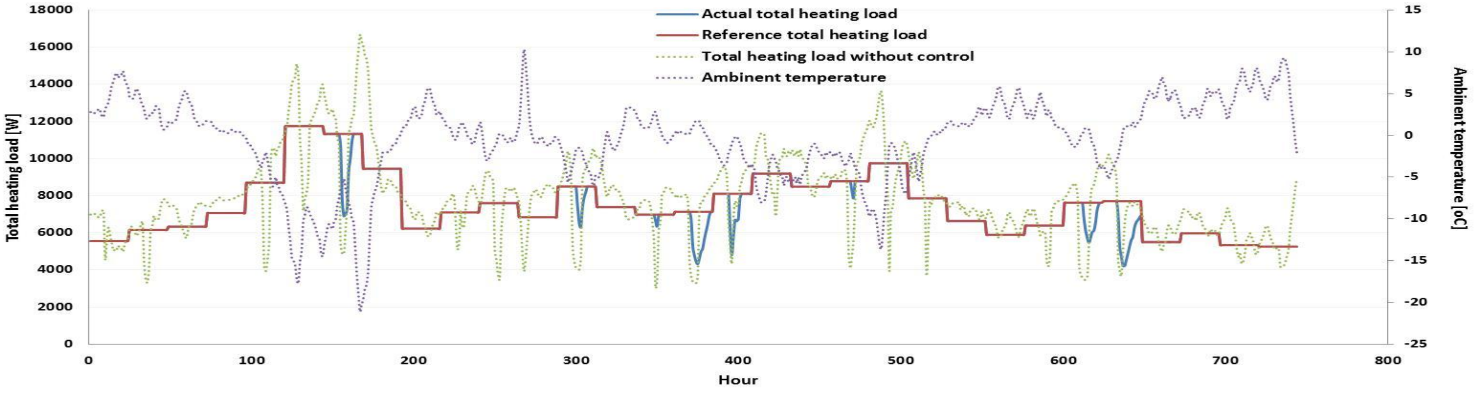
Comparsion of time constant calculation



Simulation results







Reference heating load corresponds to 100% (top) , 70% (middle) and 90% (bottom) of Q (daily average temperature)

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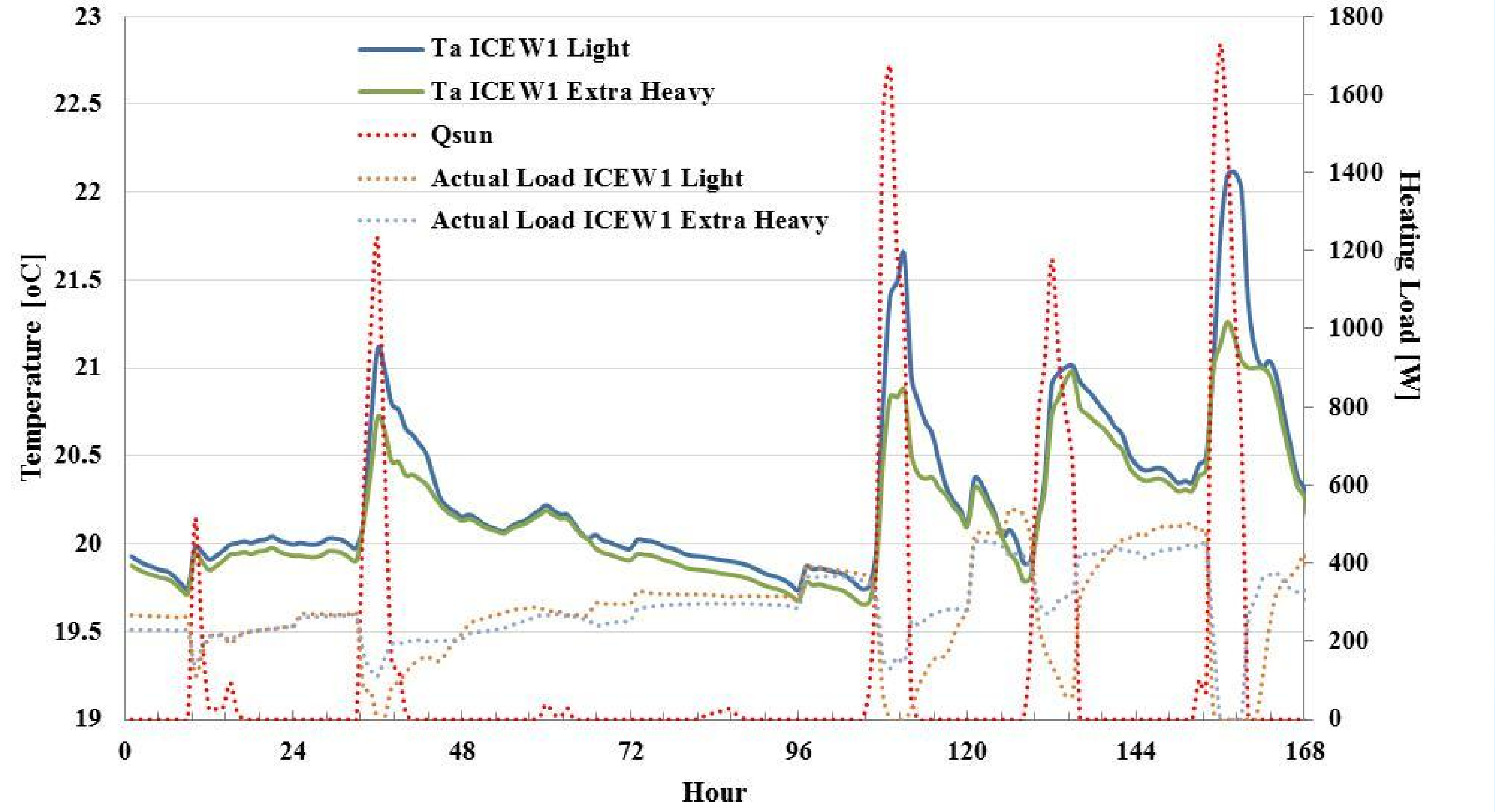
Thermal response variation due to different building thermal masses



Conclusion

- A DH load management strategy was developed based on the fairness and preserve consumer service quality principle
- The time constant dervied from dynamic building simulation showed good match with the static calculation
- Building with larger thermal mass has smaller room temperature variation and longer delay when boundary condition changes.
- By using building thermal mass, it is possible to average the total DH load below a certain therehold value

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Thank you

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