

Optimum insulation thickness of external walls by integrating indoor moisture buffering effect: a case study in the hot-summer-cold-winter zone of China

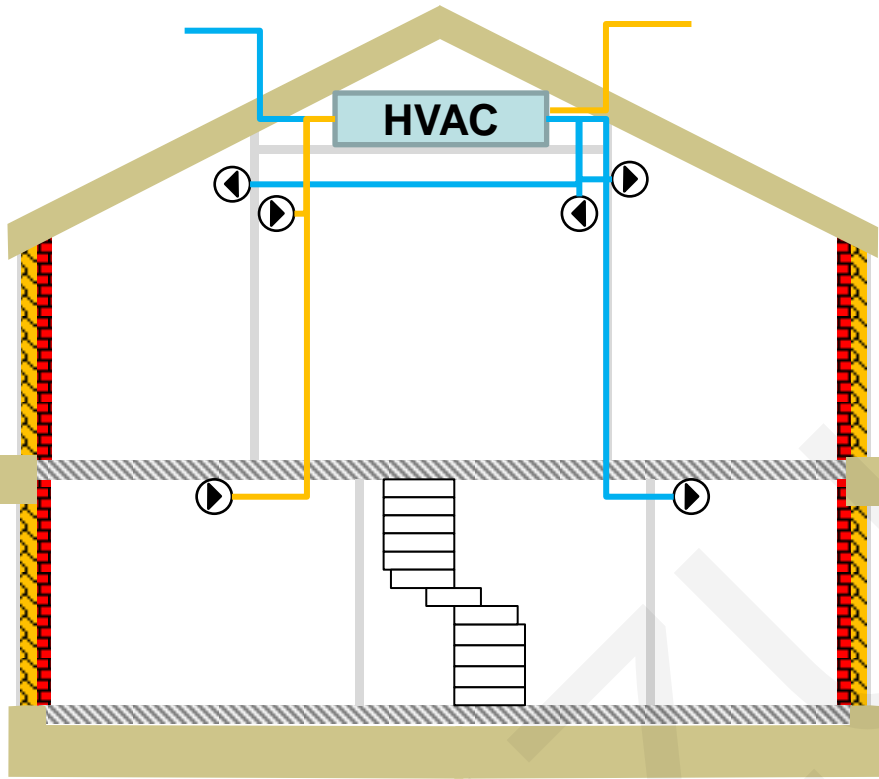
Yan-hao FENG, Zi-tao YU, Jiang LU, Xu XU

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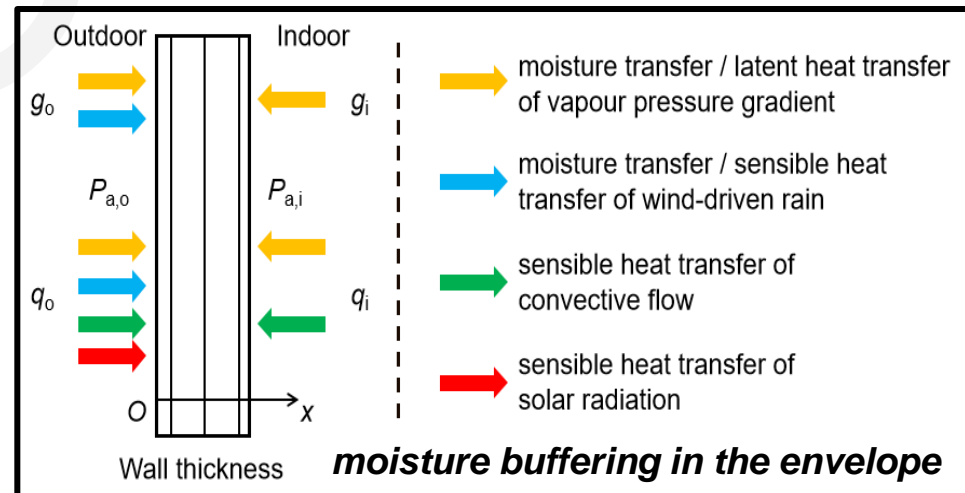
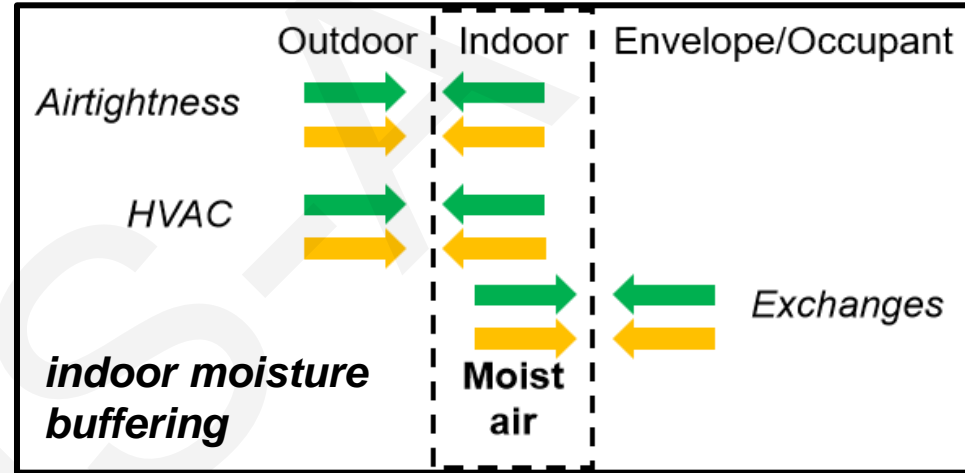
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Background



Schematic diagram of an insulation system in an ultra-low energy building

Aim: Optimizing of insulation thickness combined with indoor moisture buffering & moisture buffering in the envelope



Methodology

■ The proposed HAM-IEM methodology in insulation thickness optimization

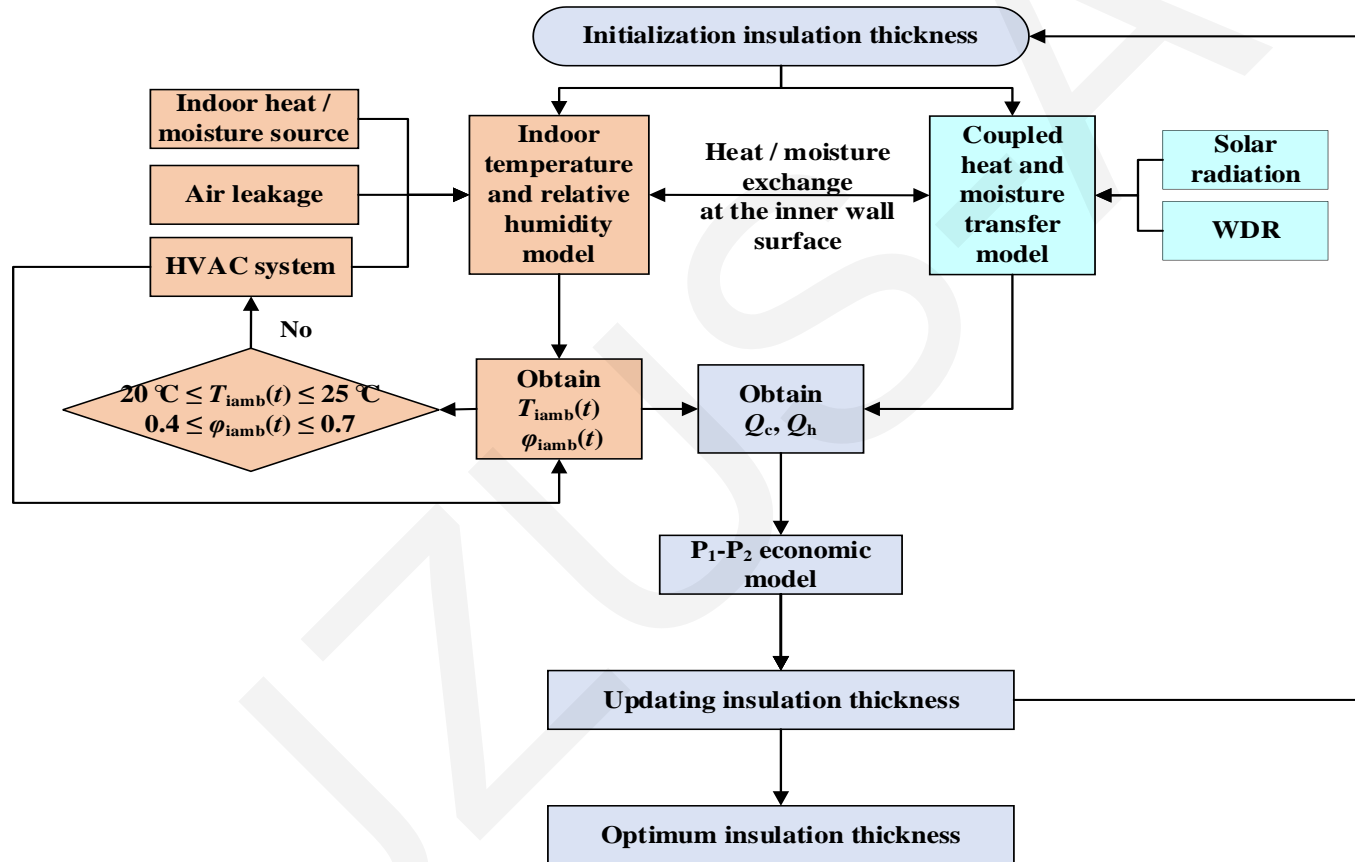
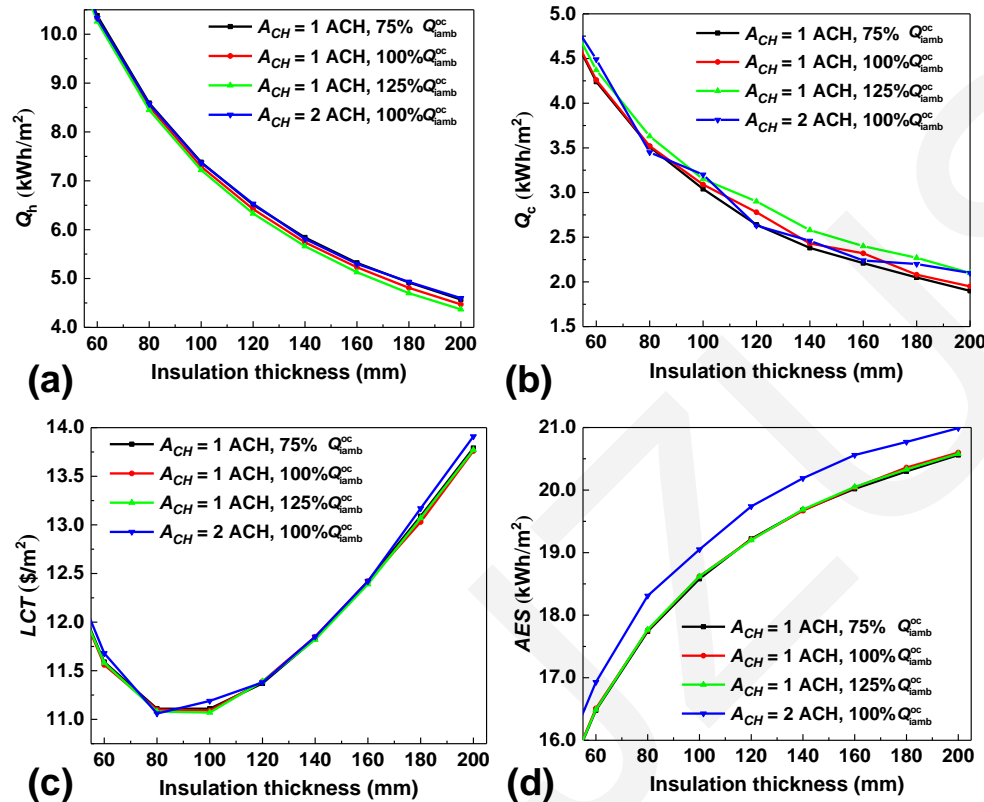


Fig. 1 Flow chart of the optimization integrated with the indoor environment

Case study & Results

- Cases are based on a residential building in Hangzhou, China, in the hot summer and cold winter (HSCW) zone
- The effect of airtightness and internal heat sources on the optimum insulation thickness



- The effect of **airtightness** and **internal heat sources** on the optimum insulation thickness is **slight**.
- The value of **airtightness** is approximately **proportional** to the **annual energy load of a wall**, especially in the thin insulation cases.
- The optimum insulation thickness is **smaller** in cases with **larger airtightness**, and the **AES** are higher in those with larger airtightness.

Fig. 2 Calculation results for different levels of airtightness and indoor heat sources of occupants: (a) the annual energy loads of a wall in heating season; (b) the annual energy loads of a wall in cooling season; (c) investment costs (LCT) and (d) Annual energy saving per unit area by the insulation material (AES)

Results & Discussions

■ Comparison of HAM-IEM with other transient optimization methods

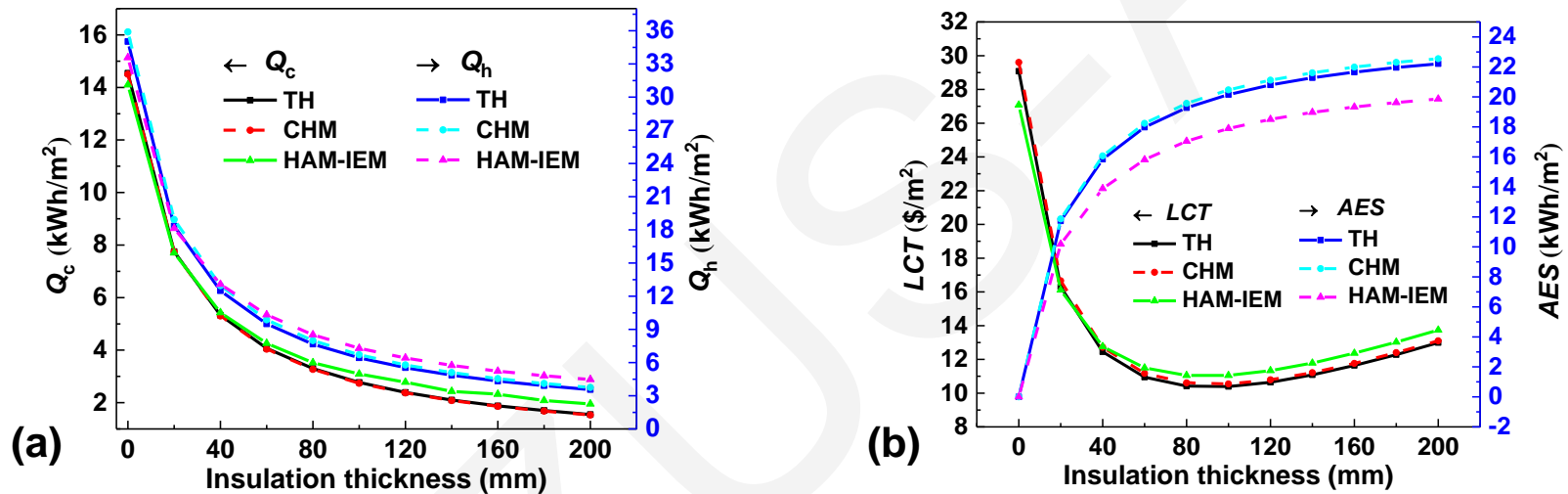


Fig. 3 Results of different transient optimization methods: (a) the annual energy loads of a wall in the cooling and heating season; (b) LCT and AES

- TH stands for the transient heat transfer method in optimization of insulation thickness;
- CHM stands for the coupled heat and moisture transfer method in optimization of insulation thickness;
- **The HAM-IEM method fully considers all moisture buffering phenomena in the envelope and interior, which is best fits the reality.**

Results & Discussions

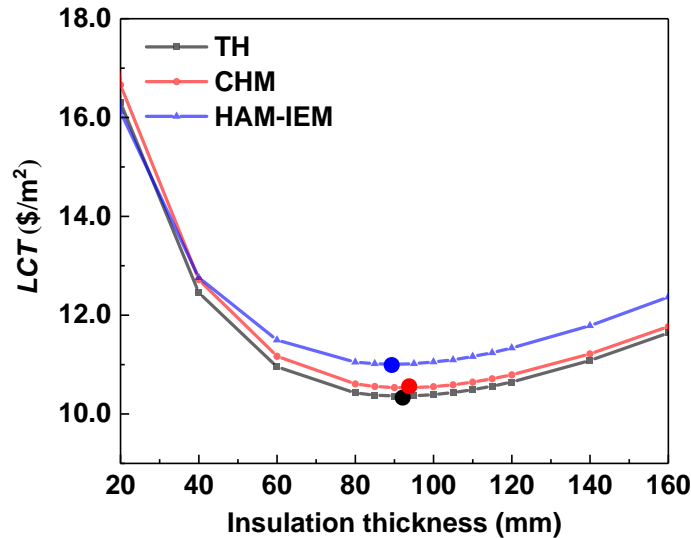


Fig. 4 Comparison of LCT and optimum insulation thickness with different transient optimization methods

Table 1 Comparison of results with different transient optimization methods

Models	TH	CHM	HAM-IEM in this study*
Optimum insulation thickness $x_{op,ins}$ (mm)	91.10	92.40	89.20
Deviation of $x_{op,ins}$ (%)	102.13	103.59	100
Annual energy load of a wall at $x_{op,ins}$ (kWh/m ²)	9.91	10.06	11.19
Deviation of annual energy load of a wall at $x_{op,ins}$ (%)	88.56	89.90	100
LCT at optimum insulation thickness (\$/m ²)	10.36	10.53	11.05
Deviation of LCT at $x_{op,ins}$ (%)	93.76	95.29	100
AES at $x_{op,ins}$ (kWh/m ²)	19.81	20.16	18.19
Deviation of AES at $x_{op,ins}$ (%)	108.91	110.83	100

- The optimum insulation thicknesses obtained from the TH and the CHM are overestimated by **2.13% and 3.59%** compared with those from the HAM-IEM in this study; the annual energy loads on a single wall are underestimated by **11.44% and 10.10%** compared to those from using the HAM-IEM.
- In HSCW zone, it can be referred from Table 1 that the indoor moisture buffering effect on the optimal insulation thickness is about **2.54 times greater** than the moisture buffering effect in the envelope, and the **two moisture buffering have opposite effects** on the optimal insulation thickness.

Conclusions

- In this study, with consideration of **indoor moisture buffering effect**, a new methodology, the **HAM-IEM**, is proposed to obtain the optimum insulation thickness of exterior walls in the HSCW zone in China.
- The **two moisture buffering effects**, the moisture buffering effect in the envelope and the indoor moisture buffering effect, have the **opposite effect on the optimum insulation thickness**. The **indoor moisture buffering effect** is about **2.54 times greater** than the moisture buffering effect in the envelope.
- The airtightness and indoor heat sources have a **slight** influence on the optimum insulation thickness, while the *AES* is higher for a larger airtightness.
- **Excessively thick insulation** can lead to **"negative energy savings"** and **this study addressed how to avoid this problem** and obtain an accurate value during the design phase.