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

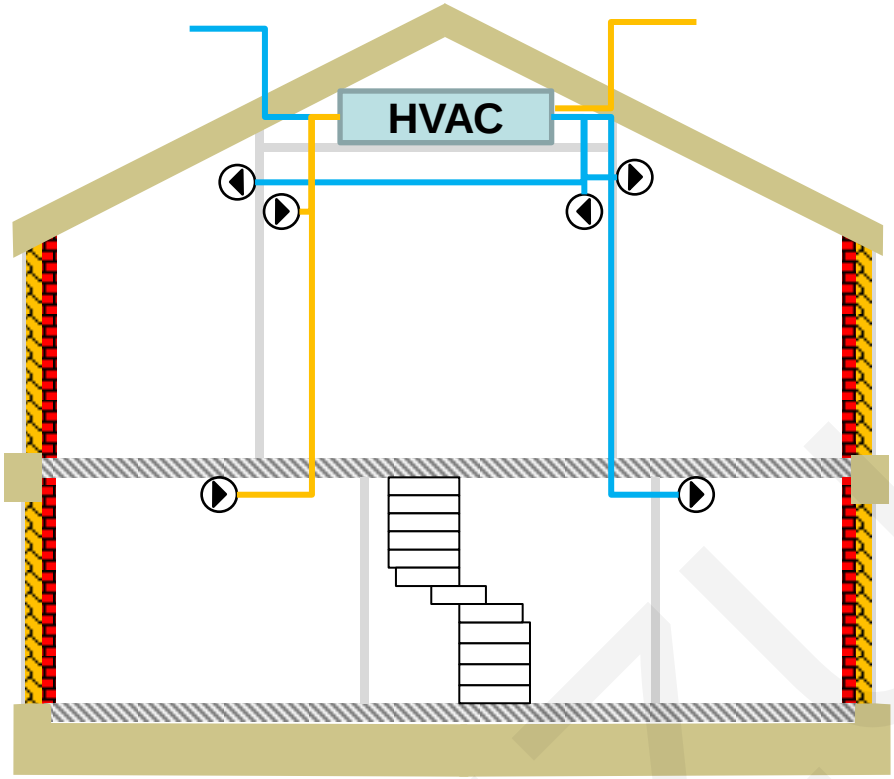
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Keywords: Insulation thickness optimization; Coupled heat and moisture transfer; Indoor moisture buffering effect

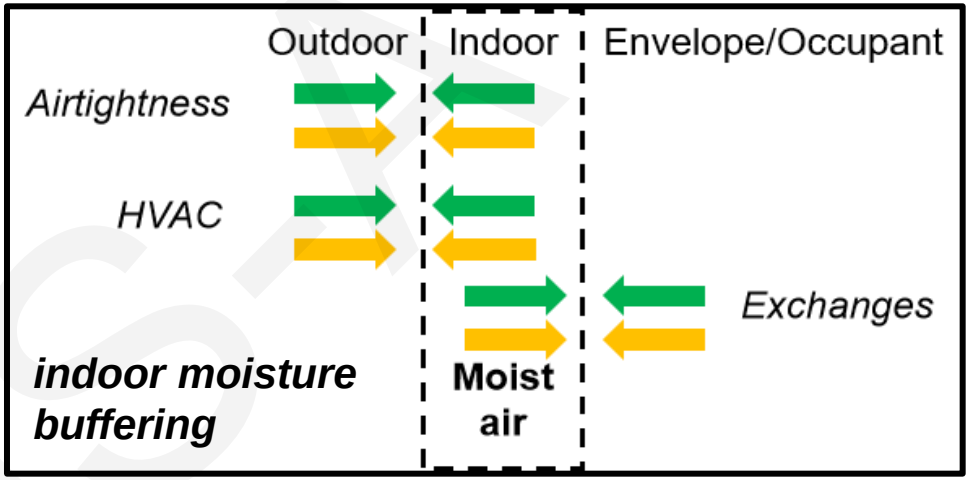
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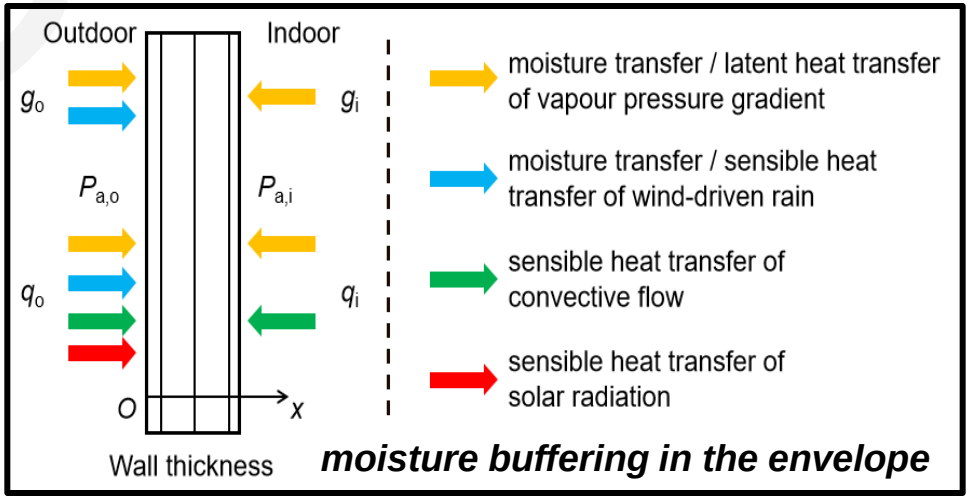
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Background



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





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

Methodology

■The proposed HAM-IEM methodology in insulation thickness optimization

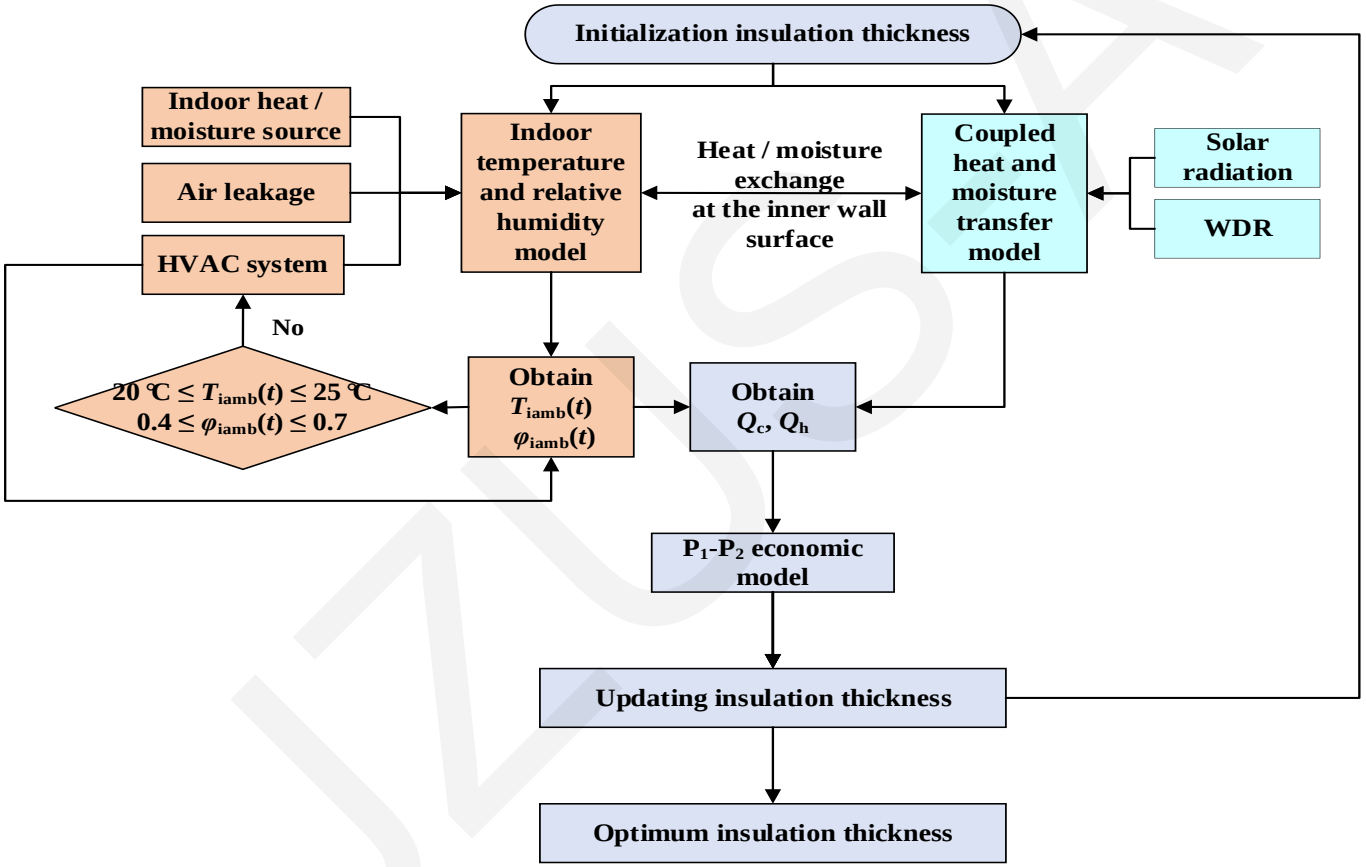
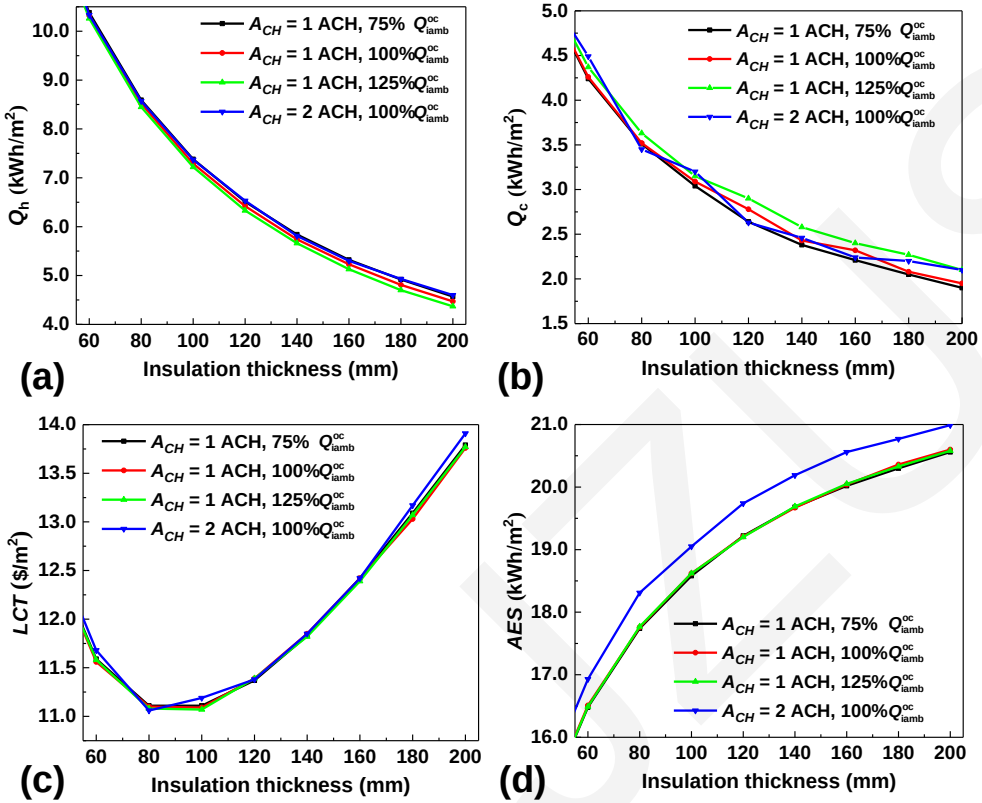


Fig. 1 Flow chart of the optimization integrated with the indoor environment

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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

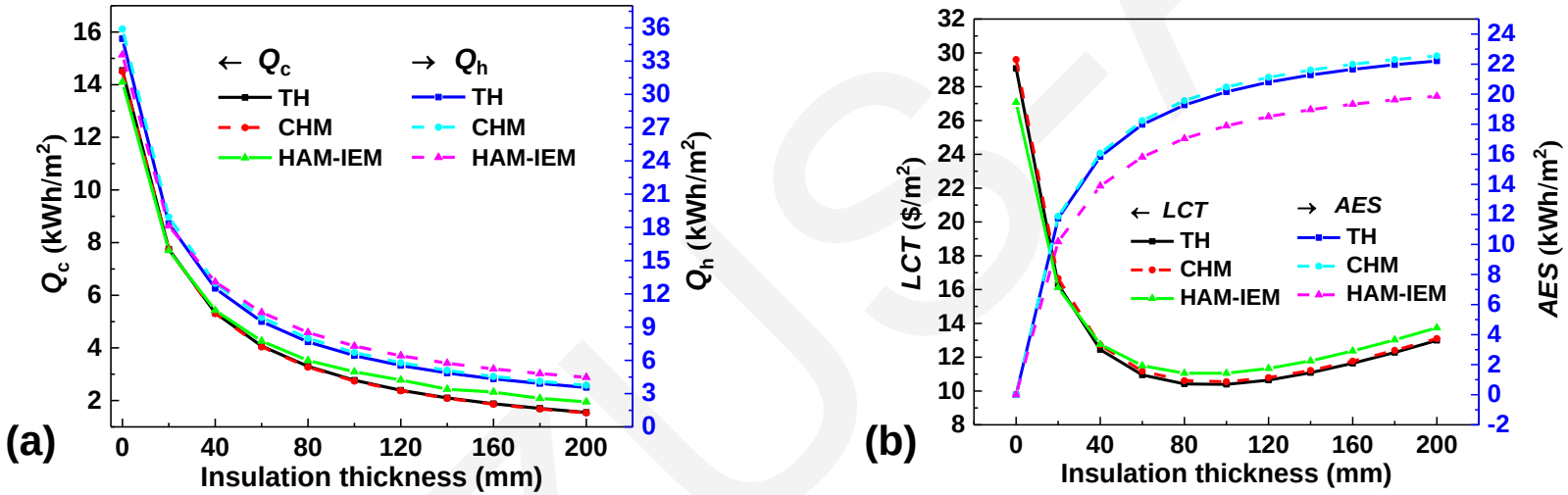


Fig. 3 Results of different transient optimization methods: (a) the annual energy loads of a wall in the cooling and heating season; (b) *LCT* and *AES*

- 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

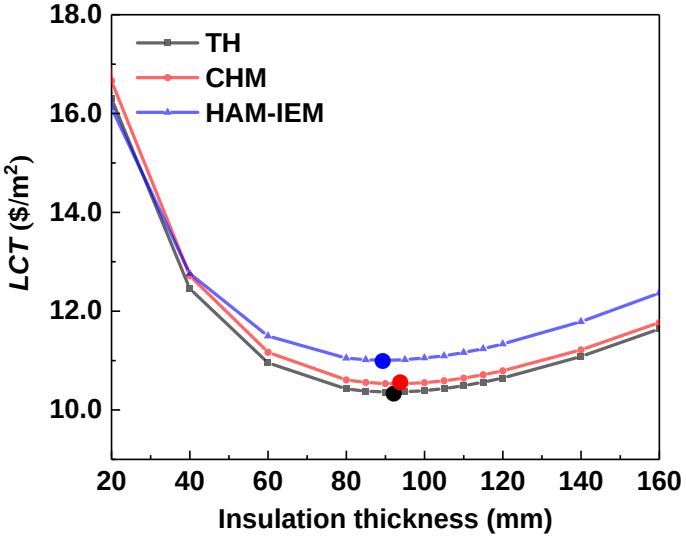


Fig. 4 Comparison of *LCT* and optimum insulation thickness with different transient optimization methods

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/m²)	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 ($/m²)	10.36	10.53	11.05
Deviation of *LCT* at $x_{op,ins}$(%)	93.76	95.29	100
AES at $x_{op,ins}$(kWh/m²)	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.**