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Interstitial condensation in Chinese residential buildings: cliché or challenge?

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Interstitial condensation in Chinese residential buildings: cliché or challenge?

Hanyu Yang[1,2]**, Xing Zheng**[1,2]**, Mingfang Tang**[1,2] **and Chi Feng**[1,2,3]
[1] School of Architecture and Urban Planning, Chongqing University, 400045 Chongqing, PR China
[2] Key Laboratory of New Technology for Construction of Cities in Mountain Area, Ministry of Education, Chongqing University, 400045 Chongqing, PR China

Email: fengchi860602@outlook.com

Abstract. In this paper, we compare the predictions of interstitial condensation by the steady-state method and the transient method under different climate conditions in China. Simulations reveal significant differences between the two methods, and the wind-driven rain also plays an important role. As a result, the transient hygrothermal simulation considering wind-driven rain should be recommended instead of the steady-state method for predicting interstitial condensation under complicated climate conditions.

1. Introduction

As interstitial condensation impacts the durability and energy efficiency of buildings, it should be analyzed and prevented at the design stage. At present, the Chinese standard adopts the classic 1-D steady-state vapor diffusion model (the Glaser's model) [1], which only suits the heating period in severe cold and cold regions in China but not necessarily other periods and climate zones. The transient hygrothermal model on the other hand provides more accurate results in general but is also more complicated [2-4]. The objectives of this research are to analyze the differences in the results from the steady-state method and the transient method under different conditions and discuss the optimum anti-condensation thermal insulation configurations for Chinese residential buildings in different cities.

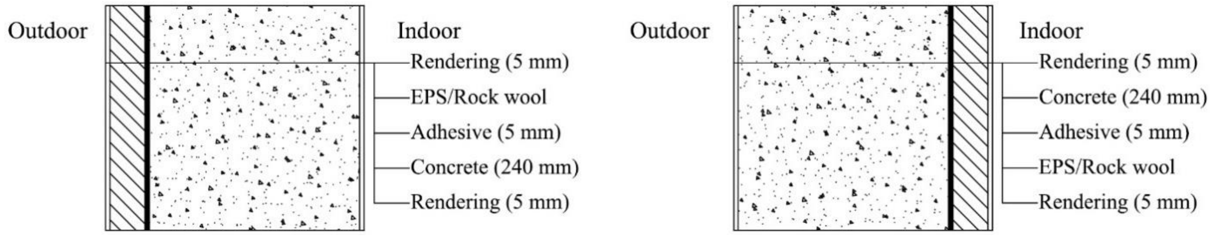
2. Methodology

In this study, Beijing, Shanghai, and Guangzhou are selected as representative Chinese cities. WUFI 6.4 is used to simulate the moisture distributions in the envelope for four cases, and input parameters of each case are shown in table 1.

Table 1. Four simulation cases.

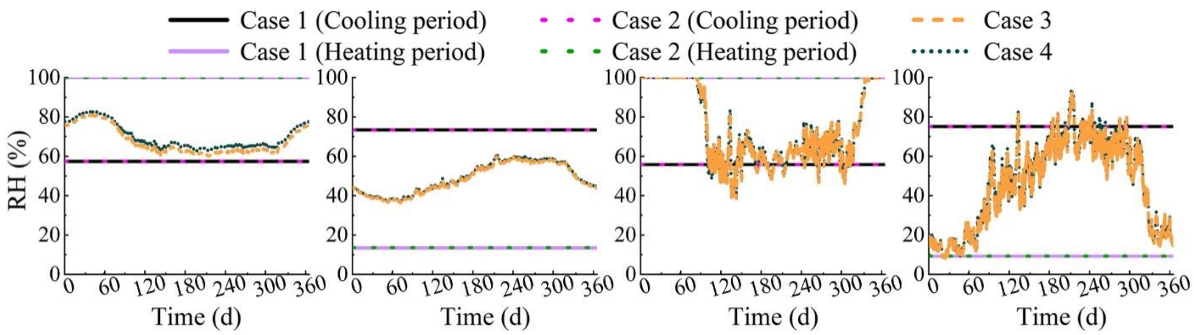
Input parameter	Steady-state method		Transient method	
	Case 1	Case 2	Case 3	Case 4
Material property	Constant	Variable	Variable	Variable
Indoor boundary condition (temperature and RH)	Cooling: 26°C, 60%; Heating: 20°C, 40%		Cooling: 26°C, 60%; Heating: 20°C, 40%; Ventilation period: ambient climate	
Outdoor boundary condition	Monthly average temperature and RH in January/July		Reference typical meteorological year	
Rain absorption factor	0	0	0	0.7

The target walls are externally/internally insulated with EPS (Expanded Polystyrene insulation) or rockwool, widely used in Chinese residential buildings. All material properties are obtained from the WUFI database. To meet the thermal performance requirement of energy-saving design standards for residential buildings in each city, the insulation thickness is 80 mm (Beijing), 40 mm (Shanghai) and 20 mm (Guangzhou), respectively. The interface between the adhesive layer and the insulation layer is selected for analysis, and the thermal insulation configurations are shown in figure 1.



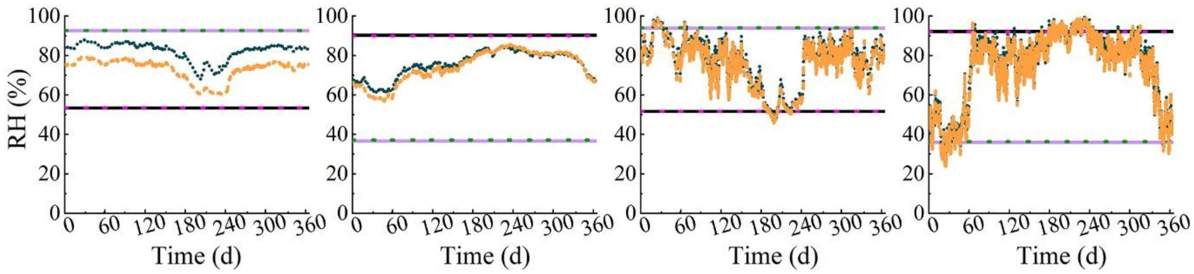
(a) External thermal insulation (ETI). (b) Internal thermal insulation (ITI).

Figure 1. Thermal insulation configurations.



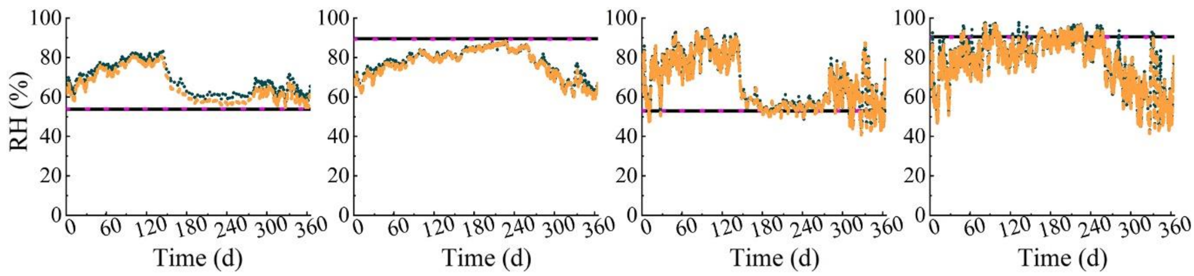
(a) ITI wall (EPS). (b) ETI wall (EPS). (c) ITI wall (Rockwool). (d) ETI wall (Rockwool).

Figure 2. RH distributions of target interfaces in Beijing.



(a) ITI wall (EPS). (b) ETI wall (EPS). (c) ITI wall (Rockwool). (d) ETI wall (Rockwool).

Figure 3. RH distributions of target interfaces in Shanghai.



(a) ITI wall (EPS). (b) ETI wall (EPS). (c) ITI wall (Rockwool). (d) ETI wall (Rockwool).

Figure 4. RH distributions of target interfaces in Guangzhou.

3. Results and discussion

Figures 2-4 illustrate the RH (relative humidity) variations of the interfaces simulated under four cases in Beijing, Shanghai and Guangzhou, respectively. The results of Case 1 and 2 are basically consistent, with a maximum difference of 0.5%, indicating that although the thermal conductivity and vapor permeability vary with temperature and moisture, the effect on interstitial condensation simulation is negligible. As Case 3 performs year-round simulations, the overall results are quite different from the steady-state predictions. The maximum difference between the results of Case 2 and 3 appears in the early heating/cooling period. Figure 2(a) shows the RH reaches 100% for Case 2 during the heating period, while the highest RH for Case 3 is 80.9%, leading to different interstitial condensation predictions. Since the transient simulation results agree with the measured values in other studies [2], the transient method is more dependable for interstitial condensation analysis. The RH's for Case 4 are significantly higher than those for Case 3, with the maximum difference of 20.1% in figure 4(d). Therefore, the wind-driven rain also plays an important role and should be included in the analysis of interstitial condensation.

Since the input parameters of Case 4 are closest to the real condition, the simulation results in Case 4 are selected to compare the applicability of different thermal insulations in different cities. As shown in figures 2-4, the maximum RH of the EPS thermal insulation walls is lower than 90% in all cities. However, the RH within the rockwool internal insulation system reaches 100% during the heating period in Beijing (figure 2(c)), causing interstitial condensation and moisture accumulation. The maximum RH of the walls insulated with rockwool also exceeds 95% in Shanghai and Guangzhou, indicating a high moisture risk [5]. In addition, the externally insulated walls display lower RH than the internally insulated walls in Beijing, but the opposite is true in Guangzhou. This should be attributed to their different moisture transfer directions.

4. Conclusion

In this study, the interstitial condensation of the residential building envelope is simulated under four cases in three representative cities of China. Simulations reveal that the effect of constant/variable material properties on the interstitial condensation analysis is negligible, while the effect of steady-state/dynamic boundary conditions is obvious, and that wind-driven rain plays an important role. In addition, it is necessary to select the ETI wall or the ITI wall according to the climate characteristics, and EPS is recommended. Finally, the transient hygrothermal simulation considering wind-driven rain should be adopted for predicting interstitial condensation under complicated conditions.

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