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Related Discussion on the Testing Method of the Air-tightness of the Building

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Abstract

Building air-tightness is one of the important indicators to achieve building energy efficiency and measure the effect of building energy efficiency. At present, the overall air-tightness test method of the building is in the stage of in-depth research at home and abroad. Based on the measured data of the overall air-tightness of the building, this article defines the air-tightness of the building, the relationship between the natural pressure difference and the number of air changes at a pressure difference of 50Pa,and that the product of the indoor and outdoor temperature difference and the height of the building shall not exceed 250m•K is analyzed and discussed, aiming to promote the development of building air-tightness testing in China and to provide references and suggestions for building air-tightness research.

Keywords

Building air tightness; Building energy conservation; Air-tightness test method; Test examples.

1. INTRODUCTION

In recent years, building energy consumption has accounted for about 30% of the total energy consumption of the whole society [1]. Related research [2-6] shows that the heat loss caused by air infiltration accounts for 25-50% of building heating energy consumption, and the energy consumption of air conditioning systems caused by air leakage has become an important part of building energy consumption. The air-tightness test method of a building is an important basis for obtaining the air-tightness of a building. Therefore, it is of great significance to study the overall air tightness test method of the building.

This article mainly discusses the definition of building air tightness, the relationship between natural pressure difference and the number of air changes under 50Pa pressure difference, the question of Whether the product of indoor and outdoor temperature difference and building height should not be greater than 250m • K is appropriate based on relevant standards and literature research and test examples of high-rise buildings, multi-storey buildings, and villa buildings. The article aims to promote the development of air-tightness of buildings in my country and provide references and suggestions for the research of air-tightness of buildings.

1.1. Definition of Air-tightness of Buildings

Although the definitions of building air-tightness in different standards and related documents are not uniform, the differences are not much difference. In order to fully

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understand the air-tightness of buildings, this article lists the definitions of air-tightness of buildings in standards and literature, see Table 1.

Table 1. Explanations and definitions of air-tightness of buildings in standards and documents

serial number	name	Standards and literature	Interpretation and definition
1	Airtight performance of the exterior doors and windows	Building exterior doors and windows airtight, watertight, wind pressure performance grading and detection methods (GB/T7106-2008)	The ability of the outer doors and windows to prevent air penetration when in a normal state.
2	The amount of ventilation with poor reference pressure	Building Air Tightness Measurement Method, Fan Pressure Method (GB/T 34010-2017)	At the reference pressure difference, the internal volume of the unit is exchanged through the air exchange of the perimeter structure
3	Building air tightness	Near Zero Energy Building Technology Standard (GB/T 5150-2019).	The ability of a building to prevent air penetration in a closed state. Used to characterize the amount of unorganled air penetration of a building or room under normal confinement. The pressure differential test is usually used to detect building air tightness to characterize building air tightness with the number of ventilations N50,i.e. the number of ventilations at the indoor and outdoor 50Pa pressure differentials.
4	The overall air tightness of the building	"Building overall air tightness detection and performance evaluation standards"(T-CECS 704-2020)	The ability of a building to prevent air penetration in a closed state.
5	Building air tightness	Du Yujuan. An overview of the air-tightness study and detection methods of the passive room	Building air tightness refers to the ability of the building's exterior doors and windows to penetrate through the perimeter structure under normal closure
6	Building air tightness	Ji Yongming, Ting Mulin, Wang Hongbin, Wang Feifan. Air tightness of new residential buildings in Dalian area is measured	Building air tightness refers to the ability of the building containment structure to resist air seeping in/out of the natural crevices of the building enclosure structure, usually expressed in terms of the amount of air passing through the natural crevices of the building enclosure structure at a specific pressure difference
7	The air tightness of the house	Chen Dongliang. The theoretical study of house air tightness in the field of building energy conservation -- based on the theoretical analysis and testing practice of air tightness of low-energy buildings in hot summer and cold winter areas	House air tightness refers to the ability to prevent air penetration when the building's exterior doors and windows are normally closed, usually using the indoor and outdoor 50Pa pressure difference under the room hourly ventilation index to measure the air tightness level of a house.

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The definition of air-tightness of buildings in the standards and literature does not clearly state that the building's closed method is "closed doors and windows" or "completely enclosed". Only "closed doors and windows" ignores the air-conditioning system, wall openings, and kitchen gas pipe openings. Influence, if "completely enclosed state" is understood as a closed space, the air-tightness test of the building will be meaningless. Therefore, this article defines the prerequisite for the air-tightness of the building as "the building is in a theoretically closed state". The theoretical closure is not a complete closure, but the theoretical closure of doors and windows, air conditioning systems, pipeline through-wall holes, gas pipe through-wall holes, etc. Closed, but not completely closed. The air-tightness is understood as "the ability to organize air penetration through the envelope structure", and the positive significance of building air-tightness is not highlighted. Therefore, this article combines the relevant standards and literature on building air-tightness to define building air-tightness as "building In the theoretically closed state, the envelope structure resists the ability of air to seep in and out from the natural gaps of the structure." It not only clarifies the prerequisites, but also shows the positive significance of the air-tightness of the building.

2. THE NUMBER OF AIR CHANGES UNDER 50PA PRESSURE DIFFERENCE AND NATURAL PRESSURE DIFFERENCE

The number of air changes of the tested building is related to the test conditions, the weather conditions during the test, the structure of the building, the layout of the building and other factors. The overall air-tightness of the building is tested in accordance with the "Building air-tightness Measurement Method, Fan Pressure Method" (GB/T34010-2017) standard, with 50Pa as the center point, selecting the appropriate test conditions, according to the pressure difference of the tested building-the air leakage curve based on the air leakage under different pressure differences, and thus obtains the number of air changes under the pressure difference of 50Pa and the natural pressure difference.

In this paper, 14 ultra-low-energy buildings are selected for overall air tightness testing, and the relationship between the pressure difference of 50Pa and the number of air changes under the natural pressure difference is studied.

2.1. Calculation of the Number of Air Changes Under 50Pa Pressure Difference and Natural Pressure Difference

The number of air changes N_{50} under a pressure difference of 50Pa is calculated in accordance with 4.4.5 of the "Standards for Testing and Performance Evaluation of Overall Air-tightness of Buildings".

$$N_{50} = q_{50} / V_t \tag{1}$$

In the formula, q_{50} is the leakage volume when the pressure difference between the inside and outside of the test space is 50Pa, m^3/h; V_t is the volume of the test space, m^3.

The number of air changes under the natural pressure difference N_n is based on the pressure difference-leakage curve of the air-tightness test of the tested building, and the pressure difference-leakage curve conforms to the formula 2, and the natural pressure difference is obtained according to the formula 2 Calculate the number of air changes under the natural pressure difference based on the ratio between the leakage and the volume of the building.

$$q_L = C_L (\Delta P)^n \tag{2}$$

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In the formula, q_L is the leakage under the pressure difference of △P during the test, m^3/h, CL is the leakage coefficient during the test, $m^3/(h·Pan)$; △P is the actual pressure difference under the test conditions, Pa; n is the airflow index during the test.

Select 5 high-rise buildings, 5 multi-storey buildings, and 4 villa buildings to test the overall air-tightness of the building. Use formula 1, 2 and air-tightness test software to obtain The number of air changes under a pressure difference of 50Pa.

2.2. Calculation of the Number of Air Changes under 50Pa Pressure Difference and Natural Pressure Difference

2.2.1. Test overview

In the test example, five high-rise buildings with the same building structure are selected. The building has 1 floor underground, 26 floors above ground, and a frame-supported shear wall structure. When the overall air-tightness test of the building under test is carried out, the construction of the outer protective structure has been completed. The doors and windows have been installed, the plastering of the exterior walls has been completed, the air conditioning and fresh air systems have been installed, and the interior of the building has not been decorated. The building is divided into two units on the east and west sides, which are connected through the basement. During the test, the two units on the east (west) side are measured separately. The first floor plan of the building is shown in Figure 1, and the building elevation is shown in Figure 2.

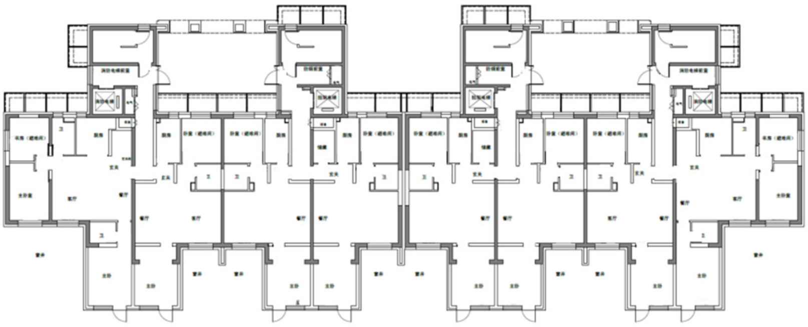

Figure 1. Floor plan of the building

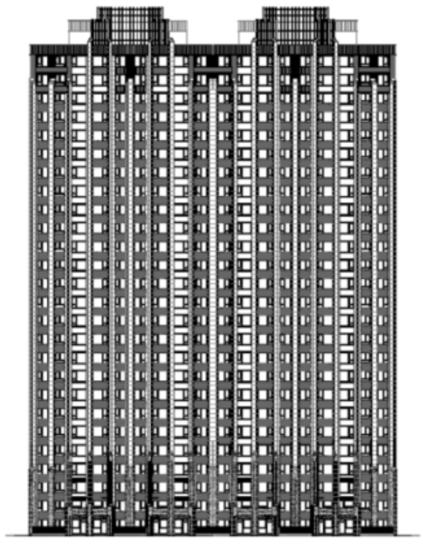

Figure 2. Elevation of the building

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2.2.2. Test process and results

Before the test, in accordance with the "Building Air Tightness Measurement Method, Fan Pressure Method" (GB/T34010-2017) standard, the building envelope structure was sealed, and all the doors in the tested area were opened at the same time to make the entire building airtight. A theoretically closed space is formed within the layer range. Install air-tightness testing equipment, use a blower to exhaust/inhale to the outdoors, make the tested area in a negative/positive pressure state, forming an indoor and outdoor pressure difference, with 50Pa as the center point, select 6 test conditions, relative The difference between indoor and outdoor pressure in adjacent test conditions is 10Pa. Calculate the volume of the building and record the indoor (outdoor) temperature during the test. The test and calculation results of high-rise buildings are shown in Table 2.

Table 2. Air tightness test and calculation results of high-rise buildings

serial number	Stress test	The amount of air leakage (m^3/h) under the 50Pa pressure difference	Natural pressure difference (Pa)	Room temperature(K)	Outdoor temperature (K)	The number of ventilations N n under the natural pressure difference	The number of ventilations at 50Pa N_{50}
1	Eastern unit negative pressure	9299	6.0	302.9	305.5	0.10	0.38
	Eastern unit positive pressure	9277	5.8	303.0	306.3	0.11	0.38
	Western unit negative pressure	9842	2.0	302.9	303.2	0.06	0.41
	Western unit positive pressure	9753	1.7	303.4	304.8	0.05	0.40
2	Eastern unit negative pressure	11003	0.6	301.5	303.4	0.03	0.45
	Eastern unit positive pressure	11077	2.0	302.2	304.4	0.06	0.46
	Western unit negative pressure	9483	4.4	301.2	305.1	0.09	0.39
	Western unit positive pressure	9216	4.6	301.6	305.4	0.09	0.38
3	Eastern unit negative pressure	8948	6.3	300.9	302.0	0.10	0.37
	Eastern unit positive pressure	9007	5.6	301.0	303.5	0.09	0.37
	Western unit negative pressure	10313	0.6	300.7	305.0	0.03	0.43
	Western unit positive pressure	10333	1.5	301.5	307.0	0.05	0.43
4	Eastern unit negative pressure	11481	9.3	304.5	300.5	0.18	0.47
	Eastern unit positive pressure	11077	7.0	304.3	300.6	0.15	0.46
	Western unit negative pressure	10327	6.0	302.4	298.9	0.12	0.43
	Western unit positive pressure	10794	5.6	302.5	299.3	0.12	0.45
5	Eastern unit negative pressure	8115	0.5	302.2	301.7	0.02	0.33
	Eastern unit positive pressure	8333	1.4	302.2	302.3	0.04	0.34
	Western unit negative pressure	8440	2.0	302.2	303.7	0.05	0.35
	Western unit positive pressure	10455	3.4	302.4	304.5	0.09	0.43

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The test results show that the relationship between the number of air changes under the 50Pa pressure difference and the natural pressure difference is related to the meteorological conditions during the test, the natural pressure difference between indoor and outdoor, the air leakage from the natural gaps of the building structure, and the building structure.

2.3. Multi-storey Building Test

Select 5 multi-storey buildings with the same building structure. The building has 3 floors underground and 7 floors above ground. It has a frame-supported shear wall structure. When the overall air tightness test of the tested building is carried out, the construction of the outer protective structure has been completed, and the outer doors and windows have been The installation is completed, the plastering of the exterior walls is completed, the air conditioning, fresh air system, etc. have been installed, and the interior of the building has not been decorated. The building is divided into east and west units, which are connected through the basement. The east (west) unit is measured separately during the test. The first floor plan of the building is shown in Figure 3, and the building elevation is shown in Figure 4.

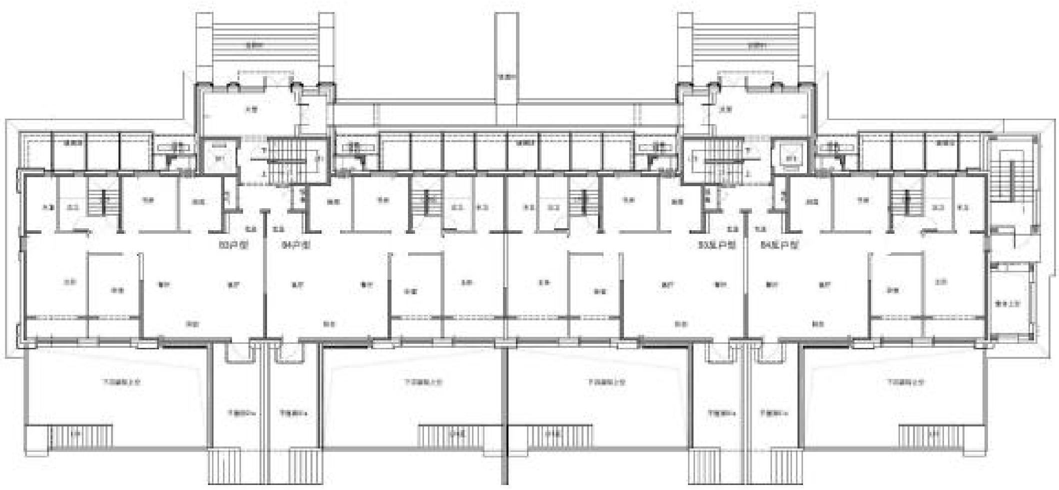

Figure 3. Floor plan of the building

Figure 4. Elevation of the building

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The air tightness test of the building is carried out according to the test process in 2.2.2 above. The air tightness test and calculation results of the multi-story building are shown in Table 3.

Table 3. Air tightness test and calculation results of multi-storey buildings

serial number	Stress test	The amount of air leakage (m^3/h) under the 50Pa pressure difference	Natural pressure difference (Pa)	Room temperature (K).	Outdoor temperature (K).	The number of ventilations N n under the natural pressure difference	The number of ventilations at 50Pa N_{50}
1	Eastern unit negative pressure	2275	0.1	300.2	303.15	0.01	0.33
	Eastern unit positive pressure	2442	0.4	300.4	303.15	0.02	0.36
	Western unit negative pressure	2443	0.4	300.2	303.55	0.02	0.36
	Western unit positive pressure	2745	0.3	300.8	303.25	0.02	0.40
2	Eastern unit negative pressure	2096	1.2	303.0	298.05	0.03	0.31
	Eastern unit positive pressure	2291	0.3	304.3	304.55	0.01	0.34
	Western unit negative pressure	2075	0.5	305.0	302.45	0.02	0.31
	Western unit positive pressure	2214	0.1	305.2	302.65	0.00	0.33
3	Eastern unit negative pressure	2872	3.9	298.7	302.65	0.09	0.42
	Eastern unit positive pressure	2976	2.9	298.8	302.85	0.08	0.44
	Western unit negative pressure	2065	0.2	299.3	302.35	0.01	0.30
	Western unit positive pressure	2167	0.1	299.6	303.05	0.01	0.32
4	Eastern unit negative pressure	2550	0.4	304.9	302.95	0.02	0.38
	Eastern unit positive pressure	2686	0.6	304.9	302.25	0.02	0.40
	Western unit negative pressure	2721	0.7	304.0	298.15	0.03	0.40
	Western unit positive pressure	2879	0.6	304.4	299.25	0.03	0.42
5	Eastern unit negative pressure	2128	1.9	293.3	299.1	0.06	0.31
	Eastern unit positive pressure	2188	0.6	294.0	299.9	0.02	0.32
	Western unit negative pressure	3241	0.5	300.6	303.8	0.03	0.48
	Western unit positive pressure	3394	0.6	300.7	304.4	0.03	0.50

The test results show that the relationship between the number of air changes under the 50Pa pressure difference and the natural pressure difference is related to the natural pressure difference between indoor and outdoor during the test, air leakage from natural gaps in the building structure, and building structure.

2.4. Villa Building Test

Select 4 villa buildings, 2 floors underground, 3 floors above ground, frame-supported shear wall structure, the tested building has completed the outer protection structure construction, the external doors and windows have been installed, the internal plastering of the external walls

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has been completed, air conditioning, fresh air system, etc The installation has been completed, and the interior has not been decorated. The first floor plan of the building is shown in Figure 5, and the building elevation is shown in Figure 6.

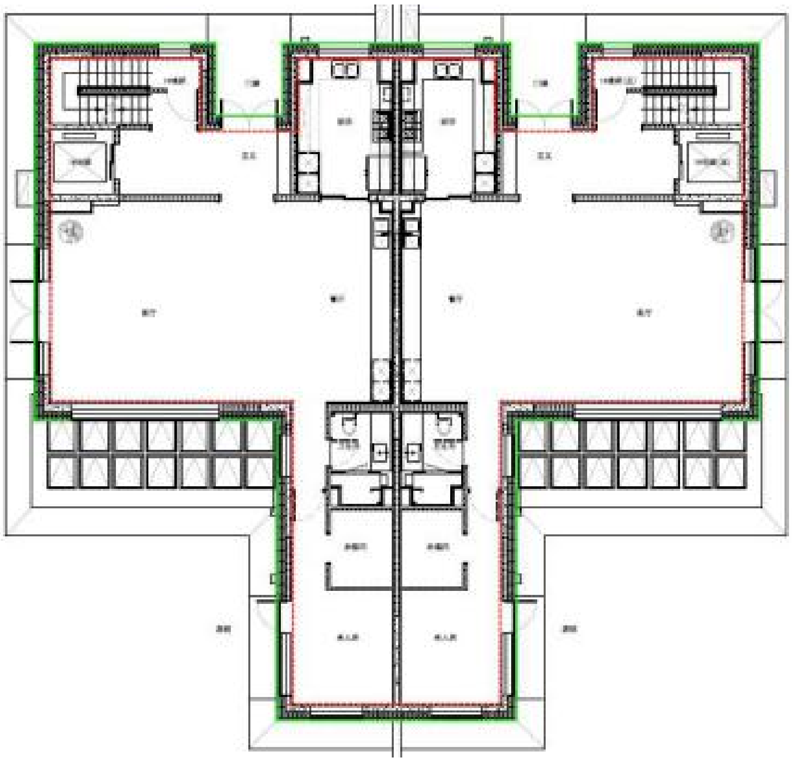

Figure 5. Floor plan of the building

Figure 6. Elevation of the building

The air tightness test of the villa building is carried out according to the test process in 2.2.2 above, and the test and calculation results are shown in Table 4.

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Table 4. Building air tightness test and calculation results

serial number	Stress test	The amount of air leakage (m^3/h) under the 50Pa pressure difference	Natural pressure difference(Pa).	Room temperature (K).	Outdoor tempera ture(K).	The number of ventilations N n under the natural pressure difference	The number of ventilations at 50Pa N50
1	Negative pressure	3644	1395	0	301.3	301.0	/
	Positive pressure	3644	1364	0.1	300.4	300.8	0.01
2	Negative pressure	3574	1405	0.85	300.0	302.7	0.03
	Positive pressure	3574	1326	0.5	301.0	303.8	0.03
3	Negative pressure	3574	1276	1.6	300.5	305.1	0.04
	Positive pressure	3574	1248	0.65	301.3	305.8	0.03
4	Negative pressure	3647	1444	0.6	300.5	304.9	0.03
	Positive pressure	3647	1446	1.15	301.3	304.5	0.04

The test results show that the relationship between the 50Pa pressure difference and the number of air changes under the natural pressure difference is closely related to the tested building and test conditions.

2.5. Test Results

Through the overall air tightness test of 14 ultra-low energy consumption buildings, it is found that the weather conditions are different during the test, the building structure is different, the natural gaps produced by the construction are different, and the pressure difference-leakage curve obtained from the test is different, and the 50Pa pressure difference is different. The number of air changes under the natural pressure difference will also change accordingly. Therefore, the relationship between the number of air changes under the pressure difference of 50 Pa and the natural pressure difference cannot be expressed in a simple linear relationship. The relationship can be determined only by testing the overall air-tightness of the building under test.

3. THE PRODUCT OF INDOOR AND OUTDOOR TEMPERATURE DIFFERENCE AND BUILDING HEIGHT SHALL NOT BE GREATER THAN 250M • K

In the "Measurement Method of Building Air Tightness, Fan Pressure Method" (GB/T 34010-2017), the meteorological conditions indicate that "the difference between indoor and outdoor temperature multiplied by the height of the building space (or the height of part of the building) should not be greater than 250m • K. ; When it is greater than 250m • K, the correct zero-flow air pressure difference cannot be obtained." According to the literature [16], the natural pressure difference on the first floor of the building as the installation location of the test device is estimated by Equation 3:

$$\triangle P=0.04h\triangle T \quad (3)$$

In the above formula, $\triangle P$ is the difference between indoor and outdoor pressure caused by thermal lift; h is the height measured from the zero pressure zone upwards; $\triangle T$ is the difference between indoor and outdoor temperature [16].

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When the test building is a low-rise or multi-storey building, the first floor of the building can be regarded as a zero pressure zone. When the product of the indoor and outdoor temperature difference and the building space height is at most 250m·K, the indoor and outdoor pressure difference caused by thermal lift is △P 10Pa. When the test building is a high-rise building, the literature [16] shows that the zero pressure zone is in the middle of the building height, and the indoor and outdoor pressure difference caused by the thermal lift at this time is 20Pa. Therefore, for different types of buildings, the allowable maximum natural pressure difference between indoor and outdoor should be set separately. At the same time, the maximum allowable pressure difference for low-rise or multi-storey buildings is set to 10Pa, and whether it is appropriate to set it to 20Pa for high-rise buildings still needs to be explored.

4. CONCLUSION

This article mainly studies the relevant standards and literature and discusses the definition of building air-tightness, the relationship between the natural pressure difference and the number of air changes under a pressure difference of 50Pa, and the product of the indoor and outdoor temperature difference and the height of the building based on the overall air-tightness test examples of the building. The question of whether it is not more than 250m·K is appropriate, mainly draws the following conclusions:

(1) Based on the relevant information and the characteristics of building air-tightness, this article defines building air-tightness as "the ability of the building to resist air infiltration and seepage from the natural gaps of the structure when the building is in a theoretically closed state."

(2) Through the overall air tightness test of 14 ultra-low energy consumption buildings, according to the test examples, the relationship between the pressure difference of 50Pa and the number of air changes under the natural pressure difference is related to the tested building and meteorological conditions. The relationship can only be determined when the building is tested for the overall air-tightness of the building.

(3) Through literature research and analysis, the meteorological conditions in "Measurement Method for Air Tightness of Buildings, Fan Pressure Method" (GB/T 34010-2017) "indoor and outdoor temperature difference multiplied by the height of the building space (or the height of part of the building)) should not be More than 250m • K", it is concluded that for different types of buildings, the maximum allowable value of the natural pressure difference between indoor and outdoor should be set separately. Whether the product of the indoor and outdoor temperature difference and the height of the building space is set to 250m • K in the standard still needs to be explored.

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