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Trends in building and ductwork airtightness in Japan

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1 General introduction

Japan is a country with currently about 123.3 million inhabitants. The total construction area in 2022 was approximately 119.5 million m^2 (down 2.3% from the previous year), including approximately 69 million m^2 of housing, 5.7 million m^2 of offices, and 2.5 million m^2 of schools. New housing starts totalled approximately 0.86 million units.

On the other hand, in 2018, the number of stock housing units was about 62 million units, with a total floor area of about 5.749 billion m^2. The housing stock was 16% larger than the total number of households (about 54 million households), which is sufficient in terms of quantity. In contrast, the total floor area of non-residential buildings such as corporations was about 1.987 billion m^2.

This paper mainly introduces trends in buildings airtightness in Japan.

2 Building airtightness

2.1 Introduction

In Japan, the Energy Conservation Law was enacted in 1979, and in February 1992, the notification of energy conservation standards was revised. As a standard in cold regions, a house with leakage area per net floor area across the building envelope at 9.8 Pa pressure difference of 5.0 cm^2/m^2 ($ELA_{F9.8} \leq 5.0$ cm^2/m^2, approximately $q_{E50} \leq 8.5$ $m^3/(h.m^2)$, approximately $ACH_{50} \leq 7.7$ h^{-1}) or less was defined as an airtight house. Furthermore, in March 1999 revised notification, the $ELA_{F9.8}$ was divided into areas with 2.0 cm^2/m^2 (approximately $q_{E50} = 3.4$ $m^3/(h.m^2)$, approximately $ACH_{50} = 3.1$ h^{-1}) or less and areas with 5.0 cm^2/m^2, and became nationwide specifications.

In March 2003, "JIS A 2201 Test method for performance of building airtightness by fan pressurization" was enacted, and in May of the same year, revisions to the Building Standards Law mandated the installation of mechanical ventilation equipment with requirement of 0.5 ACH in principle as a countermeasure against sick house syndrome.

After that, in January 2009, in the revision of the public notice of energy conservation standards for housing, the standard value for building airtightness was deleted based on the judgment that the airtightness of housing was widely known and construction was being carried out.

However, building airtightness is important, and ISO 9972 was revised in 2015 [1], so JIS A 2201 [2] the corresponding standard was also revised in December 2017. In the 2020s, some local governments began to establish and certify standards for building airtightness. In addition, the Architectural Institute of Japan (AIJ) is in the process of formulating an academic standard for building airtightness.

2.2 Airtightness indicator

The airtightness indicator used in Japan standards is specific effective leakage area per the floor area at 9.8 Pa (1 mmAq originally used) pressure difference ($ELA_{F9.8}$). The effective leakage area at the reference pressure difference (ELA_{pr}) is calculated at the test reference pressure differences across the building envelope. As defined in ISO 9972 the specific effective leakage area is an effective leakage area per the envelope area (ELA_{Epr}) or per the floor area (ELA_{Fpr}) at the reference pressure difference (pr). Table 1 shows the unit conversion table for building airtightness. Here, q_{E50} is a specific leakage rate which is an air leakage rate per the building envelope area at 50 Pa across the envelope and ACH_{50} is an air change rate at 50 Pa.

Table 1 : Unit conversion for building airtightness

$ELA_{F9.8}$ [cm²/m²]	q_{E50} [m³/(h.m²)]	ACH_{50} [h⁻¹]
Detached houses (2 stories building, floor area of 125.9 m², height of 5.0 m, envelope area of 285.1 m², internal volume of 314.7 m³, air flow exponent *n* of 0.6)		
0.5	0.9	0.8
1	1.7	1.5
2	3.4	3.1
5	8.5	7.7
Apartment buildings (Dwelling unit, floor area of 46.9 m², height of 2.4 m, envelope area of 159.56 m², internal volume of 112.56 m³, air flow exponent *n* of 0.6)		
0.2	0.2	0.3
0.5	0.6	0.8
1	1.1	1.6
2	2.3	3.2
3	3.4	4.8
5	5.7	8.1
8	9.1	12.9

2.3 Requirements and drivers

2.3.1 Building airtightness requirements in the regulation

Currently in Japan, there are no national building airtightness requirements in the regulation. On the other hand, local governments are making efforts to improve airtightness (Table 2). Local governments have subsidized construction costs for houses that meet the standards. In addition, Japanese dwellings are obliged to install mechanical ventilation equipment.

Table 2 : Standards for Airtight Performance of Housing in Local Governments in Japan

Sapporo City	Yamagata Prefecture	Nagano Prefecture	Tottori Prefecture
$3500 \leq HDD_{18\text{-}18} < 4500$	$2000 \leq HDD_{18\text{-}18} < 3500$	$2000 \leq HDD_{18\text{-}18} < 3500$	$2000 \leq HDD_{18\text{-}18} < 3000$
Starting Apr. 1, 2023	Revised Apr. 1, 2022	Starting Apr. 15, 2023	Starting Jul. 1, 2020
New construction: $ELA_{F9.8} \leq 0.5$ cm²/m² (Approximately $q_{E50} \leq 0.9$ m³/ (h.m²)) Refurbishment: $ELA_{F9.8} \leq 1.0$ cm²/m² (Approximately $q_{E50} \leq 1.7$ m³/ (h.m²))	$ELA_{F9.8} \leq 1.0$ cm²/m² (Approximately $q_{E50} \leq 1.7$ m³/ (h.m²))	New construction: $ELA_{F9.8} \leq 1.0$ cm²/m² (Approximately $q_{E50} \leq 1.7$ m³/ (h.m²))	$ELA_{F9.8} \leq 1.0$ cm²/m² (Approximately $q_{E50} \leq 1.7$ m³/ (h.m²)) Refurbishment housings are recommended value
Common standards for detached houses and apartment buildings	Applies to newly built dwellings and existing dwellings with overall thermal insulation refurbishment	New detached wooden houses are eligible	Energy-saving standards for building detached houses

2.3.2 Incentive for Building airtightness

As mentioned above, local governments set standards for building airtightness in addition to standards for insulation, etc., and partially subsidize construction costs.

2.3.3 Building airtightness justifications

Airtightness tests are not mandatory, but it must be done in accordance with JIS A 2201 in order to receive subsidies for construction costs from local governments. It is necessary to build a house by a contractor and a design office registered with the local government, carry out airtightness measurement, and apply for registration. Airtightness measurements are performed by Airtightness Measurement Technicians registered by IBECs (Institute for Built Environment and Carbon Neutral for SDGs).

2.3.4 Sanctions

Airtightness tests are not compulsory, so there is no penalty.

2.4 Building airtightness in the energy performance calculation

In Japan, there is an evaluation program for energy efficiency and conservation standards for residential and non-residential buildings, but there is no input item for building airtightness. This is based on the judgment that the airtightness of houses is well known nationwide and that construction is being carried out. This is also because airtightness testing is not mandatory.

2.5 Building airtightness test protocol

2.5.1 Qualification of Airtightness testers

IBECs[1] is conducting a training project for building airtightness measurement technicians for houses, etc. Those who have mastered the measurement methods based on JIS A 2201 are considered airtight measurement technicians. After taking the course, those who have passed the written examination can apply for airtightness measurement technician registration and airtightness measurement technician engagement office registration. About 500 people pass the exam every year, and there are 1,125 establishments engaged in airtightness measurement technicians. Airtightness measurement technicians perform the airtightness measurement required for conformity assessment of housing.

2.5.2 National guidelines

The national guideline for conducting building airtightness tests is JIS A 2201, which is the corresponding standard of ISO 9972. JIS A 2201 is a test method for performance of building airtightness by fan pressurization. And it describes the pressurization method and the depressurization method. It is not written to methods other than the airtightness test method by fan pressurization, such as the pulse method.

2.5.3 Requirements on measuring devices

The test equipment consists of a fan, airflow controller, airflow measuring device, differential pressure gauge, thermometer, etc. The accuracy of pressure measuring instruments is required to be ±0.5Pa in the pressure difference measurement range of approximately 10 to 100 Pa, the accuracy of thermometers is ±0.5 K, and the accuracy of anemometers is ±0.1 m/s.

2.6 Building airtightness Tests performed

2.6.1 Tested buildings

There is no official data available on the percentage of buildings airtightness tested. In Japan, it is common to measure the building airtightness of houses, and non-residential airtightness measurements are rarely performed except for special buildings.

2.6.2 Database

Figure 1 and Figure 2 are the results of building airtightness measurements by the authors.

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[1] https://www.ibec.or.jp/investigate/air-tightness.html

Figure 1 shows changes in the building airtightness of apartment buildings [3]. It can be seen that the $ELA_{F9.8}$ of apartment buildings around 1970 is about 5 cm^2/m^2 (approximately q_{E50} = 5.7 m^3/ (h.m^2), $ACH_{50} \leq$ 8.1 h^{-1}), and the $ELA_{F9.8}$ of apartment houses after 2000 is 1.0 cm^2/m^2 (approximately q_{E50} = 1.1 m^3/ (h.m^2), $ACH_{50} \leq$ 1.6 h^{-1}) or less. On the other hand, the building airtightness refurbishment of reinforced concrete and steel reinforced concrete stock buildings around 1970 are concentrated around the openings, and the $ELA_{F9.8}$ are improved to about 3 cm^2/m^2 (approximately q_{E50} = 3.4 m^3/ (h.m^2), $ACH_{50} \leq$ 4.8 h^{-1}).

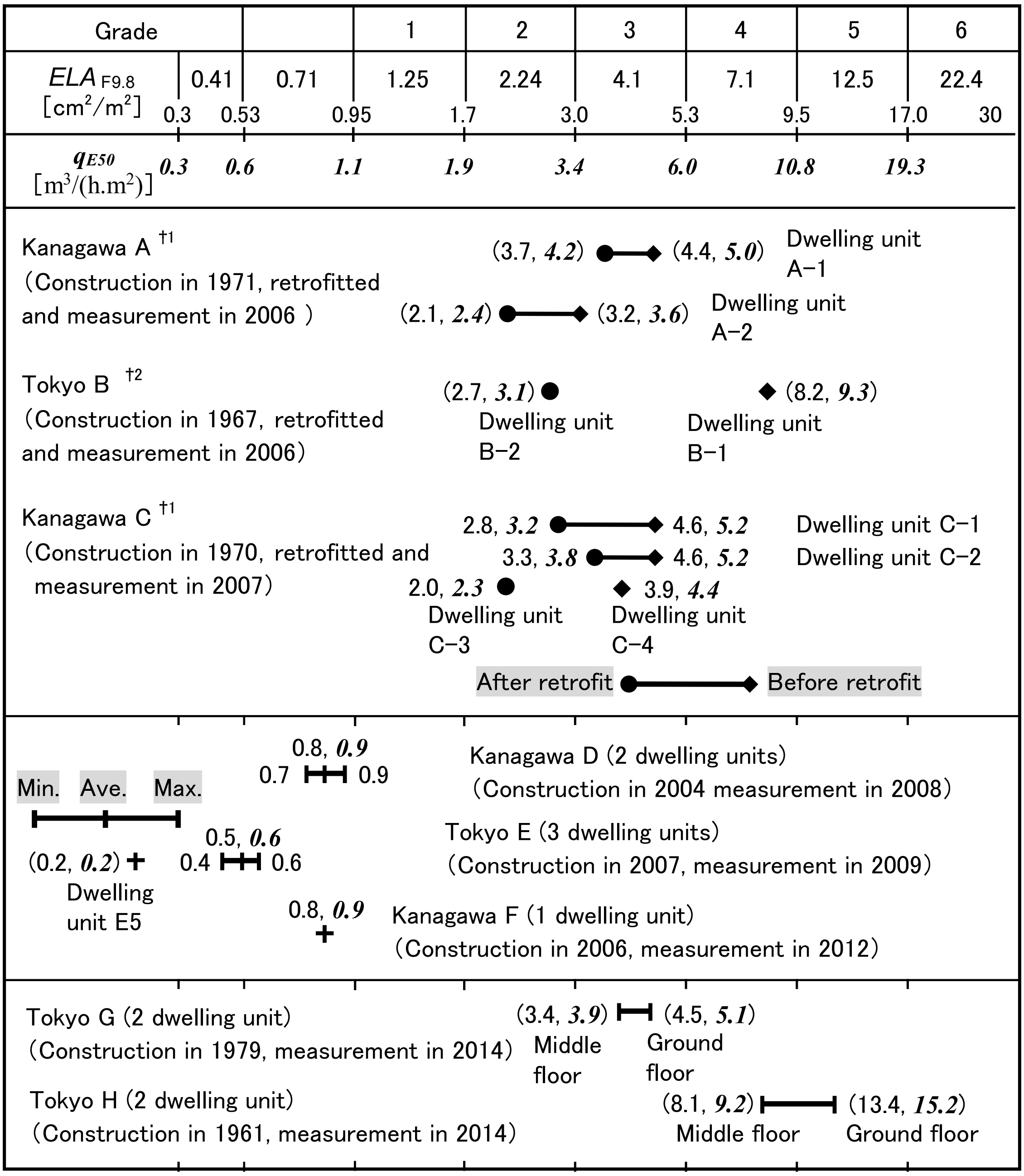

Figure 1 : Comparison of airtightness measurements (ELAF9.8) of apartment buildings in Japan [3].

Note: Numeric values in brackets are by depressurization method. Others are pressurization method. And, bold italicized values indicate q_{E50}.
†1 Windows were retrofitted.
†2 Windows and entrance door were retrofitted. (Steel window frames before retrofitting)

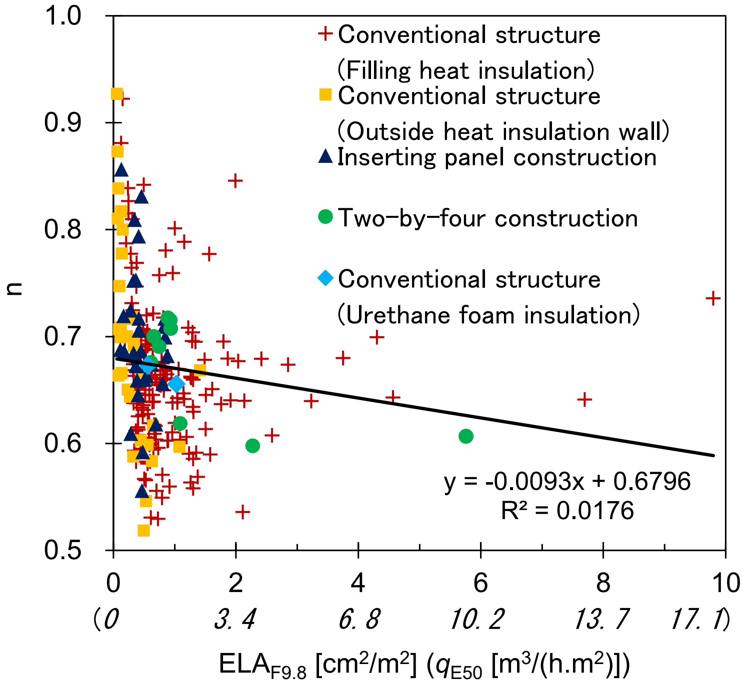

Figure 2 : Relation between specific effective leakage area per the floor area and "The power law" exponent of wooden detached houses in Japan [4].

Figure 2 shows the relationship between $ELA_{F9.8}$ and the air flow exponent n for 233 detached houses from 2015 to 2020 [4]. Over 75% of detached houses have an $ELA_{F9.8}$ of 1.0 cm^2/m^2 (approximately q_{E50} = 1.7 m^3/ (h.m^2), $ACH_{50} \leq$ 1.5 h^{-1}) or less. These represent a small amount of measured data (0-10 %) from all data.

No strong correlation is observed in Figure 2, and the n value is seen to lie between 0.6 and 0.7. In general, the n values of opening sections (such as sashes of windows and doors) are smaller than those of background openings. Even in buildings (houses) having the same $ELA_{F9.8}$, the n value varies depending on the component openings. Therefore, $ELA_{F9.8}$ and the n value are not proportional. It can be seen that $ELA_{F9.8}$ of conventional structures (with outside insulation wall) and that of inserting panel constructions is smaller than 1.0 cm^2/m^2, indicating high airtightness. And, the outside insulation wall construction method exhibited consistent high airtightness, but the filling heat insulation construction method showed variations. This is attributable to not only the construction accuracy, but also due to the mutual details of structural members and air barriers.

2.6.3 Evolution of the airtightness level

As shown in Figure 1, the $ELA_{F9.8}$ for apartment buildings built around 1970 is around 5 cm^2/m^2 (approximately q_{E50} = 5.7 m^3/ (h.m^2), $ACH_{50} \leq$ 8.1 h^{-1}), but for housing units with steel sashes, it is around 8 cm^2/m^2 (approximately q_{E50} = 9.1 m^3/ (h.m^2), $ACH_{50} \leq$ 12.9 h^{-1}), which means their building airtightness is low. By refurbishing the area around the windows, $ELA_{F9.8}$ has been improved to about 3cm^2/m^2 (approximately q_{E50} = 3.4 m^3/ (h.m^2), $ACH_{50} \leq$ 4.8 h^{-1}). $ELA_{F9.8}$ in 1990 was around 1 cm^2/m^2 (approximately q_{E50} = 1.1 m^3/ (h.m^2), $ACH_{50} \leq$ 1.6 h^{-1}), $ELA_{F9.8}$ after 2000 was less than 1 cm^2/m^2, and $ELA_{F9.8}$ for residential units completed in 2007 was 0.2 cm^2 (approximately q_{E50} = 0.2 m^3/ (h.m^2), $ACH_{50} \leq$ 0.3 h^{-1}) to 0.5 cm^2/m^2 (approximately q_{E50} = 0.6 m^3/ (h.m^2), $ACH_{50} \leq$ 0.8 h^{-1}).

Regarding the $ELA_{F9.8}$ of wooden detached houses, in 2000's it was around 5cm^2/m^2 (approximately q_{E50} = 8.5 m^3/(h.m^2), $ACH_{50} \leq$ 7.7 h^{-1}), and from 2015 onwards, many houses have an $ELA_{F9.8}$ of 1 cm^2/m^2 (approximately q_{E50} = 1.7 m^3/(h.m^2), $ACH_{50} \leq$ 1.5 h^{-1}) or less (Figure 2). However, $ELA_{F9.8}$ rarely falls below 1 cm^2/m^2 after refurbish work is performed.

2.7 Guidelines to build airtight

AIJ is currently formulating academic standards to improve building airtightness. In addition, a consortium study group on building airtightness of non-residential buildings has been established.

2.8 Conclusion

Japanese buildings ensure a certain degree of building airtightness. The awareness on building airtightness in Japan is growing again but there are still very few non-residential buildings that are tested. This is probably because the blower door tester is more expensive than the fan pressurization tester for residential use, and airtightness testing is difficult. However, research consortiums have started up, and it is expected that interest in building airtightness for non-residential buildings will increase in the future, and databases will be created.

In the case of housing, local governments are setting standards for building airtightness in some cases, and the number of airtightness testers is also increasing. Researchers have created a database of residential building airtightness, and academic standards are also planned to be developed. By ensuring the building airtightness, the ventilation passage intended in the design is realized, improving temperature differences between the top and bottom of room, and reducing heating and cooling load.

2.9 Key documents

[1] ISO 9972:2015, Thermal performance of buildings — Determination of air permeability of buildings — Fan pressurization method https://www.iso.org/standard/55718.html

[2] JIS A 2201:2017, Test method for performance of building airtightness by fan pressurization https://webdesk.jsa.or.jp/books/W11M0090/index/?bunsyo_id=JIS+A+2201%3A2017

[3] Yoshihiro Toriumi and Takashi Kurabuchi, Impact of Negative Pressure in a Room Due to Increased Airtightness in Residential Apartment Housing, CLIMA 2019 Proceedings https://dx.doi.org/https://doi.org/10.1051/e3sconf/201911101094

[4] Yoshihiro Toriumi and Takashi Kurabuchi, building air leakage characteristics and airtightness durability of single-family dwelling, IAQVEC2023 Proceedings https://dx.doi.org/https://doi.org/10.1051/e3sconf/202339602026

[5] IBECs, https://www.ibec.or.jp/investigate/air-tightness.html

3 Ductwork airtightness

In Japan, the ductwork airtightness has not been really considered so far. There is no national regulation nor guideline on this subject, so there is no requirement on the airtightness level of ductworks. Ductwork airtightness is important for ventilation and energy saving. But, there are only rare cases in which clients request a ductwork airtightness test. Regarding the ductwork airtightness, it is necessary to pay attention to international trends as well.

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