SURVEY ON MINIMUM VENTILATION RATE OF RESIDENTIAL BUILDINGS IN FIFTEEN COUNTRIES

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ABSTRACT

The Minimum Ventilation Rate standard for dwellings is essential not only to provide occupant health and comfort, but also to remove and dilute the dominant pollutants. The purpose of this survey is to clarify and compare the regulations, standards or guidelines of ventilation requirements for residential buildings of various countries. The studies are based on the many literatures and interviews with the specialists in building regulation. The main viewpoints in this study are, how much the minimum ventilation rate is required, whether the regulations are mandatory or not, and what the ventilation requirements are based on. All regulations were applied to a model house proposed by the Architectural Institute of Japan in order to compare the minimum air change rates.

The conclusions of this study are shown as follows, (1) In Sweden, Denmark, France and Japan, the regulations were confirmed to be mandatory, but in other countries, there were some obscurities. (2) In each of the regulation, the ventilation requirement was based on the total volume of houses, the conditioned volume, the floor area, people and ventilation systems etc. (3) It was found that the air change rates applied to the model house were nearly 0.5 ACH, which is equal to the Japanese requirements.

KEYWORDS

Minimum Ventilation Rate, Air Change Rate, House, Building Standard

INTRODUCTION

The objectives of this study are to compare information of the regulations, standards and guidelines of ventilation for dwellings, in 15 developed countries - Norway, Sweden, Finland, Denmark, Belgium, France, Netherlands, Germany, Switzerland, United Kingdom, Italy, Greece, the Commission of the European Communities, Canada, U.S.A and Japan, and to discuss the characteristics of each of these regulations, standards and guidelines. After that each country's minimum air change rate is applied to a model house proposed by the Architectural Institute of Japan in order to compare each other.

VENTILATION REQUIREMENT IN EACH COUNTRY

Norway [2)]

According to the Norwegian building Regulations of 1997, the total exhaust ventilation from kitchen, bathroom, the toilet and washing room must ensure a supply of outdoor air of at least 0.5 ACH for a dwelling. Minimum required extract airflows are from toilet (10 L/s (36 m^3/h)), bathroom (10 L/s (36 m^3/h) (openable window) or 30 L/s (108 m^3/h)), washing room (10 L/s (36 m^3/h) (openable window) or 20 L/s (72 m^3/h)) and kitchen (10 L/s (36 m^3/h) + 20 L/s (72 m^3/h) (from exhaust hood in use)).

Sweden [4)]

According to the Swedish building regulations (BBR94) that contains mandatory provisions and general advisory notes, the ventilation systems of buildings shall be designed in such a way that the required quantity of outside air is supplied to the building to remove contaminants from activities, respiration, products from persons and airborne emissions from building materials, as well as moisture, bad smell and substances hazardous to health. Rooms shall have air changes continuously when they are in use. The outside airflow rate shall not be less than 0.35 L/s (1.26 m^3/h) per m^2 of floor area, which corresponds to a ventilation coefficient of 0.5 ACH in a room with a free height of 2.5m. In the situation of the rooms are not in use, the airflow rate may be reduced but not to such an extent that health risks arise or there is a risk of damage to the building or in the form of intermittent operation. In general recommendation, the outdoor air to rooms or parts of rooms for sleeping and resting should not be less than 4 L/s, person (14.4 m^3/h, person). Mechanical ventilation should be designed so that the capacity to provide rates of flow of extract air is not less than those set out in Table 1.

After the building completion, airflow testing must be exercised in order to check whether the ventilation systems fulfill the mandatory provisions stated on the regulations of Obligatorisk Ventilation Kontrol (Obligatory Ventilation Check). When the ventilation systems are found not to conform to the provisions, the systems must be repaired.

Table 1
Rate of flow extract air (Sweden)

Space		Minimum rate of flow of extract air
Dwellings, institutional premises, hotel and similar.	Kitchen	10 L/s (36m^3/h)
	Kitchenette, kitchen cubicle	15 L/s (54m^3/h)
	Bathroom or shower room with open window	10 L/s (36m^3/h)
	Bathroom or shower room extraction without open window	10 L/s (36 m^3/h) rate up to 30 L/s (108 m^3/h), or 15L/s (54m^3/h)
	Lavatory	10 L/s (36 m^3/h)
Service spaces	Laundry room, drying room	10 L/s (36 m^3/h)
	Refuse storage room	5 L/s m^2 (18 m^3/h m^2)
	Refuse storage room for dry refuse only	0.35 L/s m^2 (1.26 m^3/h m^2)

Finland [5)]

Regulations and guidelines of indoor air quality and ventilation for dwellings are shown in D2 Indoor Atmosphere and Ventilation of Building Regulation and Guidelines 2003. During the periods of occupancy, an outdoor air flow that guarantees a healthy, safe and comfortable quality of indoor air must be routed to the occupied premises. Ventilation in dwellings is normally designed on the basis shown in Table 2. As a general rule, the outdoor airflow rate should be at least 0.35 L/s m^2 (1.26 m^3/h m^2).

Table 2
Airflow rate in each room (Finland)

Area / application	Outdoor air flow per person	Outdoor air flow	Extract air flow
Dwelling areas:	6 L/s (21.6 m^3/h)	-	-
Dwelling rooms	-	0.5 L/s m^2 (1.8 m^3/h m^2)	-
Kitchen -boost during occupancy	-	*1	8 L/s (28.8 m^3/h) 25 L/s (90 m^3/h)
Cloakroom, storage room	-	*1	3 L/s (11.4 m^3/h)
Bathroom - boost during occupancy	-	*1	10 L/s (36 m^3/h) 15 L/s (54 m^3/h)
WC - boost during occupancy	-	*1	7 L/s (25.2 m^3/h) 10 L/s (36 m^3/h)
Utility room - boost during occupancy	-	*1	8 L/s (28.8 m^3/h) 15 L/s (54 m^3/h)
Sauna in the apartment	-	*2	2 L/s m^2 (7.2m^3/h m^2) *2

*1: Outdoor air flow is normally substituted with transfer air flow routed from the dwelling rooms.
*2:But not less than 6 L/s (21.6m^3/h). Air flows in the sauna are not taken into account in the calculation of the sauna's ventilation coefficient if the sauna's outdoor air flow rate is equal to the used air flow rate.

Denmark [6, 7)]

The requirements of indoor air quality in Danish dwellings are provided in the Danish Building Regulations for Small Dwellings 1998 and in the Danish Building Regulations 1995. The requirements are given as minimum ventilation rates. In single-family houses it is allowed to have natural ventilation, mechanical exhaust or mechanical ventilation. In multi-story houses only mechanical exhaust or mechanical ventilation are allowed.
The regulations require that each habitable room and the entire dwelling shall have at least a total air exchange rate of 0.5 ACH. In dwellings with natural ventilation, minimum opening areas are required. In dwellings with mechanical exhaust or mechanical ventilation, minimum exhaust flow is required from kitchen or bathroom. The exhaust shall be continuously operated. In small flats with mechanical exhaust, the air exchange rate can be up to 1.0 ACH.
Kitchens, bathrooms, sanitary, lavatories etc. must be furnished with exhaust systems and should satisfy the required outdoor air flow rates.
The Danish Building Regulations are mandatory and one would get fined for the act of disobedience.
Table 3 shows the opening area and ventilation airflow rate for areas prescribed by building regulation.

Table 3
Open area and airflow rate in each room (Denmark)

Area	Small Dwellings	Multi-story houses

	Supply air flow	Exhaust air flow	Supply air flow	Exhaust air flow
Openings area in living room	At least 2.4 cm^2/m^2 floor area (natural ventilation) At least 1.2 cm^2/m^2 floor area (mechanical ventilation)	-	At least 1.2 cm^2/m^2 floor area	-
Kitchen	At least 30cm^2 or an opening of at least 100 cm^2 to the access room	72 m^3/h or a cooker hood or natural exhaust draught with a duct cross section of at least 200 cm^2	Hinged window, hatch or door or fresh air valve	72 m^3/h through an extractor hood
Sanitary accommodation	At least 100cm^2 or an opening of at least 100 cm^2 to the access room	54m^3/h or natural exhaust draught with a duct cross section of at least 200cm^2	Hinged window, hatch or fresh air valve, and/or opening to the access room	54m^3/h
Utility rooms, storerooms	At least 50cm^2 or an opening of at least 100 cm^2 to the access room	36m^3/h or natural exhaust draught with a duct cross section of at least 200cm^2	Hinged window, hatch or fresh air valve, and/or opening to the access room	36m^3/h
Basement rooms	A ventilation opening fresh air valve with at least 30cm^2	36m^3/h or natural exhaust draught with a duct cross section of at least 200cm^2	-	-

Belgium [3)]

In Belgium, the National Standard describes the requirement in terms of ventilation of residential buildings (NBN D50-001). The basis assumption of the standard is that the quality of the outdoor air must be good enough to be used as ventilation air, and the described airflows are adapted to remove occupancy pollutants only and that mechanical ventilation must be permanent. The basic rule is to deliver 1 L/s m^2 (3.6 m^3/h m^2) with minimum and maximum airflows according to the destination of the room, as shown in Table 4.

Table 4
Airflow rate in each room (Belgium)

Type of room	Supply/Exhaust	Airflow	Minimum airflow	Maximum airflow
Living rooms	Supply	1 L/s m²	75 m³/h	May be limited to 150 m³/h
Bedrooms, Studies, Play rooms	Supply	1 L /s m²	25 m³/h	May be limited to 36 m³/h per person
Kitchens, Bathrooms, Laundries	Exhaust	1 L /s m²	50 m³/h	May be limited to 75 m³/h
WC	Exhaust	25 m³/h	-	-

France [3)]

In France, the regulations of indoor air quality and ventilation for dwellings have to be obligatory applied. The ventilation was required to provide air change continuously in each

habitable room. It has to supply fresh air in order to the habitable rooms to exhaust stale air from the service rooms. The extract flow rates are given corresponding with the number of habitable rooms as indicated in Table 5. However, these flow rates can be reduced with respect to the values shown in Table 6. In the case of using controlled systems, which adjust automatically the extract flows, the values illustrated in Table 6 can be reduced in the absence of occupancy given in Table 7.

Table 5
Airflow rate in each room (France)

Number of habitable rooms	Extract flow (m^3/h)				
	Kitchen	Bathroom or shower-room	Other water-room	Toilets	
				Single	Multiple
1	75	15	15	15	15
2	90	15	15	15	15
3	105	30	15	15	15
4	120	30	15	30	15
5 +	135	30	15	30	15

Table 6
Minimum airflow rate in each room (France)

	Number of habitable rooms						
	1	2	3	4	5	6	7
Minimum flow in kitchen (m^3/h)	35	60	75	90	105	120	135
Minimum flow for all the dwelling (m^3/h)	105	120	150	165	210	210	210

Table 7
Minimum airflow rate during non-occupancy (France)

	Number of habitable rooms						
	1	2	3	4	5	6	7
Minimum flow for all the dwelling (m^3/h)	10	10	15	20	25	30	35

Netherlands [1,8)]

In the Netherlands, the building decree prescribed about ventilation is for staying area, staying room, toilet room, bathroom, and other rooms. The provision for the supply of fresh air to a staying area and for the discharge of inside air from that area shall have a capacity, and it is determined in accordance with NEN 1087 of at least 0.9 L/s m^2 of floor area of that area (3.24 m^3/h m^2), with a minimum of 7 L/s (25.2m^3/h). Minimum ventilation for a toilet room shall be 7 L/s (25.2 m^3/h) and for a bathroom shall be 14L/s (50.4m^3/h), whether or not combined with a toilet room. The above discharge of inside air shall take place directly to the open air.

Germany [3)]

The German industrial norm DIN 1946 is a series concerning ventilation and air–conditioning, in which Part 2 gives the general requirements and Part 6 deals with residential buildings. In term of CO_2 concentration, it is recommended to keep the level below 1500 ppm. Furthermore

for variably used rooms, different air change rates are specified. However, there is no instruction indicated how the demands of air change can be met. Airflows in dwellings according to DIN 1946 part 6 are shown in Table 8.

Table 8
Airflow rate (DIN)

		Planned outdoor air change rate	
Area of the flat (m^2)	Planned occupancy (persons)	Natural ventilation (m^3/h)	Mech. Ventilation (m^3/h)
< 50	Up to 2	60	60
50 ...80	Up to 4	90	120
> 80	Up to 6	120	180

Switzerland

According to SIA 180 – Heat and moisture protection in buildings (1998), the minimum airflow rate is determined by the maximum steady state pollutant or humidity concentration and the source strength. In rooms where smoking is not allowed and with a maximum CO_2 concentration of 1500ppm, the air flow rate of 12~15 m^3/h per person is required. In rooms where smoking is allowed the airflow rate has to be 30~70 m^3/h per person.
According to SIA 382 - Technical requirements to ventilation equipment (1992), in rooms where smoking is not allowed with a maximum CO_2 concentration of 1000ppm, the air flow rate of 25~30 m^3/h per person is required. On the other hand, with a maximum CO_2 concentration of 1500ppm, the air flow rate is equal to SIA 180 and the air flow rates above 0.3 ACH is recommended in unoccupied rooms.

United Kingdom [9)]

The British Building Regulations 2002 prescribe that rapid ventilation, background ventilation, extraction fan rates and passive stack ventilation, as shown in Table 9, should be designed. There is no regulation of outdoor airflow rate for habitable room.

Table 9
Airflow rate (United Kingdom)

Room	Rapid ventilation (e.g. opening windows)	Ventilation openings	Extract ventilation fan rates or passive stack -PSV
Habitable room	1/20th of floor area	$8000mm^2$	-
Kitchen	Opening window (no minimum size)	$4000mm^2$	30L/s adjacent to a hob or 60 L/s elsewhere or PSV
Utility room	Opening window (no minimum size)	$4000mm^2$	30L/s or PSV
Bathroom (with or without WC)	Opening window (no minimum size)	$4000mm^2$	15L/s or PSV
Sanitary accommodation (separate from bathroom)	1/20th of floor area or mechanical extract 6L/s	$4000mm^2$	-

Italy [1)]

According to the Italian Ministerial Decree 05.07.75 Ventilation requirements for residential buildings, airflow rates should meet the values indicated in Table 10.

Table 10
Airflow rate (Italy)

Room	Ventilation requirement
Naturally ventilated dwellings	0.35ach to 0.5ach
Kitchen	1.0 ach
Bathroom	2.0 ach
Ante - bathroom	1.0 ach
Normal living space	15m^3/h per person

Greece [1)]

The Greek Legislative Framework Document gives the demand ventilation for each room shown in Table11. The minimum ventilation airflow rate is 8.5 m^3/h per person.

Table 11
Airflow rate (Greece)

Space	Estimated persons per 100m^2 of floor area	Demanded Ventilation (m^3/h per person)	
		Minimum	Recommended
Detached houses			
Sitting rooms, bedrooms	5	8.5	12-17
Bathrooms, Kitchens	-	34	50-85
Block of Flats			
Sitting rooms, bedrooms	7	8.5	12-17
Bathrooms, Kitchens	-	34	50-85

Commission of the European Communities [10)]

In the Report No.11 - Guidelines for Ventilation Requirements in Buildings by the Commission of the European Communities, the ventilation rate required for health and comfort should be calculated separately and the highest value of ventilation rate should be used for design. The ventilation required for health is calculated by an equation including the pollution load of chemical and the allowable concentration of chemical. The ventilation required for comfort is calculated by an equation including sensory pollution load (olf) and perceived air quality (decipol). In the EC report, an example of determination of required ventilation rate is shown. In this paper, the ventilation rate - 0.4 L/s, m^2 (1.44 m3/h, m^2) is adopted as the value used for design.

Canada [11, 12)]

National Building Code of Canada

National Building Code of Canada 1995 prescribes natural ventilation and mechanical ventilation system during non-heating-season and mechanical ventilation system during

heating season. In natural ventilation, the unobstructed openable ventilation area to the outdoors for rooms and spaces in residential buildings ventilated by natural means shall conform to Table12.

Mechanical ventilation during non-heating-season shall be provided to exhaust inside air from the room or space, or to introduce outside air to there at the rate of

a) 0.5 ACH if the room or space is mechanically cooled during the season, or

b) 1.0 ACH if it is not mechanically cooled during the season.

In the meantime, mechanical ventilation during heating-season shall be designed so that it can operate on a continuous basis and has a minimum ventilation air capacity that is the greater of the sum of the individual room requirements as defined in Column 1 of Table 12; or 0.3 ACH based on the conditioned volume of the dwelling unit.

Table 12
Minimum Ventilation Air Requirements

Space classification	Column 1	Column2*1	Column 3*1
	Minimum Ventilation capacity, L/s （m^3/h）*2	Intermittent exhaust, L/s （m^3/h）*2	Exhaust, L/s （m^3/h）*2
Category A			
Master bedroom*3	10 (36)	-	-
Basement*4	10 (36)	-	-
Single bedrooms	5 (18)	-	-
Living room*5	5 (18)	-	-
Dining room*5	5 (18)	-	-
Family room	5 (18)	-	-
Recreation room	5 (18)	-	-
Other habitable rooms*6	5 (18)	-	-
Category B			
Kitchen*5	5 (18)	50 (180)*7	30 (108)
Bathroom	5 (18)	25 (90)	10 (36)
Laundry	5 (18)	-	-
Utility room	5 (18)	-	-

*1: Either intermittent or continuous exhaust is required.

*2: Based on an air temperature of 20 ^oC.

*3: Master bedroom is the bedroom most likely to be occupied by two adults.

*4: Where a basement incorporates rooms of the types designated in this Table, the ventilation requirements for each room shall be as specified above. Basement areas used for other purposes that exceed 2/3 of the total basement area shall have a minimum ventilation requirement of 10L/s; those that are less than 2/3 of the total area shall have a minimum requirement of 5 L/s. This Standard does not require ventilation of mechanical service and storage rooms.

*5: Ventilation requirements for any combined living room, dining room, and kitchen shall be determined as if they were individual rooms.

*6: Other habitable rooms not listed shall have a minimum ventilation requirement of 5 L/s. This dose not include spaces intended solely for access, egress, or storage, such as vestibules, halls, landings, storage rooms, service closets and furnace rooms.

Canada R-2000, Builders' Manual

Canada R-2000 provides that the sizing of the ventilation system shall meet the Program specifications which include:

a) The demonstrated capability of the system to provide a ventilation rate of at least 0.5 ACH or 50 L/s (180 m^3/h), whichever is greater,

b) The ability of the system to provide a minimum and constant distribution of fresh air to each room of the houses at a rate of at least 5 L/s (18 m^3/h).

ASHRAE Standard 62.2-2003 [13)]

ASHRAE Standard 62.2, Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings, provides the minimum requirements necessary to achieve acceptable indoor air quality for dwellings. It can be applied to new or existing houses. Whole-house ventilation is intended to dilute the unavoidable contaminant emissions from people, from materials and from background processes. But the Standard does not address specific pollutant concentration levels.
A mechanical exhaust system, supply system, or combination should be installed for each dwelling unit to provide whole-building ventilation with outdoor air each hour at no less than the rate specified in Table 13 or equivalent to Equation (1) which is based on the floor area of the conditioned space and number of bedrooms. And this includes a default credit for ventilation provided by infiltration of 0.36 m^3/h,m^2 of occupiable floor space.

$$Q_{fan} = 0.18\, A_{floor} + 12.6\, (N_{br} + 1)\ (m^3/h) \qquad (1)$$

Where:
A_{floor} = floor area (m^2)
N_{br} = Number of bedrooms; not to be less than 1.

Table 13
Ventilation Air Requirements, L/s (m^3/h)

Floor Area (m^2)	Bedrooms				
	0-1	2-3	4-5	6-7	>7
<139	14 (50.4)	21 (75.6)	28 (100.8)	35 (126)	42 (151.2)
139.1-279	21 (75.6)	28 (100.8)	35 (126)	42 (151.2)	50 (180)
279.1-418	28 (100.8)	35 (126)	42 (151.2)	50 (180)	57 (205.2)
418.1-557	35 (126)	42 (151.2)	50 (180)	57 (205.2)	64 (230.4)
557.1-697	42 (151.2)	50 (180)	57 (205.2)	64 (230.4)	71 (255.6)
>697	50 (180)	57 (205.2)	64 (230.4)	71 (255.6)	78 (280.8)

Japan [14)]

The Japanese Building Code of ventilation for residential buildings has been revised since July 2003 in order to deal with IAQ problems in sick buildings. According to this new code, habitable rooms adopt ventilation systems must not less than 0.5 ACH based on the conditioned volume as a rule. This value is based on HCHO emission rates and the concentration provided by Ministry of health, Labour and Welfare. When the building materials used are below a certain HCHO emission rates, minimum airflow rates required are 0.3 ACH. When the materials are beyond a certain HCHO emission rates, minimum airflow rates are 0.7 ACH.

MINIMUM VENTILATION RATES FOR A MODEL DWELLING BY ARCHITECTUAL INSITUTE OF JAPAN

Explanation for Calculation

The calculation of the minimum airflow rates for a model house is based on the regulations and standards of the 15 investigated countries in this study. The model house is shown in Figure 1 and the description of the model house is found in Table 14. This model house is assumed to be occupied by a couple with two children.

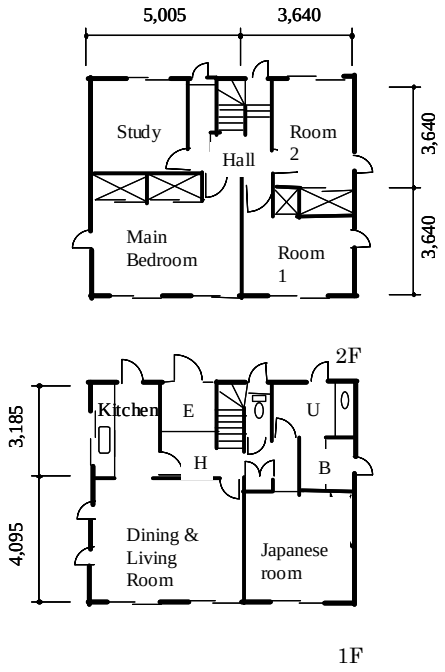

Figure 1: Floor plan of the model house

Table 14
The model house's floor area & volume

	Type of room	Floor area m^2	Volume m^3
1 F	Living & Dining room	20.5	49.2
	Kitchen	7.2	17.4
	Japanese room	13.3	31.8
	Bathroom	3.3	7.9
	Lavatory	5.0	11.9
	WC	1.7	4.0
	Other	12.0	28.9
	Sum of 1F	62.9	151.0
2F	Main Bedroom	20.5	49.2
	Room 1	11.6	27.8
	Room2	11.6	27.8
	Study	10.1	24.3
	WC	1.7	4.0
	Other	7.5	17.9
	Sum of 2F	62.9	151.0
Total		125.9	302.1

Calculation results

The minimum airflow rates of each regulation were calculated by the procedures indicated in Table 15. The calculated result obtained in this study is shown in Figure 2.

Table 15
Procedures for calculation

Norway	Though the minimum airflow rates are 0.5 ACH - 151 m^3/h, total exhaust ventilation rates (216 m^3/h -0.71ACH) from a kitchen (36m^3/h), a bathroom (108 m^3/h) and 2 toilets (72 m^3/h) are considered as the minimum in a dwelling.
Sweden / Finland	The minimum airflow rates are 159m^3/h -0.53ACH, as minimum airflow rates are 1.26m^3/h per floor area and all the floor areas are 126m^2.
Denmark / Italy /Japan	The minimum airflow rates are 0.5 ACH- 151 m^3/h.
Belgium	The minimum airflow rates for each room were calculated according to the basic rule, which is to deliver 3.6m^3/h, m^2 with minimum and maximum air flows shown in Table 1, and add together in this paper, as the standard of Belgium does not describe the total minimum airflow rates.
France	The minimum airflow rates are 210m^3/h -0.70ACH- according to Table 1 and 6 rooms in this house.
Germany	The minimum airflow rates are 180m^3/h -0.60ACH- according to Table1.
Switzerland	The minimum airflow rates are 60 m^3/h -0.40ACH- according to 15 m^3/h per person and 4 people living in this house.

Greece	The minimum airflow rates are 153m^3/h -0.50 ACH- according to the requirements for the rooms as defined in Table 11, as the standard of Greece does not describe the total minimum airflow rates.
Canada	The minimum airflow rates are 198m^3/h -0.66 ACH- according to the sum of the individual room requirements greater than 0.3 ACH.
Canada R-2000	The minimum airflow rates are 180m^3/h -0.59 ACH greater than 0.5 ACH.
U.S.A	The minimum airflow rates are 118m^3/h -0.36 ACH- according to Equation (1), 3 bedrooms and 126m^2 floor areas
Commission of the EC	The minimum airflow rates are 181.3m^3/h –0.60 ACH- according to the ventilation for comfort 1.44m3/h, m^2 and 126m^2 floor areas.

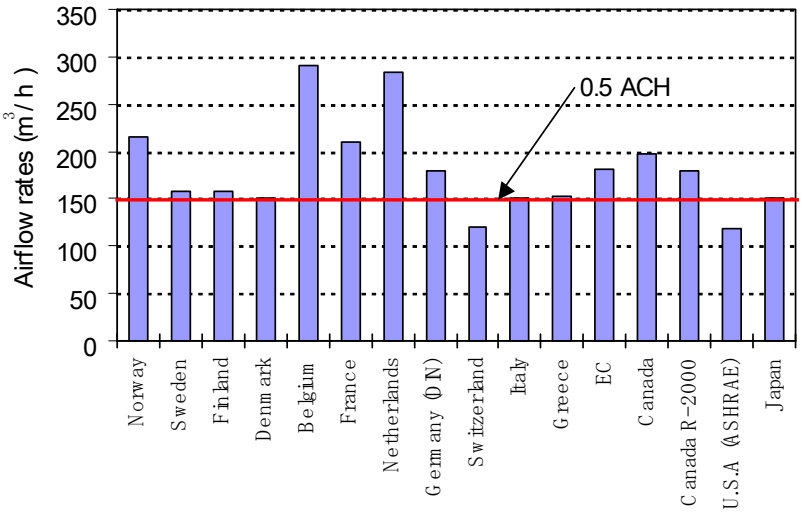

Figure 2 : Calculation results

CONCLUSIONS

A survey of the regulations, standards or guidelines of ventilation for dwellings of 15 developed countries was carried out in this study. The airflow rates of each of the regulation were based on the total volume of houses, the conditioned volume, the floor area, people, and ventilation systems etc.

In Sweden, Finland, Denmark, France and Japan, the regulations have mandatory provisions. Especially, in Sweden, airflow testing must be exercised in order to check whether the ventilation systems fulfill the mandatory provisions after the building completion. When the ventilation systems are found not to conform to the provisions, the systems must be repaired. In Denmark, there are penalties for disobeying the regulations.

Concerning the grounds for these regulation requirements, Switzerland, the Commission of the European Communities and Japan use the pollutant/humidity concentration and strength to calculate the minimum airflow rates. In contrast with the other countries' regulation in this study, what those values are based on is not obvious.

In this paper, most of the air change rates applied to a model house were found nearly 0.5 ACH.

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11) National Building Code of Canada 1995

12) CANADA R-2000 BUILDERS' MANUAL

13) ANSI/ASHRAE Standard 62.2-2003, ASHRAE STANDARD Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings

14) Ministry of Land, Infrastructure & Transport, http://www.mlit.go.jp/english/index.html