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Evaluation of the COMIS Model by Comparing Simulation and Measurement of Airflow and Pollutant Concentration

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Abstract This paper describes the measured and calculated results of airflow rates and pollutant concentration profiles in an airtight test house, the aim being to evaluate the calculation model COMIS for multizone air infiltration and pollutant transport. Firstly, the leakage areas of internal doors, exterior walls and windows were measured by the fan pressurization method. Secondly, two measurements were carried out, assuming that the test house consisted of ten zones. The concentrations and injection rate of SF_6 were measured in order to determine the airflow rates by a system identification method. The boundary conditions, such as indoor and outdoor temperatures, wind speed and direction, and wind pressures were also recorded *in situ* and saved simultaneously on diskettes, using a computerized data acquisition system. Thirdly, the measured boundary data and leakage characteristics were used as input in the simulation of airflow using COMIS; initial concentrations, injection rate, along with the previous data were used for simulating pollutant transport, assuming tracer gas SF_6 as a pollutant. Lastly, the comparisons between measurement and simulation results of airflow rates and pollutant concentrations were carried out by linear regression analysis. The correlation coefficient between the measured and calculated air change rates was 0.72, and that for pollutant concentration was 0.94.

Key words COMIS; Multizone airflow; Pollutant concentration; System parameter identification; Measurement; Simulation

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Introduction

For evaluating the calculation model and code, COMIS (Conjunction of Multizone Infiltration Specialists), studying the physical phenomena of airflow and pollutant transport in multizone buildings, it is necessary to obtain information concerning the leakage distribution within a building and measurment data of airflow, wind direction and speed, indoor and outdoor temperature, ect. For this purpose, measurements of airflow rate and indoor pollutant transport were conducted using an airtight test house. Experimental validation of COMIS, which is a part of the subtask of Annex 23 projects of IEA-Energy Conservation in Building and Community Systems, is essential in order to certify the confidence and accuracy intervals of this model. Therefore the data measured *in situ* were used for the simulation of multizone airflow and pollutant concentration profiles.

Details of the Measurements

Description of the Test House

The measurements were made using a two-storied airtight test house in Sukagawa city, Fukushima prefecture, Japan. Figures 1 and 2 show the elevations and the floor plans of the house. The first and second floors are at heights of 0.6 and 3.4 meters above ground level, respectively. The width from the east to the west of the house is 10 meters and the depth from the north to the south is 8 meters. The total floor area of the house is 133 m^2 with an air volume of 350 m^3. The height of the building is 7.5 meters. The interior of the test house is considered to have nine zones. The halls on the first and second floors connected by stairs, are regarded as two zones. The numbered zones are shown in Figure 2. Zone No. 10 signifies outdoor.

Measurement System

Wind and Temperature

The eight-meter long pole, located at the southwest of the house, was equipped with a wind direction meter

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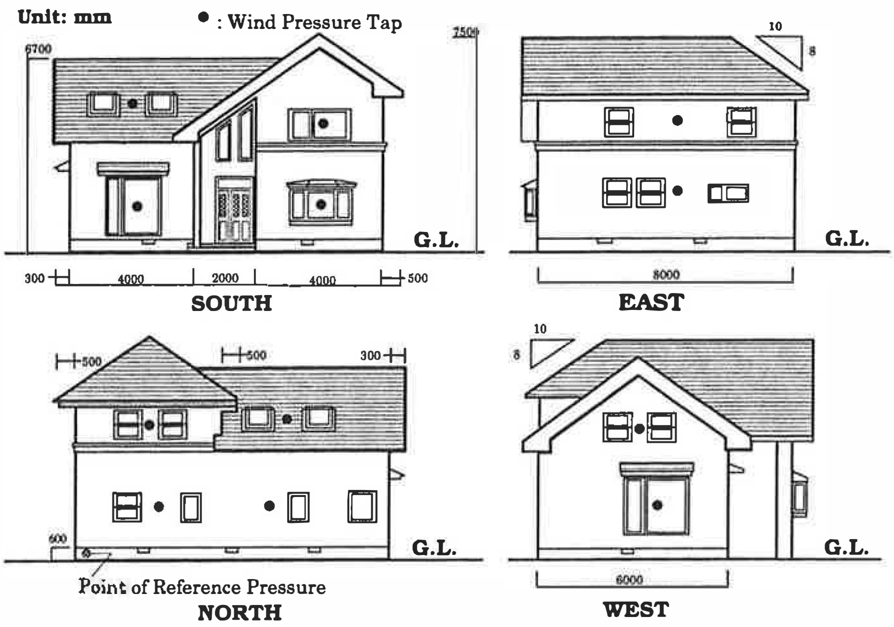


Fig. 1 Elevations of test house

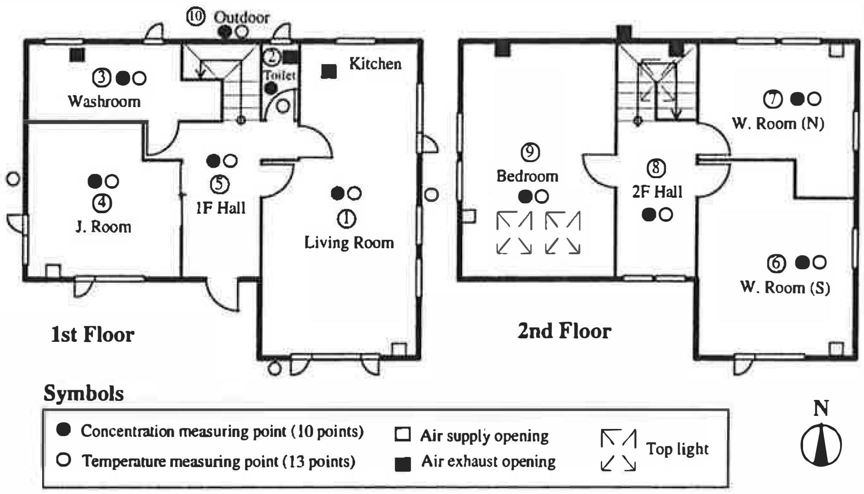


Fig. 2 Plan of test house

at the top and five wind meters at different levels, namely 8, 5, 2.7, 1.6 and 0.5 meters above ground level. The outdoor temperature was measured at the four points around the external walls shown in Figure 2, and indoor temperatures were measured at the center points of the rooms at a height of 1.1 meters above floor level. Tracer gas concentrations were also measured at the same positions. Wind pressure (P) taps on the outside walls were located at the points shown as black circles in Figure 1. The point of reference pressure (P_{ref}) was assumed to be at ground level and was measured in the crawl space under the first floor.

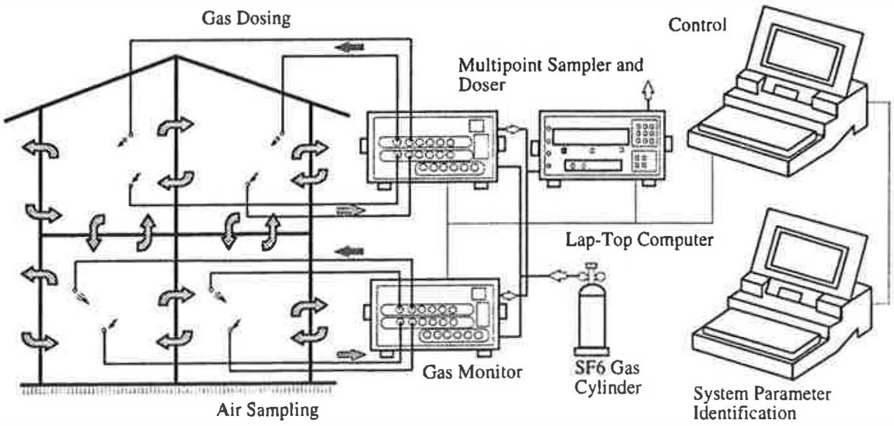
Airflow Rates

Airflow was measured using the system parameter identification method developed by Okuyama (1992). A diagram of the multizone airflow measuremen tem is given in Figure 3. Tracer-gas SF_6 was i into each room to identify airflow rates. The cha concentration in each zone occurred as a respo the injection. The gas injection schedule and ra shown in Figure 4. The indoor gas concentrat each room was sampled every ten minutes. Bas these data, every one-minute data were calculat linear interpolation approximation. In each small fans were used for mixing the indoor a tracer gas.

Indoor Pollutant Transport

To evaluate the multizone pollutant transport indoor pollutant transport was measured. The

Fig. 3 Diagram of multizone airflow measurement system



urement system for air pollutant (i.e. tracer gas) concentration is the same as that for airflow rates. Tracer gas injection is shown in Figure 7. The gas was injected only into the living room for one hour from the beginning of the measurement. The indoor gas concentration in each room was sampled every ten minutes.

Measurement Results

Measured Leakage Area

Effective leakage areas of the windows, walls, doors and other components were measured by the fan pressurization method. The results of the leakage area are shown in Table 1. The equivalent leakage area for an indoor-outdoor pressure difference of 9.8 Pa, αA, of building envelope and windows was 33.5 cm^2 and 67.0 cm^2, respectively. The total of the αA of internal doors is 910 cm^2. The equivalent leakage area per floor area of the building envelope was 0.8 cm^2/m^2. The airflow through leakage was calculated using the following equations:

$$Q_m = C_m(\Delta P)^{1/n} = \frac{\alpha A}{10000} \times \sqrt{2g\rho} \times (\Delta P)^{1/n} \qquad (1)$$

or,

$$Q_V = \frac{C_m}{\rho}(\Delta P)^{1/n} = \frac{\alpha A}{10} \times \sqrt{\frac{2g}{\rho}} \times (\Delta P)^{1/n} \qquad (2)$$

where

Q_m = mass flow rate through the leakage [kg/s]

Q_V = volumetric flow rate through the leakage, [L/s], or [dm^3/s]

C_m = mass airflow coefficient, [kg/s@9.8Pa], or [kg/s@1mmH2O]

ΔP = pressure difference across the leakage site [mmH2O]

n = flow exponent of leakage [−]

αA = equivalent leakage areas [cm^2]

g = acceleration of gravity [m/s^2]

ρ = air density [kg/m^3]

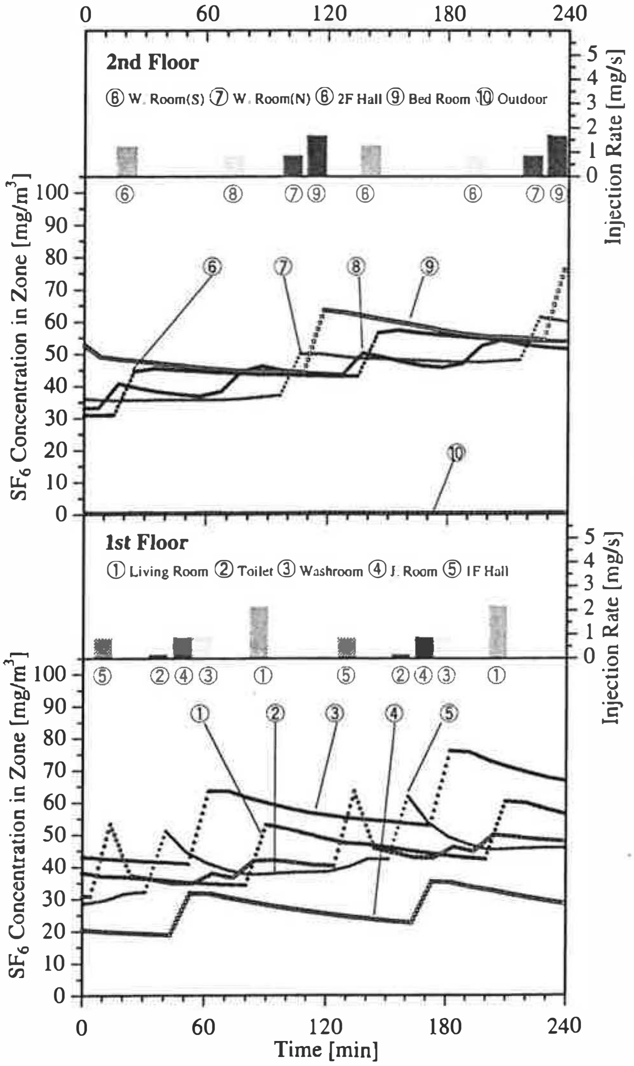


Fig. 4 Tracer gas concentration in measurement of airflow

Measurement Conditions

During the measurements of airflow rates and indoor pollutant transport, the living room was heated by six heaters of equivalent power, and the mechanical ventilation system was not in operation. All windows and doors were closed. The average values of wind speed and direction, as well as outdoor and indoor temperatures during measurements, are shown in Table 2. It was found that the two sets of boundary condition data for the measurements for airflow rate and indoor pollutant transport were quite similar.

Airflow Rates

The concentration profiles of tracer gas in the ten zones are shown in Figure 4. The concentrations in each room increase sharply during injection of the trace After the injection, the concentration decreases s The concentrations in other rooms were affecte to interzonal airflow. The 180-minute (omitting 3(utes each at the start and end) average of airflow between zones was estimated using the systen ameter identification method.

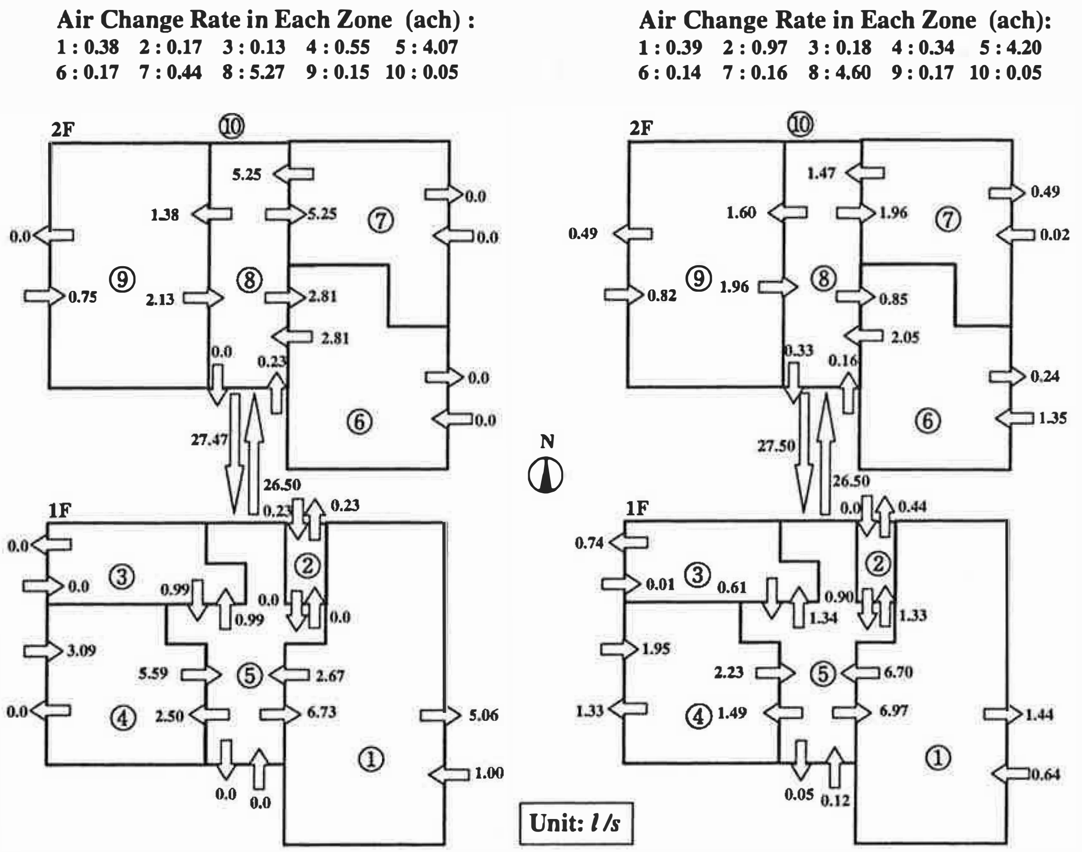
For this measurement, it was assumed that the gas was mixed instantly and uniformly with the i air. The results are shown in Figure 5(a). The a rates between the living room, which was heatec the hall on the first floor were greater than for rooms. The interzonal air exchange rates were g than the infiltration rates between indoors anc doors. For this building, the outdoor air infilt

Table 1 Measured values of equivalent leakage areas

Element/Component	Equivalent Leakage Area αA	Flow Exponent of Leakage n
Building *envelope*	33.50	1.25
Living Room South *Window*	3.44	1.27
Living Room East *Window*	0.00	1.25
Windows of Toilet, Washroom	17.49	1.50
Windows of J. Room	19.66	1.53
South *Window* of W. Room(S)	6.06	1.50
Windows of W. Room(S), (N) and Bedroom	9.28	1.42
Top Light *Windows*(Ventilating Opening CLOSED)	11.29	1.56
Vestibule *Door*	0.00	1.50
Air Conditioner Outlet	0.00	1.20
Air Supply Opening(CLOSED)	0.00	1.21
Air Supply Opening(OPEN)	51.26	1.62
Air Exhaust Opening(OPEN)	20.86	1.55
Kitchen *Door*	103.47	1.78
Living Room *Door*	106.51	1.69
Toilet *Door*	113.82	1.60
Washroom *Door*	120.31	1.76
Door of J. Room	106.18	1.80
Door of W. Room(S)	119.24	1.81
Door of W. Room(N)	135.23	1.77
Bedroom *Door*	106.18	1.80

Table 2 Average values of wind and temperature in two measurements

Measurement		Airflow Rate	Indoor Pollutant Transport
Wind speed	m/s	2.32	1.42
Wind direction		East	East
Wind angle direction measured clockwise from geographic north	degree	92.77°	84.51°
Temperatures on 1st floor [°C]	Zone 1	33.89	33.35
	Zone 2	19.57	18.26
	Zone 3	14.63	12.54
	Zone 4	11.81	15.64
	Zone 5	16.04	15.62
Temperatures on 2nd floor [°C]	Zone 6	13.64	15.94
	Zone 7	13.03	13.21
	Zone 8	16.16	15.71
	Zone 9	11.24	13.21
Outdoor temperature	Zone 10	−6.86	−4.30



5(a) Measurement 5(b) Simulation

Fig. 5 Measurement and simulation results of airflow

rate was only 0.05 [ach], which in this case is very small.

Air Pollutant Concentration Profile

To measure the indoor pollutant transport, the tracer gas was injected into the living room for 1 hour at the start. As shown in Figure 7(a), the concentration in the living room reached 200 mg/m^3 level. After the injection stopped, the concentration in the living room decreased sharply. The concentrations in other zones increased slowly, and after reaching their respective peaks, they decreased gradually with time. In the toilet, the concentration did not change smoothly. The reason for this may be that the volume of the toilet room was so small that it could not easily be influenced by outdoor wind flow, a sudden change of which can be seen in Figure 6.

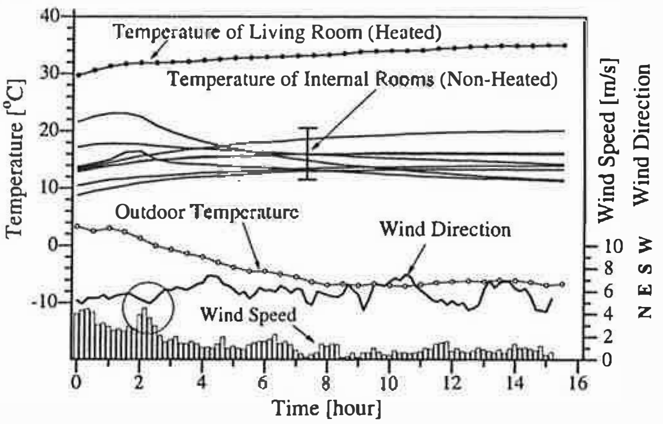
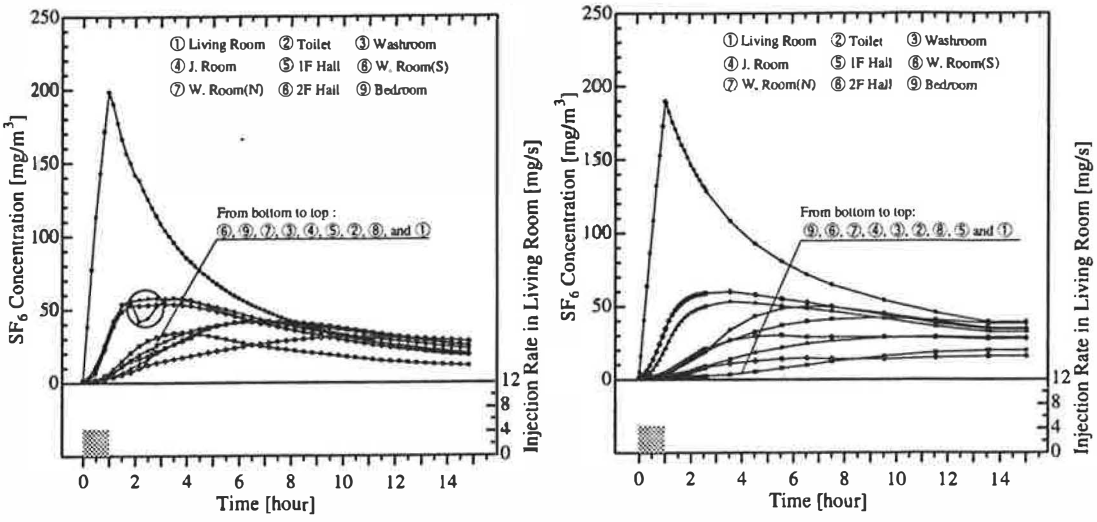


Fig. 6 Variation of wind and temperature in measurement of indoor pollutant transport

Numerical Simulation

COMIS Model

Computer simulation of airflow and pollutant transport is one of the primary research tools with which ventilation performance can be predicted. During the past few decades, a number of airflow models have been developed. The COMIS infiltration model is a simulation model developed by a multi-national team



7(a) Measurement

7(b) Simulation

Fig. 7 Measurement and simulation results of indoor pollutant transport

(Feustel and Raynor-Hossen, 1990). The COMIS not only takes crack flow into account, but also covers airflow through large openings, single-sided ventilation, cross ventilation and HVAC- systems.

Simulation Parameters

In the measurement for airflow, the driving forces are provided by the wind pressure and the buoyancy. The reliable prediction of naturally driven airflow depends mainly on the quality of outdoor climate data and indoor temperatures (i.e. boundary condition data).

The wind pressure input data for simulation is measured *in situ*. The dimensionless wind pressure coefficient is the ratio of the difference between wind pressure at a given point on the test house envelope and the pressure at outdoor ground level, to the dynamic pressure of the wind at a height of 8 meters above ground level. The wind pressure coefficient in a certain wind direction is determined by the following equation:

$$Cp(h)=\frac{P-P_{ref}}{0.5\rho\left(V_8\left(\frac{h}{8}\right)^{\alpha}\right)^2} \tag{3}$$

where

$C_p(h)$ =pressure coefficient at height h reference to outdoor ground level static pressure [-]

P =pressure at building envelope [Pa]

P_{ref} =outdoor ground level static pressure [Pa]

ρ =density of outdoor air [kg/m^3]

V_8 =wind velocity at a height of 8 meters [m/

h =height of wind pressure tap [m]

α =wind velocity profile exponent [-]

For simulation of airflow, input data of wind and perature are 180-minute average values as show Table 2. The input data for leakage of the test h are the same as shown in Table 1. For simulati indoor pollutant transport, the characteristics o wind direction, wind speed and temperatures are trated in Figure 6. Input data of temperatures wind speed are averaged for 10 min and 30 mi spectively.

As a database is lacking for large openings, th flow measured between the first and second floor are taken as constant input for two simulations, boundary condition data in two sets of experimen quite similar.

In addition, although the tracer gas SF_6 is non- non-reacting with air and is different from air lutants, it was chosen as an agent to simulate the b ior of a pollutant of similar density, but the usual and/or deposition characteristics of a pollutant a considered. Its concentration is uniform in a zone transported from zone to zone by the flow of air.

Results of Simulation and its Evaluation

Airflow Rates

The calculated airflow rates using COMIS are trated by Figure 5(b). It can be seen that the agre

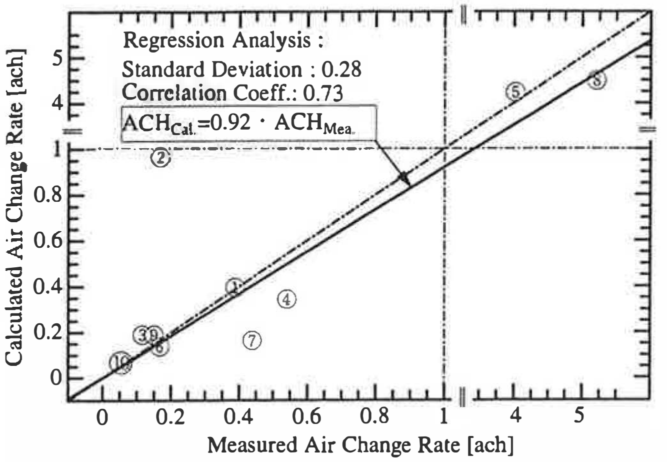


Fig. 8 Comparison between measured and calculated air change rates

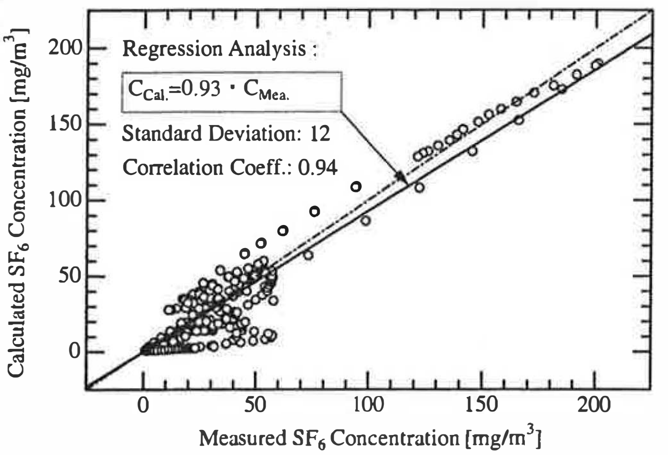


Fig. 9 Comparison between measured and calculated gas concentrations in indoor pollutant transport

between simulation and measurement is quite close for some zones. For other zones, the agreement is somewhat poorer. Figure 8 presents a comparison of the air change rates measured with calculated results using the COMIS model. For the toilet (zone 2), with a small air volume, there was a difference between the measurement and calculation results; the same phenomenon can be observed in the case of zone 7. The regression coefficient between the two sets of air change rates was 0.92. The correlation coefficient between measurement and calculation was 0.72. It is considered satisfactory because this degree of accuracy is based on the precision of the average input data and the measurement technique.

Indoor Pollutant Transport

The simulation of an indoor concentration profile was made using the boundary condition and leakage data, tracer gas injection rate and the concentrations measured at the start of gas injection as initial concentrations. Figure 7(b) shows the variation of indoor gas concentrations against time, using the COMIS model. Figure 9 gives a comparison between measured and calculated indoor pollutant concentrations. The results indicate that the measured and calculated gas concentrations are not exactly the same but the deviation is only slight. The regression coefficient and correlation coefficient between calculated and measured concentrations was 0.93 and 0.94 by linear regression analysis. Good agreement between measurement and simulation was achieved for some zones, especially for pollutant source in one zone (living room), but the agreement is less good for the other zones. This may be attributed to the input data for simulation being approximate averages, especially wind pressure coefficients, distribution of leakage area, etc.

Conclusions

For measurement of the multizone airflow and indoor pollutant transport, tracer gas SF_6 was injected into the airtight test house which was assumed to have ten zones. By means of the COMIS model, the multizone airflows and pollutant transport pattern were simulated using the data measured *in situ*. For airflow, the regression coefficient and correlation coefficient between measured and simulated air change rates was 0.92 and 0.72. It is considered satisfactory because this degree of accuracy was based on the precision of the input data and on the measurement technique. For air pollutant concentrations, the regression coefficient and correlation coefficient was 0.93 and 0.94 by linear regression analysis. From the results of case studies, the conclusion can be drawn that the COMIS model is useful for the simulation of multizone airflow and pollutant transport under the natural conditions of airflow through leakage. Experimental evaluation should be continued to verify the accuracy of this model, taking the measurement error into account and also considering other ventilation systems.

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Reference

Okuyama, H. (1992) "Recent progress on the multi-chamber airflow measurement system". In: *Proceedings of Room Air Convection and Ventilation Effectiveness*, Atlanta, Am Society of Heating, Refrigerating and Air-Condit Engineers Inc., pp. 351–356.