ESTIMATION OF AIR EXCHANGE RATES IN KUWAITI RESIDENTIAL BUILDINGS

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ABSTRACT

Air exchange rates of ten residential buildings were measured according to ASTM-E741-83 using SF_6 as a decaying tracer. Air exchange rates were also predicted based on the characteristics of the HVAC system, openings (such as windows), leakage areas, pertaining average wind speed, average indoor/outdoor temperature difference and wind and stack coefficients. It was found that measured air exchange rates were higher by 34% than those predicted if the literature coefficients were used. Therefore, a modified procedure has been proposed to accurately predict the air exchange rate of tightly controlled residential buildings of this region.

INTRODUCTION

The air exchange rate (ACH) is a measurement of how much fresh outdoor air replaces indoor air in a given time period. It is measured in units of air changes per hour and equals the ratio of the hourly indoor air volume replaced by the outdoor air to the total indoor volume. An accurate estimate of ACH is an essential part of any indoor air quality (IAQ) modeling and it can be estimated given the location and leakage functions for every opening in the building envelope, the wind and stack coefficients over the building envelope, and any mechanical ventilation airflow rates. Although these inputs are normally available, it is not certain whether these techniques can be used for buildings that may have different physical natures- such as those found in Kuwait and the Arabian Peninsula. Buildings in this region are relatively new and are designed to cope with harsh conditions, such as extreme temperature and dust storms. Here a modified predictive technique is presented and compared with the traditional procedures.

METHODS

A tracer gas (SF_6) method was used to determine ACH in 10 houses with different volumes, configurations and occupant activities. Five of the houses were investigated in summer and the rest were studied in winter. Plot of log (concentration) versus time gave good straight lines and from the slopes ACH values were obtained according to ASTM E741-83 [1]. The results of measured ACH are given in the third column of the Table and pertinent details can be found elsewhere [2].

Total ACH can also be calculated from its components, which are natural ventilation Q_N, forced ventilation Q_F, and the infiltration Q_I. Eqn. (1) gives Q_N (m^3/hr) which is air forced through openings by wind [3]:

$$Q_N = C_V A_R V \tag{1}$$

Here C_V is effectiveness of opening and is assumed to be 0.5 to 0.6 for perpendicular wind, and 0.25 to 0.35 for diagonal winds. V (m/s) is wind speed and A_R (m^2) is the free area of

House No.	Volume (m^3)	Merasured ACH	Q_F	Q_I	Q_N	Total (calc.)	ACH (from Eq.(3))
1	1400	0.445	0.485	-	**	0.485	0.340
2	1500	0.558	0.566	-	**	0.566	0.396
3	600	0.250	0.350	-	**	0.320	0.245
4	626	0.350	0.320	-	**	0.320	0.224
5	900	1.725	*	0.097	2.362	2.459	1.721
6	1600	0.600	*	0.284	0.886	1.170	0.819
7	1100	0.350	0.463	-	**	0.463	0.324
8	1400	1.350	*	0.275	1.856	2.131	1.492
9	1500	1.147	*	0.172	1.417	1.319	0.923
10	750	0.601	0.680	-	**	0.680	0.476

*Air conditioner not working. ** No opening while air conditioner was working.

opening. For the HVAC system, duct measurements involving usual aneometry techniques were used to determine the value of Q_F from both duct make-up and recirculated air. The airflow due to infiltration can be calculated by the following equation:

$$Q_I = L\,(A\,\Delta T + BV^2)^{0.5} \times 10^{-3} \qquad (2)$$

Here L (cm^2) is the effective leakage area, A is the stack coefficient, ΔT (C) is average indoor-outdoor temperature difference and B is the wind coefficient. The total leakage area can be calculated from the contribution of the type of leakage (e.g., doorframe) using the values given in reference [3]. Table gives also the components Q_F, Q_I, and Q_N and the total, which is the sum of them. A plot of measured air exchange rate versus predicted ones gave a linear relationship. As a result the following modified air exchange model was proposed:

$$ACH = (0.7/\text{Indoor Volume})\,\{\, C_V A_R V + Q_F + L(A\,\Delta T + BV^2)^{0.5} \times 10^{-3} \} \qquad (3)$$

CONCLUSION

The results clearly show that the predictions based on the coefficients of [3] consistently overestimates by about 30 % of the measured ACH of the Kuwaiti residential buildings. On the other hand, Eqn. (3) is recommended for buildings such as those in Kuwait, which may differ in configuration and openings as necessitated by local weather conditions.

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