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Paper 2

Natural Airflows between Roof, Subfloor, and Living Spaces

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1 Synopsis

This paper is concerned with natural air flows between major construction cavities in New Zealand houses. A two tracer technique was developed to measure infiltration rates in the subfloor (crawl space), the living space and roof space, together with air flow rates connecting these zones. Five experimental houses were chosen to represent expected extremes in air flow resistance between subfloor and roof space. Two were clad in brick veneer over timber frame walls, allowing possible air leakage paths through the wall cavities, and the other three were clad in weatherboards with little likelihood of air leakage paths through the wall cavities. Subfloor to roof space air flows of around 30% of the roof space ventilation rate were measured in the brick clad houses while in the weather board examples it was only 7%. Air flows connecting subfloor and roof space with living space were generally in the range 1-30 m^3/h with a general tendency for upward flows to exceed downward flows. Interzone flows involving the living space were not obviously dependent on the type of building or on wind speed and zone temperature differences.

2 Airborne Moisture

Little attention has been given to natural air flows between construction cavities under the floor, within walls, between ceiling and roof (attic), and the living space of houses in New Zealand. There is an incentive to know more about these air flows because they can carry moisture from wet areas into parts of the structure where prolonged high moisture contents can eventually lead to decay in framing timber.

Some attention has been given to air flows between construction cavities in other countries. In the UK, Edwards and Irwin[1] measured air flows between living and roof spaces while investigating the effectiveness of ridge ventilators. In the Netherlands, Oldengarm[2] investigated ventilation in crawl spaces and the possibility of air leaks into wall cavities. More recently, the problem of airborne radon carried into houses from the subfloor has been widely reported and has kindled an interest in air flows from cavities in contact with the ground.

An unusually high incidence of roof space condensation problems has occurred in masonry veneer houses in the south of New Zealand. This has been linked to air flows carrying subfloor moisture through inadequately sealed wall cavities into the roof space. Covering the ground with a vapour barrier was found by Trethowen and Middlemass[3] to more reliably cure the problem than sealing the wall cavities; thus indicating that other flow paths may be present.

Evaporation rates from the ground in the subfloor (crawl space) have been measured under New Zealand houses by Abbott[4] and found to be little different from that of a free water surface. Even when the subfloor soil is apparently dry, evaporation rates in the range 150 to 250 g/m^2day were normal. This translates to about 20 kg/day of moisture which would have to be removed by subfloor ventilation from under a 100 m^2 house. Trethowen[5] has already indicated that at least 10 air changes/h of subfloor ventilation would be necessary to reduce the condensation hazard of air leaks into the roof space in masonry veneer houses without ground cover.

3 Experimental Houses

Five experimental houses were chosen to represent expected extremes in air flow resistance connecting subfloor and roof spaces. They were all fully furnished but unoccupied houses, rented while their owners were on holiday. Two were brick veneer houses with wall cavities potentially open at roof and floor level. The other three were weatherboard houses, with little likelihood of air leakage paths up the stud cavities.

Typical construction details for masonry veneer and weatherboard houses are illustrated in Figure 1. In New Zealand, the subfloor is the only zone which must have fixed vents to satisfy building codes. Here, the code of practice for light timber frame buildings[6] calls for a ventilation area of $0.0035m^2/m^2$ of floor area to be placed in the subfloor perimeter wall. There are no mandatory airtightness levels for living spaces, and roof spaces need not have the special ridge or soffit ventilators required in some countries. Two potential air leakage paths from subfloor to roof space are illustrated in Figure 1. One is a leakage path between masonry veneer and studs, which may be difficult to seal, even though the building code[6] requires it to be blocked. Another likely flow path passes through plumbing perforations in the floor and ceiling in the hot water cylinder cupboard.

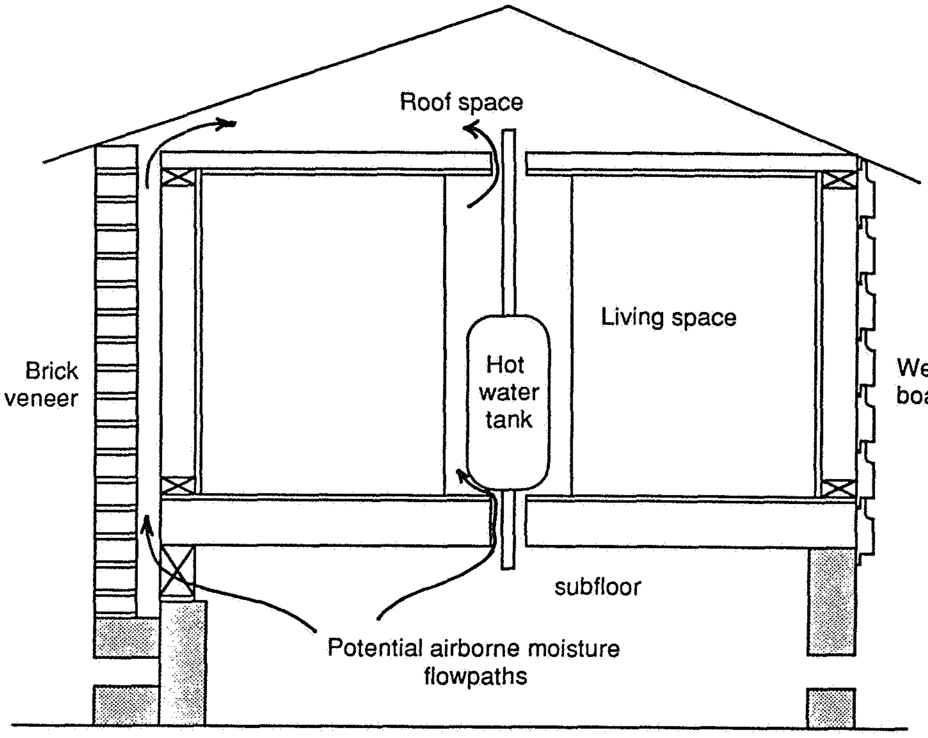

Figure 1: House construction details and potential air flow paths

Airtightness characteristics of roof, living and subfloor zones were measured by fan depressurization with equipment described by Bassett[7]. A length of 400mm diameter flexible duct was used to connect the fan housing to access hatches to the subfloor and roof space. Table 1 gives basic construction and airtightness information for the houses labelled A to E. Airtightness characteristics are given in Table 1 as leakage areas at 4Pa calculated from fitted exponents and coefficients defined as follows:

$$Q = Coef \Delta P^{Exp}$$

and

$$L = Coef \sqrt{\frac{\rho}{2}} \Delta P^{Exp-0.5}$$

where

Q is the fan induced air flow rate m^3/s
$Coef$ is the flow coefficient
ΔP is the indoor-outdoor pressure difference in Pa
Exp is a flow exponent
L is the leakage area at pressure difference $\Delta P = 4Pa$ in m^2
ρ is the density of air at reference temperature and pressure kg/m^3

CHARACTERISTIC	HOUSE				
	A	B	C	D	E
Wall Type	Masonry	Timber	Timber	Timber	Masonry
Roof Type	Tile	Metal	Metal	Metal	Tile
Floor Material	Wood chipboard in all Houses				
LIVING SPACE					
Volume m^3	213	210	234	242	229
Floor Area m^2	84	88	98	97	95
Leakage Area m^2	0.072	0.036	0.083	0.021	0.051
ROOF SPACE					
Volume m^3	75	71	128	86	69
Leakage Area m^2	0.33	0.28	0.096	0.088	0.33
SUBFLOOR					
Volume m^3	83	65	56	73	52
Leakage area m^2	0.31	0.29	0.12	0.15	0.29

Table 1: Physical and airtightness details of experimental houses

The air tightness of the five experimental houses is shown in Figure 2 compared with about 90 houses chosen at random from houses recently constructed in New Zealand[8]. The airtightness of the experimental houses was between 6.5 to 16.1 air changes/h at 50Pa.

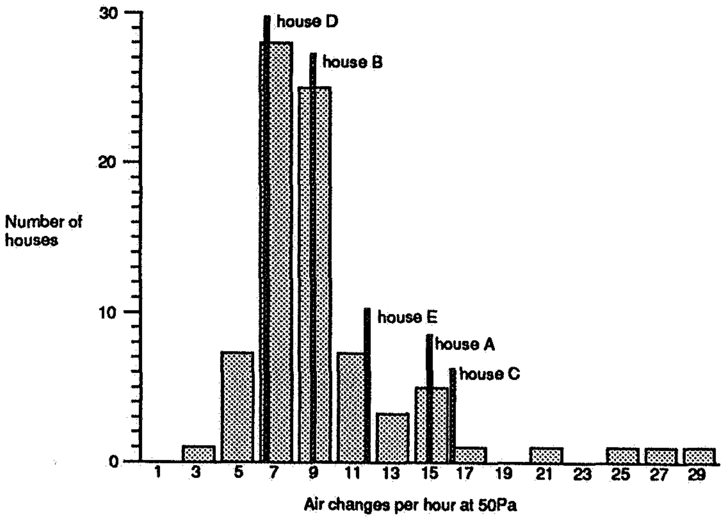

Figure 2: Histogram of the airtightness of houses built between 1962 and 1982

An attempt was made to measure interzone air flow resistances with an extension to the airtightness method. This can best be described as an attempt to perturb the air leakage characteristics of a zone by altering the leakage characteristics of an adjacent zone. If, for example, the subfloor airtightness was being measured, this involved making a change to the airtightness of the roof space and looking for a change in the apparent airtightness characteristics of the subfloor. If removing the manhole cover in the ceiling influenced the subfloor airtightness, then the linking air flow resistance could, in principle, be determined. Airtightness tests at each house were carried out systematically to look for measurable linking air flow resistances, but in all but one case (the leakage path between subfloor and roof space in house A) no significant resistances could be resolved. This established that the linking air flow resistances between zones were in general much higher than the resistance to outside, and that tracer gas techniques would be required for their investigation.

4 A Multi Tracer Technique

A system based around a micro computer controlled gas chromatograph has been developed for measuring infiltration rates in two zones at the same time as flow rates between the zones. A comprehensive description is given in reference[9] and a brief outline is given below;

4.1 Mode of Operation

The main components of the fully automated system are shown schematically in Figure 3.

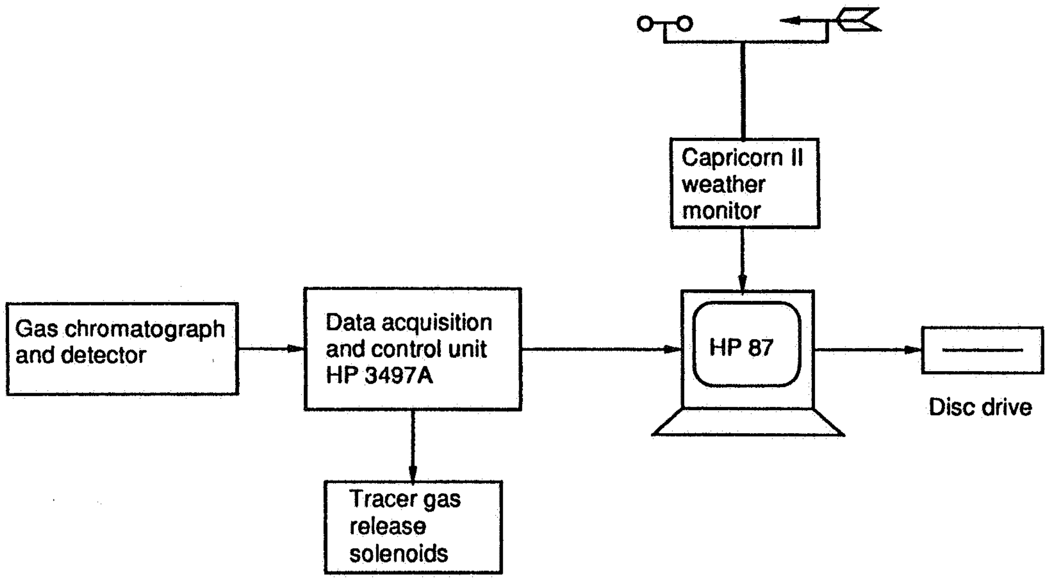

Figure 3: Schematic of automated gas chromatograph

When working in constant composition mode, the GC samples air from a zone, measures both tracer concentrations, tops up the chosen zone tracer gas to target concentration, and then moves on to the next zone. It repeats the process every three minutes, stepping sequentially between zones and writing tracer concentrations and injection volumes to disk. Meteorological data and zone temperatures were also recorded to disk. Wind speed and direction were measured 10m above ground on the building site from the top of a portable mast. The sample handling network is shown schematically in Figure 4. Its main role is to maintain an up-to-date sample in the loop. Further important aspects of design are the location of as many pumps and solenoid valves as possible downstream of the loop to avoid contamination reaching the electron capture detector. An additional, and novel, solenoid valve S1 isolates the loop from the pumping pressure oscillations prior to sampling, thus ensuring the loop always captures the same sample size. Hardware for topping up tracer concentration in a zone is also illustrated in Figure 4. It releases discrete shots of tracer gas from a small pressure vessel using computer controlled solenoid valves.

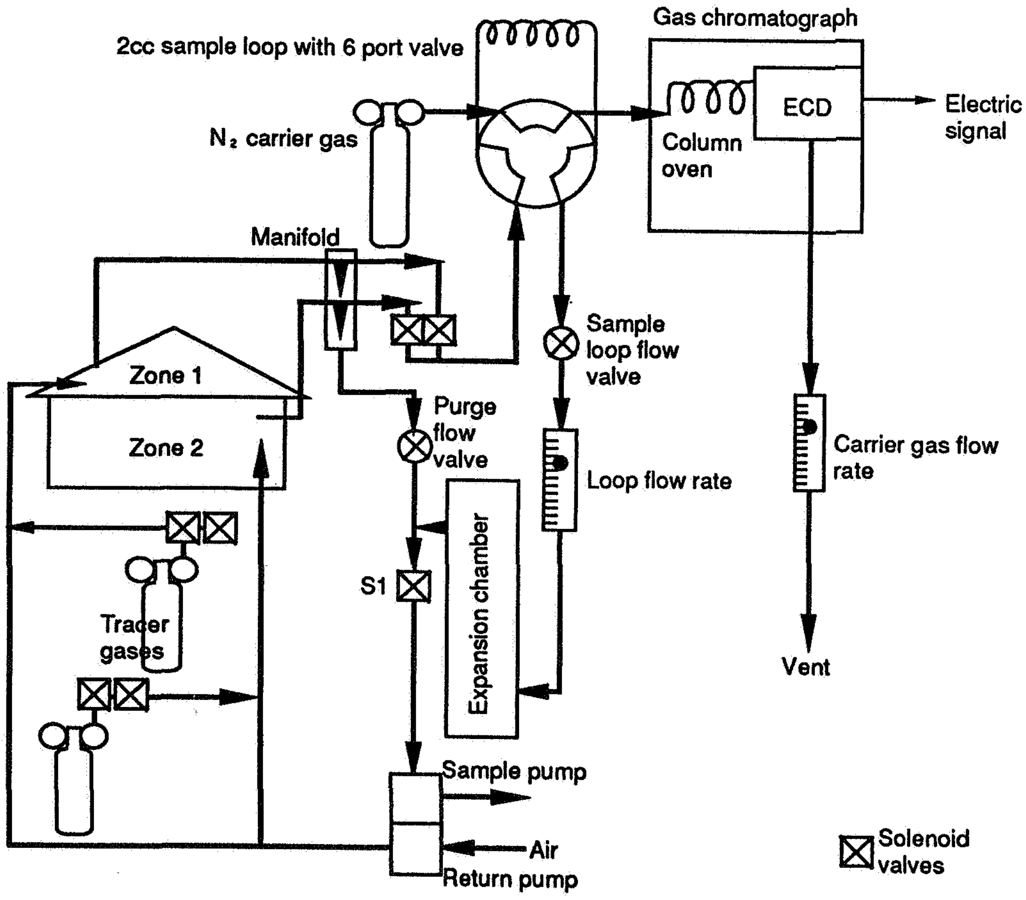

Figure 4: Tracer gas sampling and top up network

4.2 Tracer gases

Freon-12 (CCl_2F_2) and SF_6 concentrations were detected with an electron capture detector after separation in a 2 m long molecular sieve column at 100^0C. Retention times were 75s, 100s and 120s for SF_6, CCl_2F_2, and O_2 respectively. Peak areas were determined by integration and working concentration ranges were 1-60 ppb for SF_6 and 200-1500 ppb for CCl_2F_2. Each tracer was sent to the appropriate zone and discharged at two or three places by a network of small bore tubes connected to the return air pump. Further mixing was achieved within each zone with portable fans. These were arranged carefully to avoid adding to infiltration driving pressures. On several occasions, infiltration rates were shown to be insensitive to changes in mixing arrangements.

5 Analysis

Transforming measured tracer concentrations and injection rates into air flows was carried out with a method similar to that outlined by Perera[10]. The development is outlined below with the assumptions of uniform mixing within each zone and a unique tracer injected into each zone.

Nomenclature

Q_{ij} is the air flow rate from zone i to zone j in m^3/h
Q_{i0} is the air flow from zone i to outside in m^3/h
V_i is the volume of zone i in m^3
C_{ij} is the concentration of tracer i in zone j in units *ppb*
G_i is the release rate of tracer i in zone i in units *ppb/h*
$\dot{C}_{ii}$is the rate of change of concentration of tracer i
in the ith zone in units *ppb/h*

If the outflow of air from zone i is S_i then:

$$S_i = Q_{i0} + \sum_{j=1}^{N} Q_{ij}(1 - \delta_{ij})$$

Where δ_{ij} is the Kronecker delta function
$\delta_{ij} = 1$ for $i = j$
$= 0$ for $i \neq j$

The mass balance of the ith tracer in the ith zone requires the following:

$$-C_{ii}S_i + C_{i0}Q_{0i} + \sum_{j=1}^{N} C_{ij}Q_{ji}\left(1-\delta_{ij}\right) = V_i\left(\dot{C}_{ii} - G_i\right)$$

If tracer gas concentrations outside are very small, then:

$$-C_{ii}S_i + \sum_{j=1}^{N} C_{ij}Q_{ji}\left(1-\delta_{ij}\right) = V_i\left(\dot{C}_{ii} - G_i\right)$$

There are a further $(N-1)$ mass balance equations for the other tracer gases in zone i that take the form:

$$-C_{ji}S_i + \sum_{i=1}^{N} C_{ji}Q_{ji}\left(1-\delta_{ij}\right) = 0$$

With the number of zones and tracers both equal to N there will now be N^2 equations. There are, however, $(N^2 - N)$ linking air flows and $2N$ flows to and from outside. Solving for all the air flows using measured C_{ij} , $\dot{C}_i$, and G_i requires a further N equations which follow by requiring the bulk flow of air into each zone to equal the outward flows.

$$-S_i = Q_{0i} + \sum_{j=1}^{N} Q_{ji}\left(1-\delta_{ij}\right)$$

Inter zone air flows were measured in this study using two tracers released into two zones. In this cases the tracer mass balance equations for zone 1 take the form:

$$-C_{11}S_1 + C_{12}Q_{21} = V_1\left(\dot{C}_{11} - G_1\right)$$
$$-C_{21}S_1 + C_{22}Q_{21} = 0$$

Or in matrix form

$$\begin{bmatrix} -C_{11} & C_{12} \\ -C_{21} & C_{22} \end{bmatrix} \begin{bmatrix} S_1 \\ Q_{21} \end{bmatrix} = \begin{bmatrix} V_1\left(\dot{C}_{11} - G_1\right) \\ 0 \end{bmatrix}$$

From S_1 and Q_{21}, Q_{01} can be calculated and the process repeated for zone 2.

A computer program was developed to calculate air flows for the general N zone N tracer problem using the method of Gaussian elimination for solving the linear set of mass balance equations. Because all the concentration measurements were not made at the same time, a simultaneous set of C_{ij} and $\dot{C}_{ii}$ had to be calculated. First, the discrete tracer concentrations were transformed into a smoothed single valued function using a third degree polynomial interpolating procedure. Then the tracer release term was similarly smoothed and interpolated after being expressed in units ppb/h using the following equation:

$$G_i = \frac{N_s V_s C_i 10^3}{V_i \Delta T}$$

Where G_i has units of ppb/h

N_s is the number of shots of tracer released in time interval ΔT

V_s is the volume of tracer released in each shot (cc)

C_i is the tracer gas concentration $(mole fraction)$

V_i is the volume of zone i m^3

ΔT is the time interval between tracer gas top up in h

6 Zone Infiltration Rates

Infiltration rates were measured in the subfloor, living and roof zones over periods of 4-6 days. The sensitivity of these infiltration rates to wind speed measured on site, and the zone to outside temperature difference has been examined. As with living space infiltration rates[11] wind pressures were the dominant driving force of infiltration in the subfloor and roof zones. As an example, Figure 5 gives infiltration rates, averaged over two hours, for the roof space of house C against wind speeds measured 10m above ground.

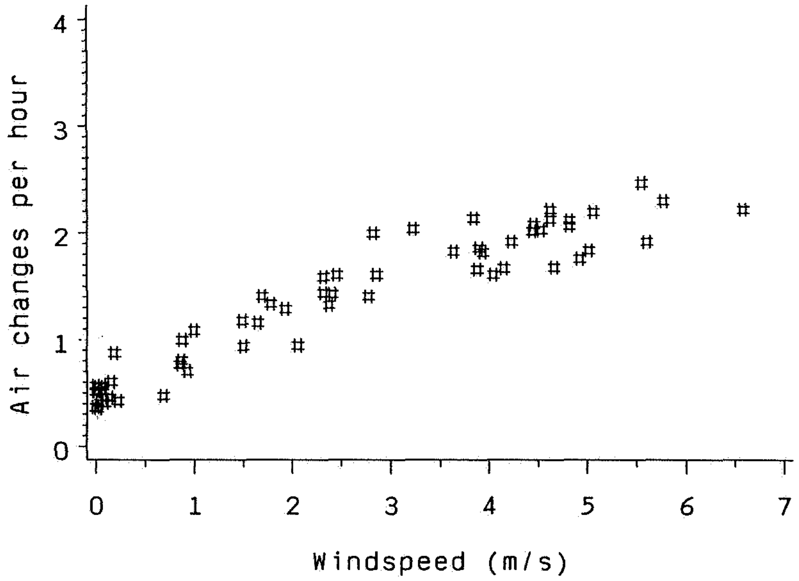

Figure 5: Measured infiltration in roof space of house C

Infiltration rates in subfloors and roof spaces can be expressed in air changes-/hour but it would be unrealistic to expect the mixing process that took place during measurement to be present normally. In fact, some form of plug flow between the windward and lee sides of the building would be expected in the subfloor. In roof spaces the pattern of flow is more uncertain because the location of the main leakage openings in relation to pressure coefficients on the roof are unknown.

Infiltration rates in the three zones in each of the experimental houses are summarised in Figure 6. Here the infiltration rate at 4 m/s wind speed is plotted against the equivalent leakage area of the zone at 4Pa. This wind speed is representative of the mean wind speed in sheltered parts of suburban Wellington measured 10 m above ground. Although quite different wind pressures will have driven air leakage in the three zone types, a smooth trend to higher air leakage rates in more leaky enclosures irrespective of type is clear.

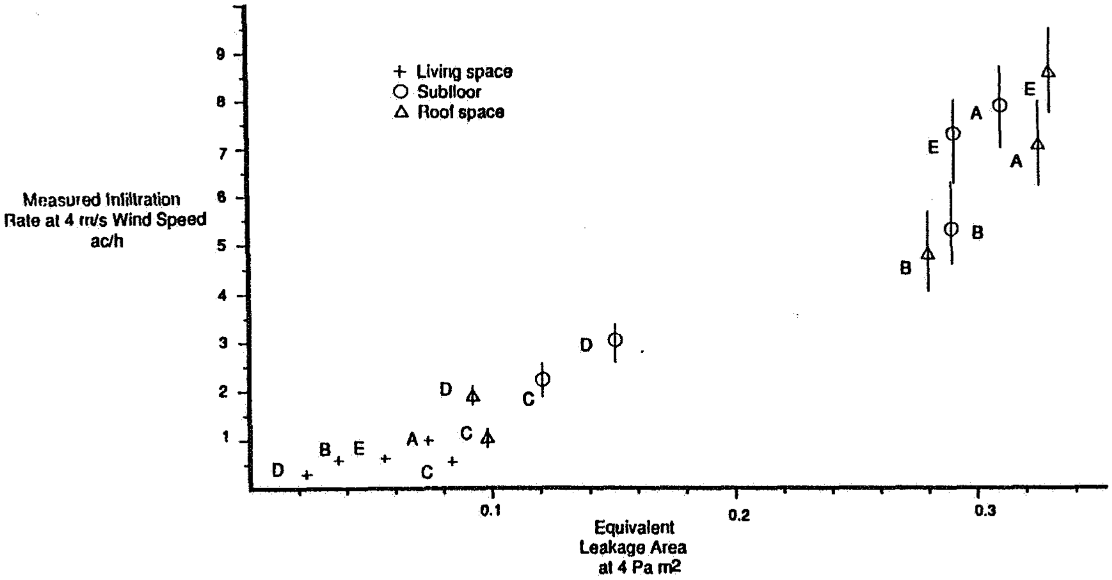

Figure 6: Zone infiltration rates at 4m/s wind vs Leakage area at 4Pa

Infiltration rates in living spaces have been measured in a number of New Zealand houses[12] and when wind speeds are recorded on site, the infiltration rates agree with those calculated using the LBL model[12]. Data for the five houses in this survey are no exception as Figure 7 will confirm.

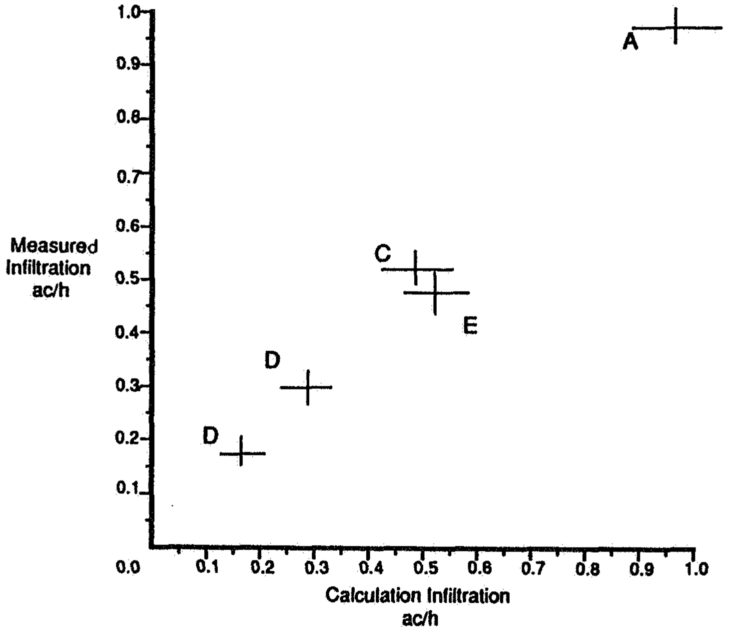

Figure 7: Measured vs Calculated Infiltration for Living Spaces

Figure 6 shows that infiltration rates in subfloors are quite variable. With standard provisions for subfloor ventilation called for by the building code[6] this may be unexpected. All of the experimental houses had about the same number and type of ventilators in the subfloor perimeter wall, contributing 0.05 to 0.1 m^2 to the subfloor leakage area at 4 Pa. In all cases a greater source of air leakage lay elswhere. The subfloor of house A was clearly vented to the roof space, but in houses B to E a further 0.07 to 0.2 m^2 of leakage area lay elsewhere; much of it, from observation, at the joint between wall cladding and rough cast perimeter wall.

Metal clad roofs were more airtight, and infiltration rates were lower, than for the two concrete tile roofs, even though all of the roofs had building paper under the roof cladding. In a 4 m/s wind the infiltration rate in the metal clad roof spaces fell in the range 100 to 300 m^3/h and in concrete tiled roof spaces it was around 500 m^3/h. Clarification of the reasons for these differences requires more knowledge about the location of leakage openings in roofs.

7 Interzone air flows

Air flow rates between the subfloor, living and roof spaces have been measured for each of the 5 experimental houses. The data take the form of flow rates averaged over approximately two-hour periods spanning several days. In contrast with zone infiltration rates, the interzone flows were less obviously influenced by wind and any of the temperature differences measured. Air flows between roof and subfloor of house A are plotted against wind speed in Figure 8 and against temperature difference between zones in Figure 9. They are representative of the wind speed dependence of the other interzone air flows in this and the other houses.

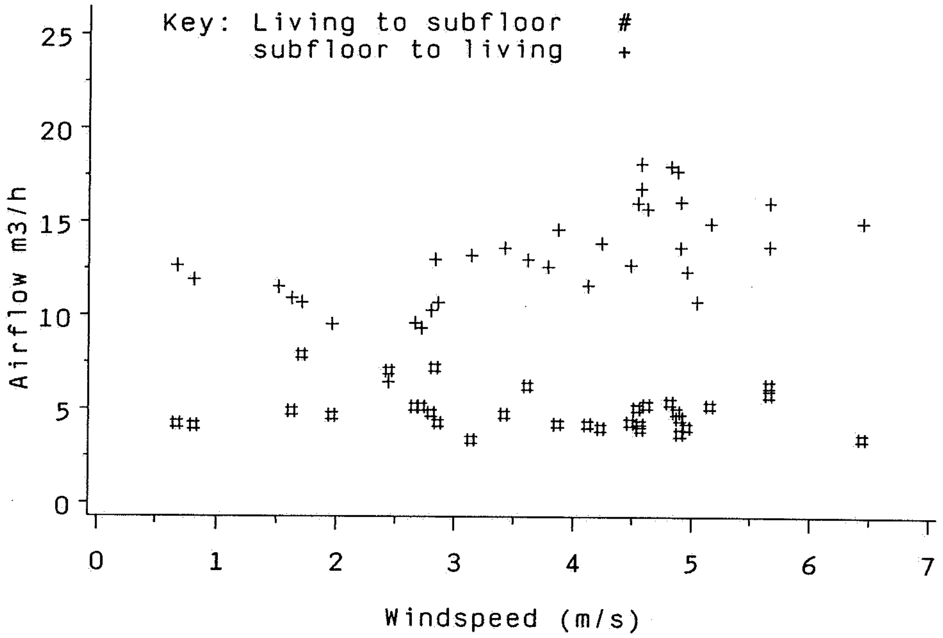

Figure 8: Windspeed dependence of interzone air flow

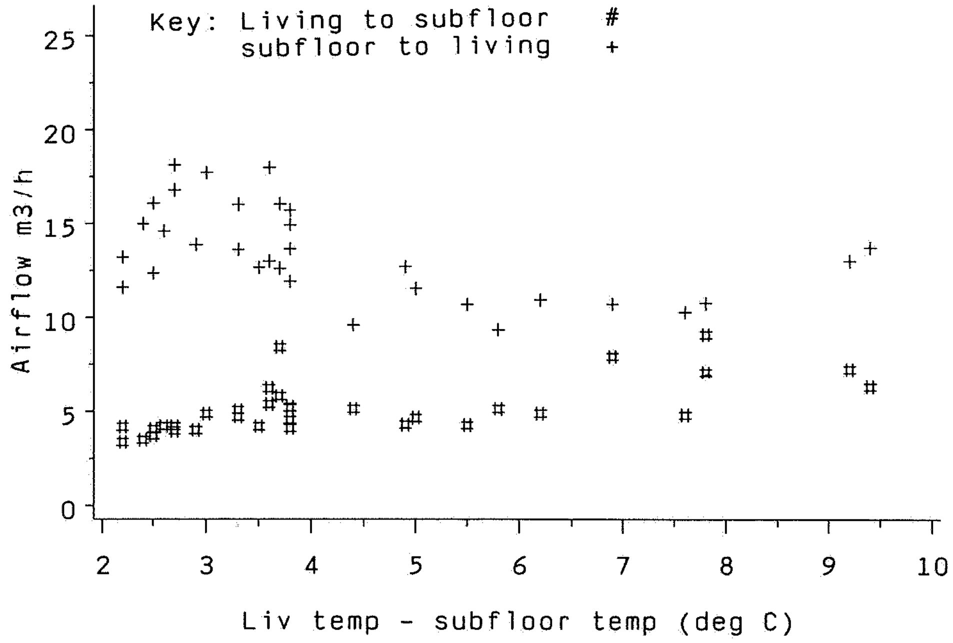

Figure 9: Dependence of interzone air flow on temperature difference between zones

7.1 Paths for Subfloor to Roof Space Air Flows

Air flows between subfloor and roof space can potentially be driven by a variety of pressure differences in different parts of the building. Because wind pressure coefficients on pitched roof surfaces are mostly negative, it might be anticipated that air will travel up from living and subfloor areas. In addition, there are possible stack flow processes which could, for example, be driven in wall cavities warmed by the sun, or in hot water cylinder cupboards which have leaks around plumbing where it passes through the floor and ceiling. The living space may also be a significant path for subfloor to roof space air flows. In all these situations, the most likely flow direction is upward.

No attempt was made to measure directly the components of subfloor to roof space air flows through the living space using tracer gases. However, ventilating the living space was found to have little effect on subfloor to roof space tracer gas flows in several houses. In addition, a flow rate passing through the living space consistent with interzone air flows involving the living space has been calculated as follows. With the subfloor, living space and roof space defined as zones 1, 2 and 3 respectively, and the concentration of air originating from the subfloor air in zones 1, 2 and 3 defined as C_1, C_2 and C_3 respectively, the mass balance of subfloor air in the living space requires:

$$Q_{12}C_1 + Q_{32}C_3 = S_2C_2$$

where S_2 is the total outflow of air from zone 2 . Normally $Q_{32}C_3 << Q_{12}C_1$ and the concentration of subfloor air in the subfloor $C_1 = 1$ and therefore

$$C_2 = \frac{Q_{12}}{S_2}$$

If the flow rate of subfloor air into the roof space passing through the living space is Q^*_{13}:

$$Q^*_{13} = Q_{23}C_2 = \frac{Q_{23}Q_{12}}{S_2}$$

Calculated and measured values of Q^*_{13} were only around 5% of measured Q_{13} in brick veneer houses A and E, and between 15 to 40% in weatherboard houses B to D. Significant flowpaths linking subfloor to roof space that do not involve the living space were clearly present in all of the experimental houses.

A quite different pattern of interzone air flows was seen in the two types of house in this survey. In weatherboard-clad houses the subfloor to roof space flows were almost an order of magnitude smaller than those in the two brick veneer examples. The living spaces were in contrast about equally coupled to the roof and subfloor zones in all but one house.

7.2 Weatherboard houses

Dealing with the weatherboard houses in more detail, Table 2 gives average interzone flow rates in a 4 m/s wind at the 10 m height. The standard error of these mean flow rates is around 20%.

HOUSE	subfloor to living	subfloor to roof	living to subfloor	living to roof	roof to subfloor	roof to living
B	20	30	10	35	0	0
C	10	6	2	30	2	10
D	4	10	10	25	1	1
Means	11	15	7	30	1	4

Table 2: Interzone air flow rates measured in weatherboard houses m^3/h

The most significant points that can be derived from from the data are as follows:

1. Interzone air flows in an upward direction exceeded downward flows in all but one case; that of the subfloor to living space air flows in house D.
2. Air flows through the ceiling were generally quite close to the area-weighted infiltration flow into the living space.
3. The component of flow from subfloor to roof which passed through the living space was in general quite small.

7.3 Brick Veneer Houses

Inter zone air flows at 4m/s wind speed are given in Table 3 for the two brick veneer houses A and E. While they share the characteristic of high air flows in the direction of subfloor to roof space, they differ in that the living space of house A was more closely coupled to the roof space. The coupling between subfloor and roof space in houses A and E is clearly quite similar with very large upward air flows and strongly suppressed downward flows. The interzone air flows involving living space of house E are similar to those in the weatherboard houses. This has to be expected because similar materials and construction details are involved in the living space internal lining. The locations of leakage openings that lead to higher air flows between roof and living spaces in house A are unknown.

HOUSE	subfloor to living	subfloor to roof	living to subfloor	living to roof	roof to subfloor	roof to living
A	20	190	*	90	0	30
E	14	135	5	50	0	8

Table 3: Interzone air flow rates measured in brick veneer houses in m^3/h
(* flow rate not adequately defined)

7.4 Differences in interzone air flow characteristics

The main differences between the examples of brick-clad and weatherboard-clad houses are as follows:

1. Subfloor and roof spaces were found to be more closely coupled in the brick veneer houses. A small fraction (5%) of the connecting air flow passed through the living space. In house A a connection through the wall cavities was established using airtightness techniques but in house E the link could not be measured with this method.
2. Similar construction methods used to enclose the living space would lead us to expect similar flows involving the living space. With the exception of house A this was confirmed.

The differences in the pattern of air flows are demonstrated in Figure 10 which shows interzone and infiltration air flows drawn approximately to scale.

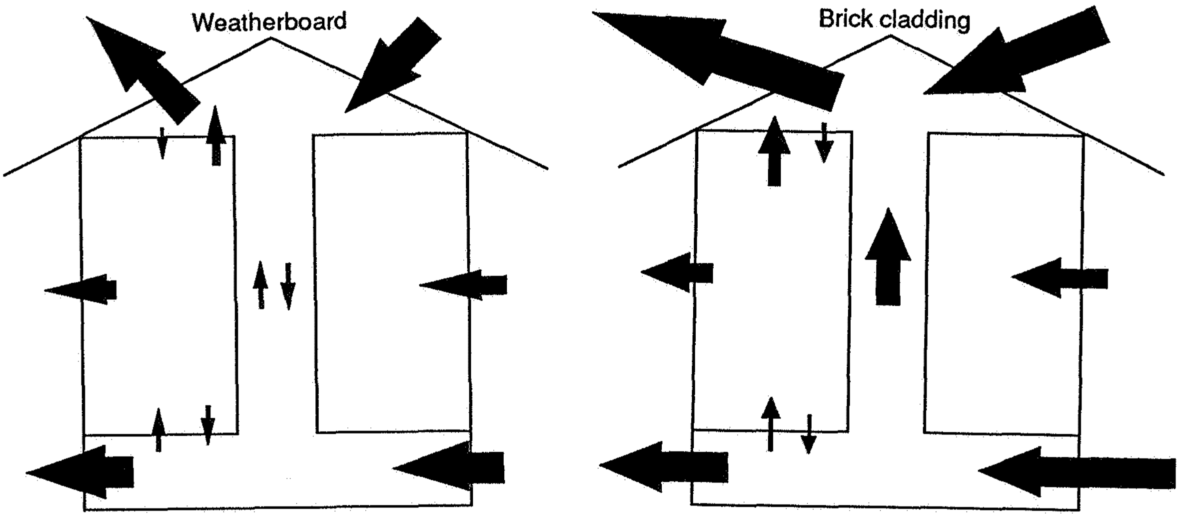

Figure 10: Approximate scale of interzone air flows in three weatherboard houses and brick veneer house E. The shaft through the centre of the building is symbolic of leakage paths that bypass the living space.

8 Conclusions

A new appreciation of ventilation rates in subfloors and roof spaces in New Zealand houses has been achieved. This should help lead to more quantitatively based provisions for ventilating roofs and subfloor spaces. The most important observations concerning infiltration rates are:

1. Natural ventilation rates in subfloors fell in the range 100-600 m^3/h or from 2 to 8 air changes/h.
2. Average ventilation rates in two concrete tile roofs were around 500 m^3/h or 8 air changes/h and in three sheet metal-clad roof cavities ventilation rates of 100-300 m^3/h or 1 to 5 air changes/h were measured.
3. Infiltration rates in living spaces fell in the range 0.3 to 1.0 air changes/h and were in good agreement with predictions based on airtightness and wind exposure details.

Air flow rates between subfloor, living and roof spaces were also successfully measured using a two tracer constant composition technique. The following conclusions were formed:

1. Subfloor to roof space airflows around 150 m^3/h were measured in two masonry veneer houses. Put in perspective with roof space ventilation rates, these airflow rates were 0.25 to 0.35 of the roof ventilation rate.
2. Interzone flow rates between all other zone combinations except floor to roof spaces in masonry veneer houses, and air flows in house A, fell in the range 0-30 m^3/h. They exhibited little tendency to change with wind speed and differences between zone temperatures.
3. Air flows in the downward direction (roof to living space, living space to subfloor and roof to subfloor) were generally smaller at 0-10 m^3/h than flows in the upward direction.

9 Acknowledgements

The technical help of H M Beckert in the laboratory and in setting up experimental work is gratefully acknowledged, together with the work of Dr A H Dechapunya on the data analysis software.

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Discussion

Paper 2

W. Fisk(Lawrence Berkeley Laboratory, USA) You mentioned that covering the soil prevented moisture problems. Are you referring to placing plastic sheets over the soil or other methods? Is the cover over the soil air tight?

M. Bassett(Building Research Association of New Zealand) The vapour barrier placed over the ground was a polyethylene sheet. It was not made airtight at joints or at the perimeter.

M. Sherman (Lawrence Berkeley Laboratory, USA) Wood members have an enormous potential to store and release moisture. Many potential moisture problems are averted because of this capacity to absorb, and subsequent thermal cycling. The conditions you describe appear to indicate that the magnitude of the source (i.e. ground moisture) is so large that neither storage in materials nor (reasonable) ventilation can solve the problem. Does this mean that source control is the only reasonable mitigation strategy?

M.Bassett (Building Research Association of New Zealand) Source control with a vapour barrier over the ground was the most effective remedial measure tried in existing houses, but at the construction stage it may be easier to block leakage paths through the wall cavities. Only a small fraction of brick veneer houses have this particular roofspace condensation problem, so in most cases ventilation and storage deal with the moisture from the subfloor.

O. Nielsen (Ministry of Housing and Building, Denmark) How do you define a house with a moisture problem? For example must there be visible moulds on surfaces?

M.Bassett (Building Research Association of New Zealand) Houses have a moisture problem when the occupants consider there is a problem. Typically these include condensation, moulds, musty smells and, only occasionally, interstitial condensation resulting in decay in framing and lining materials. Moisture problems do however rank as the most common reason for unsatisfactory house performance in New Zealand.

M. Liddament (AIVC, Warwick, UK) Can you explain how the houses are ventilated in New Zealand and if any method of ventilation is used to minimise moisture problems?

M.Bassett (Building Research Association of New Zealand) There is no common use of either passive or mechanical ventilation in New Zealand houses, although range hoods are now quite popular. Ventilation is provided by window opening, which of course is quite variable. A reasonable level of space heating is also an essential part of indoor moisture control, and there are many different methods of heating employed in New Zealand houses.

M. Liddament (AIVC, Warwick, UK) Have you investigated pollutants other than moisture in these houses?

M.Bassett (Building Research Association of New Zealand) There have been some pollutant concentration surveys in New Zealand houses for radon and formaldehyde. In most houses we consider moisture to be the pollutant requiring the highest ventilation rate (around 1 air change per hour).

P. Charlesworth (AIVC, Warwick, UK) You have indicated that the leaks around the hot water tank area are of special interest in your work. Could you elaborate upon this subject?

M.Bassett (Building Research Association of New Zealand) The interzone air flows were found to be insensitive to the normal driving forces of infiltrating outdoor air, wind speed and temperature differences. For this reason we looked for regions in the building where there might be constant stack pressure differences. One of these was the region around the hot water tank.

D. Harrje (Princeton University, USA) Referring to Fig. 10, does the central vertical arrow in the brick clad house represent flow behind the brick cladding, and is this the reason for higher crawlspace flows?

M.Bassett (Building Research Association of New Zealand) For the houses in this survey the air flow between crawlspace and roofspace in brick veneer houses (150 m3/h) is about 10 times higher than that in weatherboard houses. The only structural differences we see, which could explain this, are in the wall cavity area. However 150 m3/h is small compared to the differences in crawlspace ventilation rates measured in the 5 houses surveyed.