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Infiltration and leakage paths in single family houses - a multizone infiltration case study

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Annex V Air Infiltration and Ventilation Centre

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Infiltration and leakage paths in single family houses - a multizone infiltration case study

Mark Bassett
(Visiting specialist from the
Building Research Association of New Zealand)

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PREFACE

International Energy Apency

The International Energy Agency (IEA) was established in 1974 withln the framework of the Organisation for Economic Cooperation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the twenty-one IEA Participating Countries to increase energy security through energy conservation. development of alternative energy sources and energy research devclopmcnt and demonstration (RD&D). This is achieved in part through a programme of collaborative RD&D consisting of forty-two Implementing Agreements, containing a total of over eighty separate energy RD&D projects. This publication forms one element of this programma.

Energy Conservatlon In Buildings and Communlty Systems

The IEA sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is sponsoring various exercises to predict more accurately the energy use of buildings. including comparison of existing computer programs, building monitoring, comparison of calculation methods, as well as air quality and studies of occupancy. Seventeen countries have elected to participate in this area and hnve designated contracting parties to the Implementing Agreement covering collaborative research in this area. The designation by governments of a number of private organisations. as well as universities and government laboratories, as contracting parties, has provided a broader range of expertise to tackle the projects in the different technology areas than would have been the cnse if participation was restricted to governments. The importance of associating industry wlth government sponsored energy research and development is recognised in the IEA, and every effort is made to encourage this trend.

The Executive Commlttee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but identifies new areas where collaborative effort mny be beneficial. The Executive Committee ensures that all projects fit into a pre-determined strategy, without unnecessary overlap or duplication but with effective liaison and communication. The Executive Commlttee has initiated the following projects to date (completed projects are identified by *):

- I. Load Energy Determination of Buildings *
- II. Ekistics and Advanced Community Energy Systems *
- III. Energy Conservation in Residential Buildings *
- IV. Glasgow Commercial Building Monltorlng *
- V. Air Infiltration and Ventilation Centre

VI. Energy Systems and Design of Communities *

VII. Local Government Energy Planning *

VIII. Inhabitant Behaviour with Regard to Ventilation *

IX. Minimum Ventilation Rntes *

X. Building HVAC Systems Simulation

XI. Energy Auditing *

XII. Windows and Fenestration *

XIII. Energy Management in Hospitals *

XIV. Condensation

XV. Energy Efficiency in Schools

XVI. BEMS – 1: Energy Management Procedures

XVII. BEMS – 2: Evaluation and Emulation Techniques

XVIII. Demand Controlled Ventilating Systems

XIX. Low Slope Roof Systems

XX. Air Flow Pnttcms within Buildings

XXI. Energy Efficient Communities

XXII Thermal Modelling

Annex V – Air Infiltration and Ventilation Centre

The IEA Executive Committee (Building and Community Systems) has highlighted areas whcrc the level of knowledge is unsatisfactory and thcrc wRs unanimous agreement thnt infiltration was the area about which least was known. An infiltration group was formed drawing experts from most progressive countries, their long term aim to encourage joint international resenrch and incrcnsc the world pool of knowledge on infiltration nnd ventilation. Much valunble but sporadic and unco-ordinated research was already taking place and after some initial groundwork the experts group recommended to their executive the formation of an Air Infiltration and Ventilation Centre. This recommendation was nccepted and proposals for its establishment were invited intemntlonnlly.

The aims of the Centre are the standardisation of techniques, the vnlidndon of models, the catalogue and trnnsfer of information, and the encouragement of research. It is intended to be a review body for current world research, to ensure full disseminndon of this research and based on a knowledge of work already done to give direction and Ann basis for future research in the Participating Countries.

The Participants in this task are:

Belgium

Canada

Denmark

Federal Republic of Germany

Finland

Italy

Netherlands

New Zealand

Norway

Sweden

Switzerland

United Kingdom

United States of America

Infiltration And Leakage Paths In Single Family Houses - A Multi-zone Infiltration Case Study

M.R. Bassett

1 Summary

One of the continuing tasks of the Air Infiltration and Ventilation Centre has been to independently validate infiltration and ventilation models. In 1983. AIVC Technical Note TN11 gave details of the accuracy achieved by a range of infiltration models in replicating single zone Infiltration data Since then, the work of the ATVC has steadily assisted and supported the more detailed investigations of air leakage in buildings necessary to confirm advanced multi-zone analytical procedures.

This document describes preliminary work towards validating models that predict air flow rates between several zones. It is preliminary in the sense that it examines the quality and definition of physical data needed for a more testing and thorough validation.

The exercise has used a version of the multi-zone computer model developed by Walton at the National Bureau of Standards with **some** modifications to the the treatment of wlnd pressure coefficients.

The experimental data consisted of air flows between the subfloor, living space, and roof space zones for five single storey houses, together with air leakage rates from outside. There were approximately 300 data points supported with climatic data measured on site, and individual zone air tightness data.

Satisfactory agreement was generally achieved between measured and calculated infiltration rates in each of the three zone types, The most uncertain components of input data wcrc the wind pressure coefficients and the distribution of leakage openings to different parts of the building. Literature values for pressure coefficients and a simple area-based rule for allocating leakage openings to different surfaces was followed. In many cases, calculated inter-zone air flow were similar to measured air flows and in others, better definition of inter-zone air flow characteristic was clearly necessary.

A more complete validation exercise would need to give greater attention to the location of significant leakage openings and may require specifically measured wind pressure coefficients.

2 Introduction

Multi-zone air flow models play an essential part in calculating air flows that transport heat, contaminants and moisture through the occupied spaces and construction cavities in buildings. They havc the potential to replace time-consuming and difficult to perform multi-tracer gas measurements and to eventually take their place as widely acccptcd tools in huilding design.

The accuracy and applicability of single zone infiltration models has been examined in more detail than Is the case for models in a multi-zone role. AIVC Tech Note TN11 (1) examined the accuracy of 10 models against single zone data sets and concluded that agreement within 25% could generally be expected when complete details of climate. location of leakage openings and wind pressure coefficients were available. The same arbitrary 25% criteria was applied to comparisons between measured and calculated data in this report.

There have been a number of occasions where measured and calculated multi-zone alr flows have been compared. Perera tlnd Warren (2) compared air flows calculated with the computer program BREEZE with tracer gas measurements in a multiple-zoned domestic building. Using wind pressure coefficients derived from wind tunnel studies, and some area weighting of background leakage openings, favourable agreement was achieved. Similarly, Etheridge and Alexander (3) found satisfactory agreement between the British Gas multi-zone model and measured air flows using measured wind pressure coefficients. Mort recently the COMIS group (4) have undertaken extensive development and validation of multi-zone models.

The objectives of this work were as follows:

1 Tu organise measured building air tightness and local wind exposure data into data sets for numerically modelling infiltration and inter-zone air flows.

2 To calculate air flows corresponding to measured wind speeds and zone temperatures, and compare these with data measured using a multi-tracer system.

3 To define the level of accuracy achieved and the assumptions made, and to identify further critical physical parameters that are required for a more testing validation of multi-zone models.

3 Experimental data and theoretical model

Airtightness details and natural air flow data wcrc available for five domestic buildings. They are referred to as buildings A to E in thls report. Plan details, wind exposure descriptions and airtightness test details are given In Appendix A. Experimental methods used for measuring air tightness and natural air flow rates are given by Bassett (5). Important differences in air tightness characteristics and the assumptions made in allocating leakage openings to different parts of the building are discussed below.

3.1 Building descriptions

All five buildings modelled in this report were single family detached residences. They varied in age from 4 to 20 years and were of two significantly different construction types. Buildings A and E had concrete brick veneer claddings and concrete tile roofs whereas buildings B,C and D had weatherboard claddings and galvanised steal roofs. The significance of this difference is that brick veneer houses constructed in New Zealand often have an air leakage path connecting subfloor with roof space through the cavity between brick veneer and timber framing. This is thought to be a flow path for humid subfloor air into the roof space where it can cause a condensation problem. The relationship between zones, together with significant construction details are given in Figure 3.1.1.

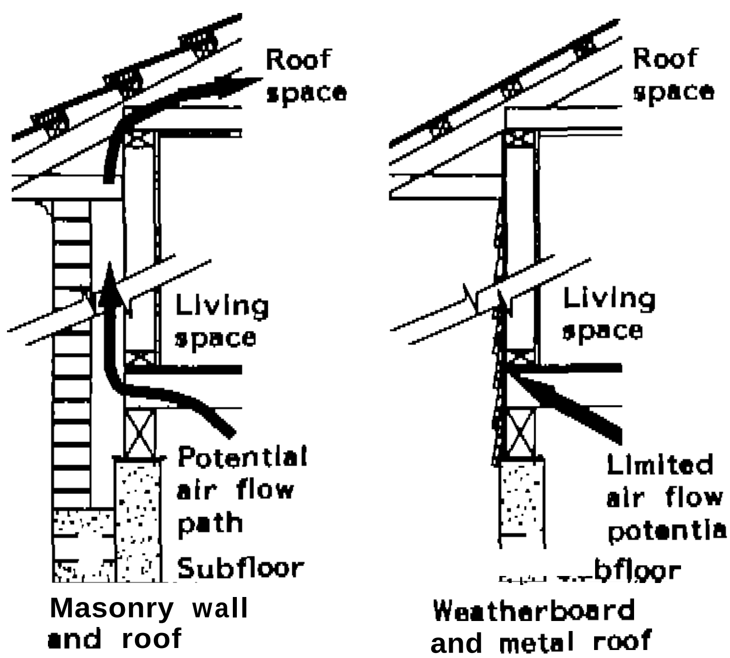

Figure 3.1.1 Schematic of differences in construction leading to big differences in subfloor to roof air flow characteristics

3.2 Airtightness results

Airtightness test results for the subfloor, living space and roof space zonas of each building are given in Appendix A. Figure 3.2.1 gives the living space airtightness compared with domestic buildings of a similar age group in New Zealand. There is no comparative survey data for subfloor and roof space zones.

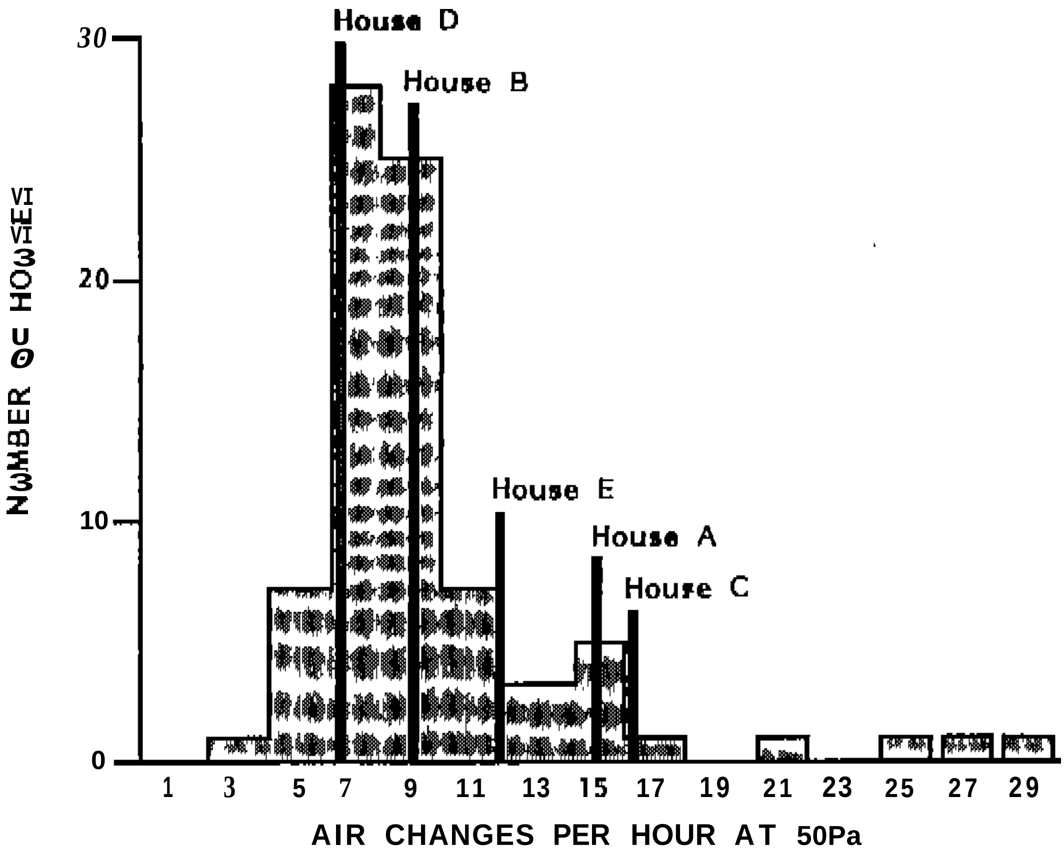

Figure 3.2.1 Histogram of living space airtightness for New Zealand houses

Significant observations concerning subfloor and roof space airtightness were as follows:

1 Air leakage paths connecting subfloor and roof space were not able to be resolved using standard airtightness test methods.

2 Subfloor and roof space leakage characteristic varied over a range of approximately 3 to 1.

3 Purpose-built vents generally contributed less than 50% to leakage into the sub floor. Most of the remainder originated at the joint between flooring joists, external cladding and the foundation perimeter wall.

Further details are presented in the following sections.

3.3 Distribution of leakage openings

Airtightness tests have given the overall leakage characteristics of each zone but not located specific leakage sites and their sizes over the building envelope. While there Is some experience of how leakage openings are dispersed over average living space envelopes, there is little guidance available for allocating leakage openings over roof surfaces and around subfloor perimeters. AIVC Technical note TN16 (6) surveyed the distribution of leakage openings in buildings In different countries and compared the background component, which excluded leakage around doors and windows. Large differences were noted between different building types and between buildings from different countries. This has to be expected because there are quite considerahle architectural differences between buildings in different countries. Houses in New Zealand, for example, do not have vapour barriers in the walls and no conscious effort is made to achieve airtight construction. Limited studies of air leakage sites in New Zealand houses (7) have suggested the following way of distributing leakage openings around the airtight perimeter of the living space:

1 Assign 20% of the leakage opening to external walls (to account for windows and doors)

2 Area-weight the remaining 80% to walls, roof and floor

Subfloor: In the absence of specific measurements, the leakage has been area-weighted to the perimeter wall and represented as a single leakage opening mid-height on each face.

Roof space: There has been no attempt to measure individual leakage openings into galvanised steel roofs in New Zealand. The assumption made was that most of the air leakage opening into galvanised steel roofs occured at the perimeter. For tile roofs with more obvious leaks around individual tiles, it was simply proportioned by area over pitched and gable end surfaces.

The main leakage sites represented in numerical modelling are illustrated in Figure 3.3.1. Here the size of the leakage sites is given as effective leakage areas at 4 Pa for building C. Leakage openings around walls were then proportioned by area to all orientations, and leakage around the roof perimeter was proportioned by length.

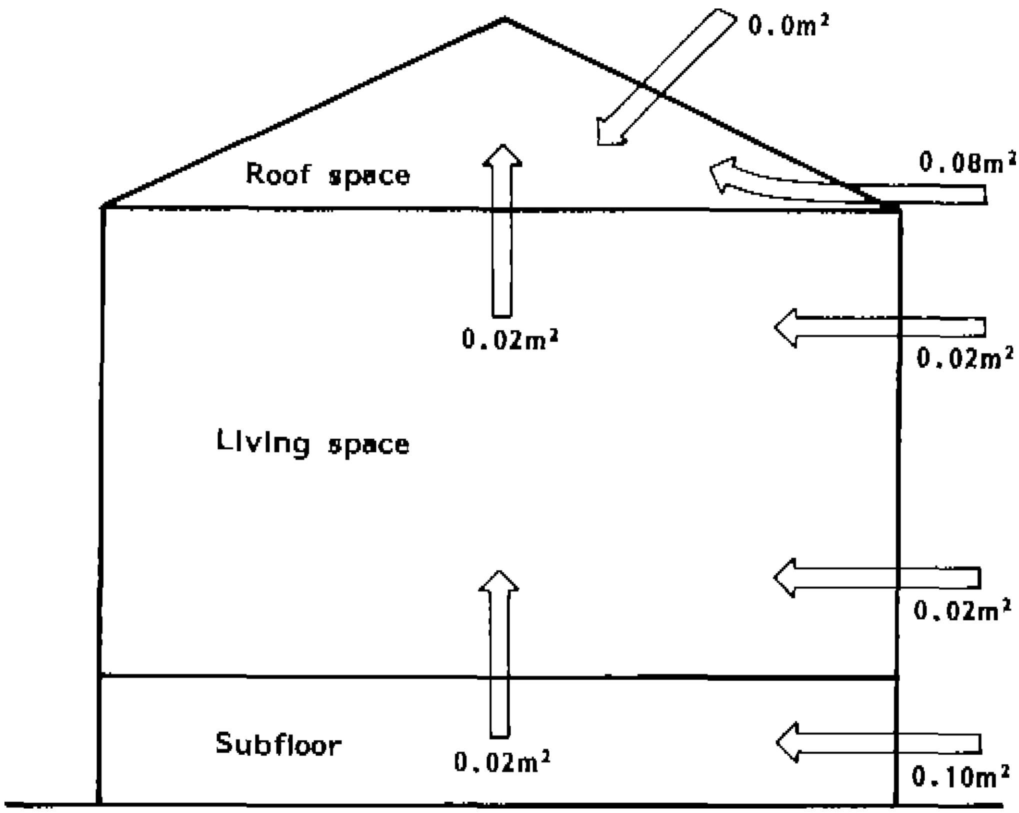

Figure 3.3.1 Main leakage site locations used in the numerical model, illustrated with effective leakage areas at 4 Pa for building C

Inter-zone flow characteristics: These have not been measured. It has been assumed that the leakage characteristics of the floor and ceiling were simply area-weighted components of the background living space leakage. In most cases this was about 25% of the living space leakage characteristic. Air leakage between subfloor and roof space through the wall cavities was ignored in buildings B, C and D because measured air flows bypassing the living space were small. In buildings A and E where large air flows were measured, flow characteristics were selected to give the measured flow rates.

3.4 International Comparisons

Airtightness of living spaces has been well documented in the literature but less emphasis has been given to construction cavities such as subfloor and roof cavities. Figure 3.4.1 summarises living space n50 data from a selection of surveys of recently constructed houses.

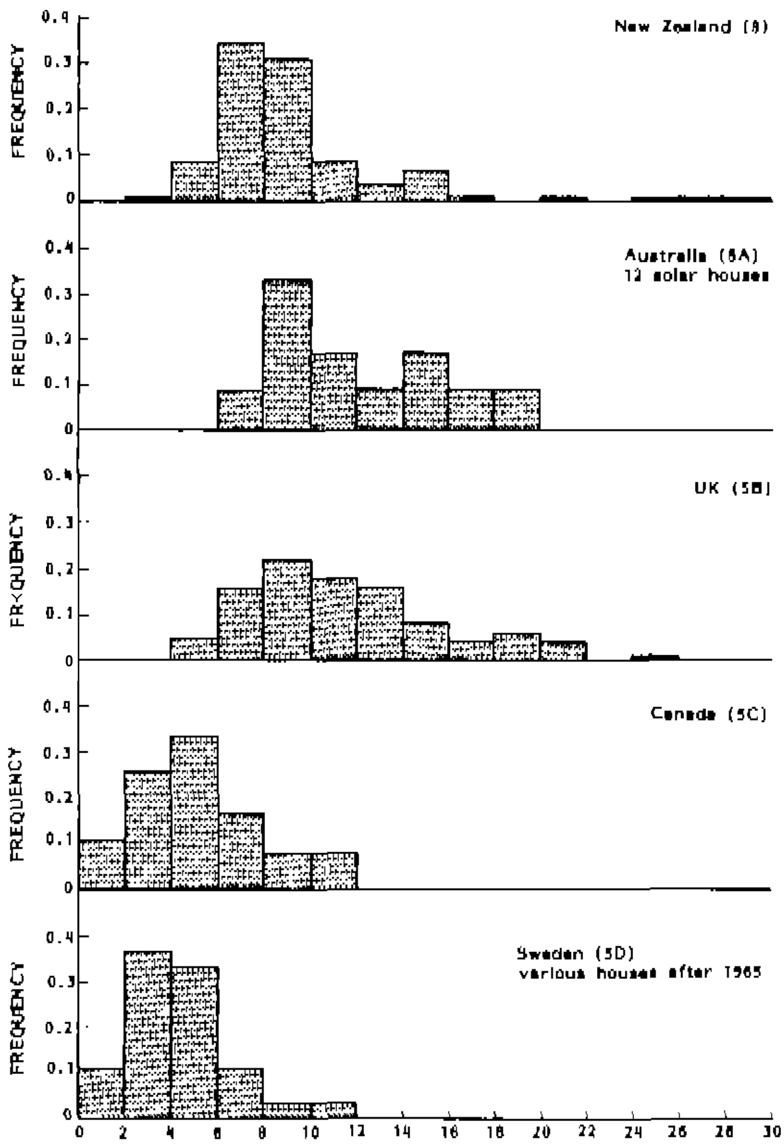

Figure 3.4.1 A comparison of n50 values for recent houses in a variety of countries.

While there are differences originating from the **way** fixed vents and flues are treated during the measurement, the **comparison** does **show:**

1 Houses of recent construction in countries not having an airtightness standard or severe winter climate, **occupy** a similar range of airtightness. **In** the examples given, the variation between houses is more significant **than** inter country differences.

2 Substantially improved airtightness is achieved in countries with cold winters.

Ventilation openings in perimeter foundation walls tend to **be well** defined **in** building regulations but there have been few surveys of crawl **space** airtightness that show the actual location and size of leakage openings. Table 3.4.1 gives ventllation areas required by some building regulations in crawl space perimeter walls, indicating that they tend to fall in the range: 0.001 - 0.005 m^2 of ventilation area for every m^2 of floor area.

TaMe 3.4.1 Example of ventilation openings required in crawl space perimeter walls

Country	Crawl space vent openings	Reference
New Zealand	0.0035 m2/m2 floor area	NZS 3604 (12)
UK	0.003 m^2/m perimeter wall	C4 (13)
Sweden	0.001-0.002 m^2/m^2 floor area	SBN (14)

Oldengarm (15) measured the airtightness of crawl spaces of houses in the Netherlands in the course of investigating air flows that carry moisture into other parts of the building. Lilly (16) measured the airtightness of a crawl space and found, as did Bassett (5) that purpose made vents contributed around half of the leakage area Into the space. There is little comparative information on the size of leakage openings linking the crawl space with the living space and other construction cavities.

3 .5Theoretical model

The multi-zone model **used** in this study was developed by Walton and published with an annotated Fortran 1V listing (17). The program version used in this modelling ***study*** **has been** cut down to calculate infiltration and inter-zone flow rates, leaving aside the ability to interface to the NBS dynamic heat transfer program TARP, and the sophistication of calculating inter-room contaminant transfer rates.

The program has been further modified to allow Wind pressure coeffldents to be added as input data, rather than calculated internally on the basis of wind direction and building geometry. **This** has allowed alternative levels of shielding and wind pressure coefficients to be easily investigated.

4 Wind pressure coefflclents

Assigning wind pressure coefficients to leakage openings around walls and **roofs** is known to be **a** critical factor in modelling infiltration and inter-zone air flows in buildings. Data used for wind loading calculations has often been found to average over too large an area of the building envelope or to represent exceptional exposure to wind. AIVC Technical Note TN13.1 (18) gives the proceedings of a workshop on wind pressures on buildings and goes some **way** to providing the special data needed for air infiltration simulations. Of particular note are the results of full scale wind pressure measurements over a grid of points on real buildings by Gusten (19) and Tanaka **(20).** They clearly show pressure coefficient variations over plane **surfaces** and, therefore the importance of matching this detail with a measured distributions of leakage openings. Scale modelling of buildings in a wind tunnel has been used by Bowen (21) and Wiren (22,23) to arrive at pressure coefficients over buildings in a variety of model suburban environments. A blend of the available data has been presented in Tables 6.2.1 to 6.2.6 in the ATVC calculation techniques applications guide AG-1(24).

This modelling exercise has used pressure coefficients from the calculation guide where possible. They are rcfcranced to wind speed at roof height. The exception has been at subfloor ventilators because these were generally sheltered by shrubs planted close to the perimeter wall. Alternative pressure coeffldents were arrived at by consultation with W de Gids (25) and are llsted in Table 4.1, together with data for wall and roof surfaces from the calculation techniques guide. For more exposed orientations, data in Table 4.2 was used. Here the subfloor vent pressure coefficients art the sheltered wall pressure coefficients from Table 4.1.

The exposure classes "sheltered" and "semi sheltered" are defined in the ATVC calculation techniques applications guide AG-1 (24) as follows:

Sheltered - Urban, building surrounded on all sides by obstructions of similar size.

Semi sheltered - Rural surroundings, some obstructions.

All five houses modelled in this study were considered to be either sheltered or semi sheltered. All were sited close to trees and buildings of similar height and generally in a residential setting. Buildings were treated as sheltered where trees or other buildings of similar height came within two house heights on the windward side. Where significant obstacles were further away, or where the ground fell away to windward, it was considered to be semi sheltered. No building orientations were exposed to large expanses of open ground or shielded by very much taller obstacles and therefore, did not require further wind exposure categories.

There are other ways of describing the wind exposure of suburban buildings that give finer rankings. The LBL method (26), for example, defines both terrain and local shielding coefficients and gives a more flnely resolved wind exposure description. This classification was used on a separate occasion to calculate infiltration rates into the living spaces of buildings A to E (5) and it is of value to note that buildings considered "sheltered" were given terrain and shielding class 4 and those given semi sheltered were class 3.

Table 4:1 Wind pressure coefficients for sheltered buildings
Low rise buildings
Length to width ratio 2:1
Wind speed reference level = building height

								Wlrd Angle
Location	0	46	90	135	160	226	270	316
Subfloor								
Vent 1	0	-.15	-.15	-.15	-.15	-.15	-.15	-.15
2	-.15	-.15	-.15	-.15	0	-.15	-.15	-.15
3	-.15	0	0	0	-.15	-.15	-.15	-.15
4	-.15	-.15	-.15	-.15	-.15	0	0	0
Wall 1	.06	-.12	-.20	-.38	-.30	-.38	-.20	-.12
2	-.30	-.38	-.20	-.12	.06	-.12	-.20	-.38
3	-.30	.15	.18	.16	-.30	-.32	-.20	-.32
4	-.30	-.32	-.20	-.32	-.30	.15	.18	.15
Roof front	-.49	-.46	-.41	-.46	-.49	-.46	-.41	-.46
< 10 rear	-.49	-.46	-.41	-.46	-.49	-.46	-.41	-.46
Rad front	-.49	-.46	-.41	-.46	-.40	-.46	-.41	-.46
11-30rear	-.40	-.46	-.41	-.46	-.49	-.46	-.41	-.46
Roof front	.06	-.15	-.23	-.6	-.42	-.6	-.23	-.15
> 30 rear	-.42	-.60	-.23	-.15	.06	-.15	-.23	-.60

Table 4.2 Wind pressure coefficients for semi-sheltered buildings Low rise buildings Length to width ratio 2:1 Wind speed reference level – building height								
								Wird Angle
Location	0	45	90	135	180	225	270	315
Subfloor								
Vent 1	.06	-.12	-.20	-.38	-.30	-.38	-.20	-.12
2	-.30	-.38	-.20	-.12	.06	-.12	-.20	-.38
3	-.30	.15	.18	.15	-.30	-.32	-.20	-.32
4	-.30	-.32	-.20	-.32	-.30	.15	.18	.15
Wall 1	.50	.25	-.W	-.80	-.70	-.80	-.50	.26
2	-.70	-.80	-.50	.26	.50	.25	-.50	-.80
3	-.90	.20	.60	.20	-.W	-.60	-.35	-.60
4	-.90	-.Bo	-.35	-.60	-.90	.20	.60	.20
loof front	-.70	-.70	-.80	-.70	-.70	-.70	-.Bo	-.70
< 10 rear	-.70	-.70	-.80	-.70	-.70	-.70	-.80	-.70
loof front	-.70	-.70	-.70	-.60	-.50	-.60	-.70	-.70
11-30rear	-.50	-.60	-.70	-.70	-.70	-.70	-.70	-.60
loof front	.25	0	-.60	-.90	-.80	-.90	-.60	0
>30 rear	-.80	90	60	0	.26	0	60	90

oof pressure coefficients

For some roof pitches and wind directions, the pressure coefficients averaged over the pitched surfaces, as shown in Tables 4.1 and 4.2, take the same value. A more detailed description of the way wind pressures vary over pitched roofs is illustrated in Figure 4.3 This shows considerable variation in wind pressure over roof surfaces.

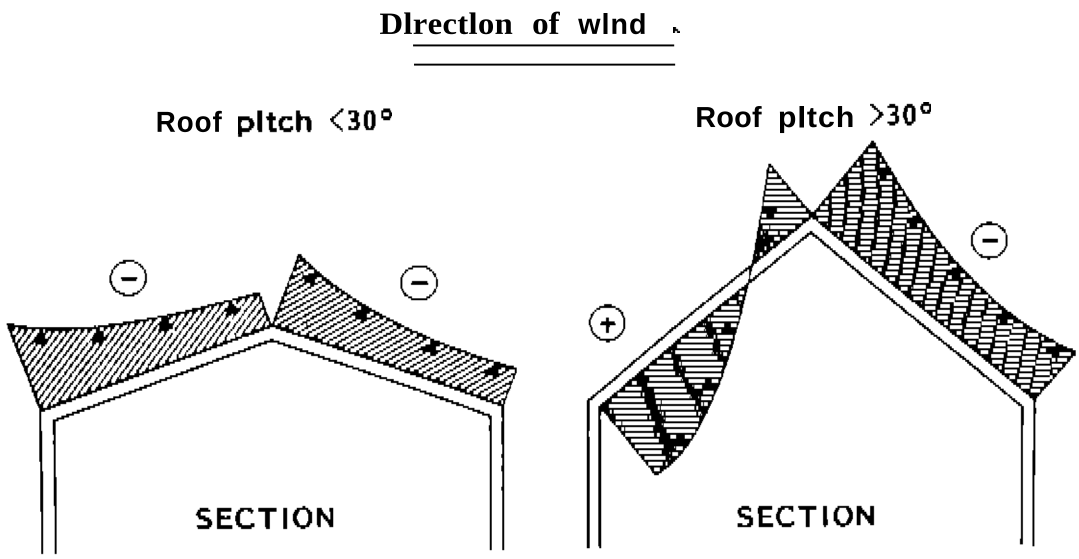

Figure 4.3 Typical distribution of wind pressure over a pitched roof

Allocating average pressure coefficients to the major leakage openings in a roof can clearly lead to unrealistically low intiltration rates from outsida. In this modelling exercise, it was found necessary to allocate leakage openings to a variety of pressure coefficients over the roof to find agreement with measured infiltration rates. Usually this was achieved by assigning a significant fraction of the leakage opening to the roof outer edge where wall pressure coefficients have been applied.

5 Buildings and analysis of results

A detailed comparison between measured and calculated air flows for each building is given in Appendix B. This section gives a more global view of the accuracy achieved in predicting different generic types of air flow rates.

Zone **infiltration** rates

A convenient single parameter describing the accuracy of air flow rate calculations in ERR defined as:

$$Err = \frac{\text{Measured airflow rate} - \text{Calculated airflow rate}}{\text{Measured air flow rate}}$$

Figures 5.1 to 5.3 are histograms of ERR for infiltration air flows into subfloor, living space and roof space zones. The cell width has been arranged to place all predictions falling within *25%* of measurement in the cell centred on ERR = 0. Similarly, cells centred on ERR = .5 contain predictions falling within 25% to 75% of measurement.

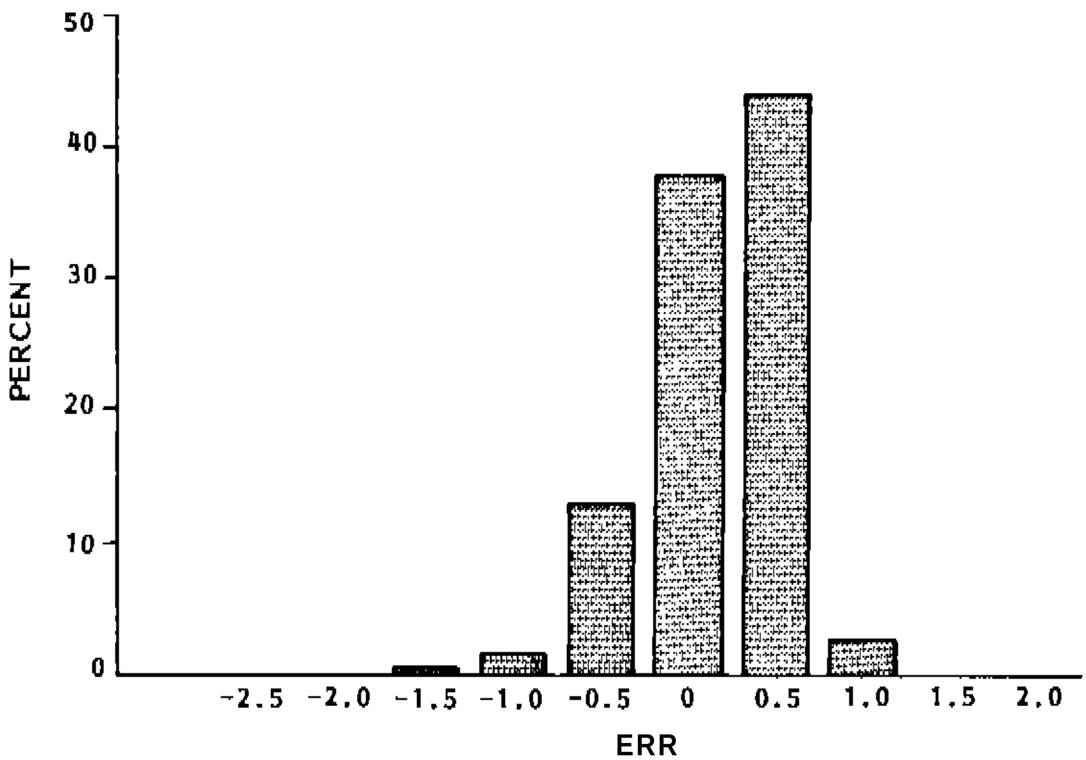

Figure 5.1 Histogram of ERR for subfloor infiltration rates in buildings A to E

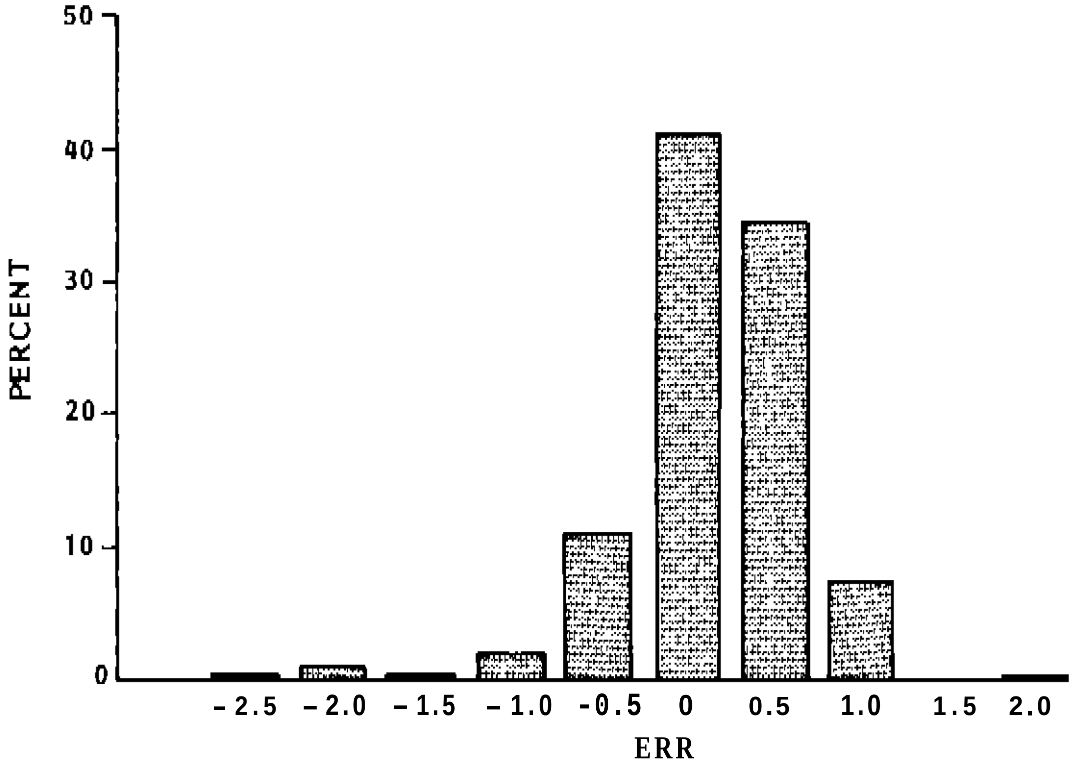

Figure 5.2 Histogram of ERR for living space infiltration rates in buildings A to E

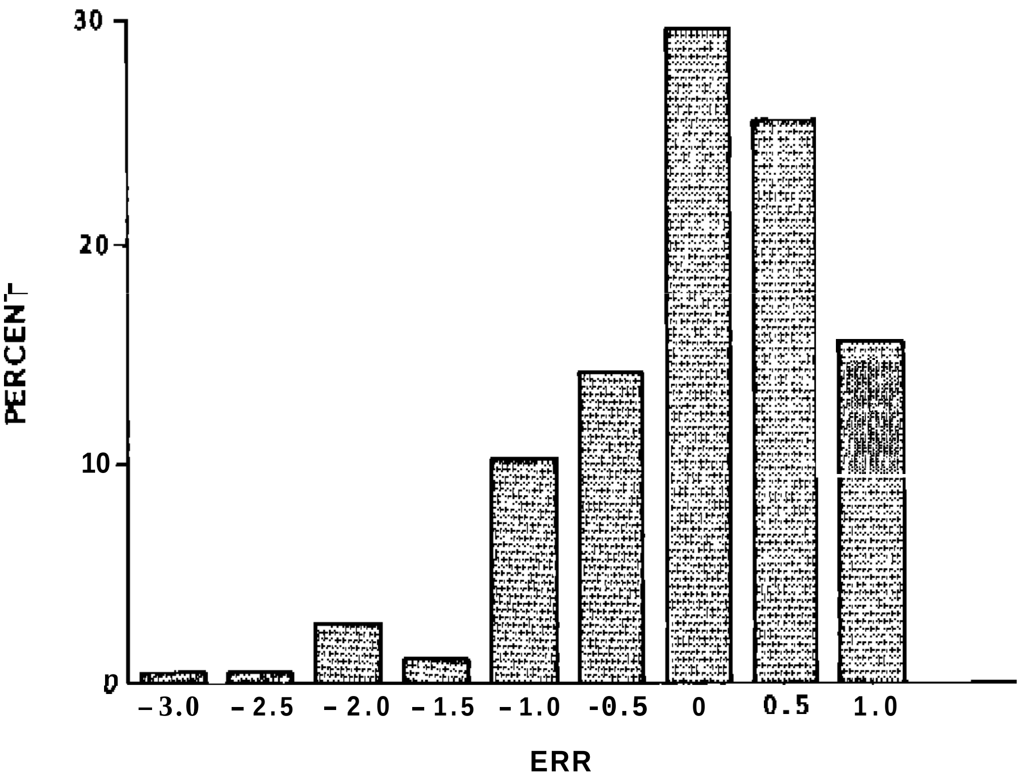

Figure 5.3 Histogram of ERR for roof space infiltration rates in buildings A to E

In all three zones, most predictions fell within **75%** of measurement with approximately 3040% falling within ***25%.*** Roof space infiltration rates were the least **well** reproduced, with about **25%** of predictions more than 75% in error compared to 5% and 11%for suhfloors **and** living spaces respectively. By plotting the **mean** values of measured and calculated infiltration rates in Figures **5.4** to 5.6 **an** indication is given of significant differences **between** calculation and measurement for individual zones, showing no preference for a particular zone type or building. **The** error bars **in** Figures ***5.4*** to ***5.6*** are two standard errors calculated **on** the basis of a **log** normal distribution of infiltration.

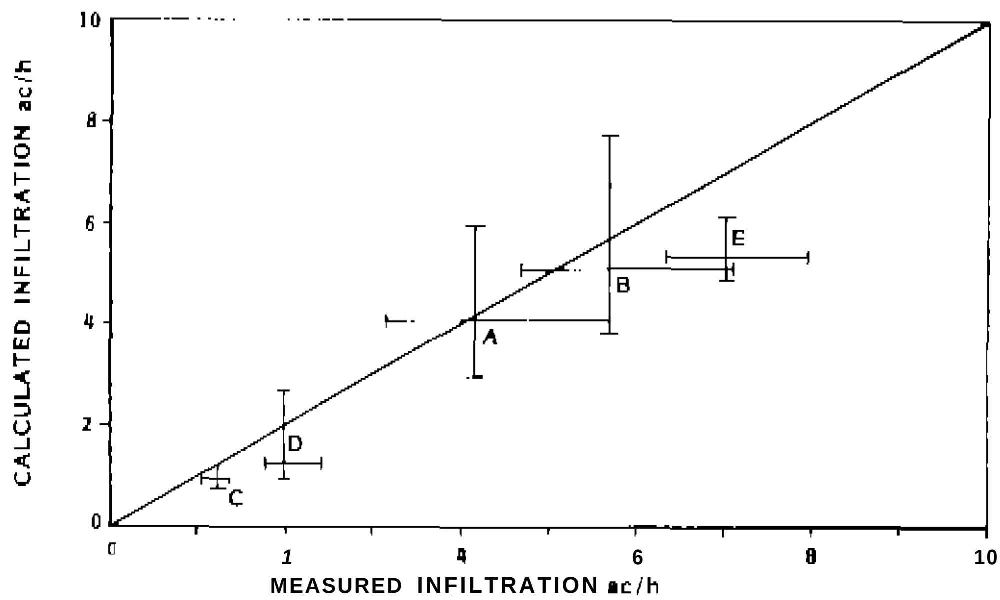

Figure 5.4 Mean measured and calculated infiltration in subfloors of buildings A to E

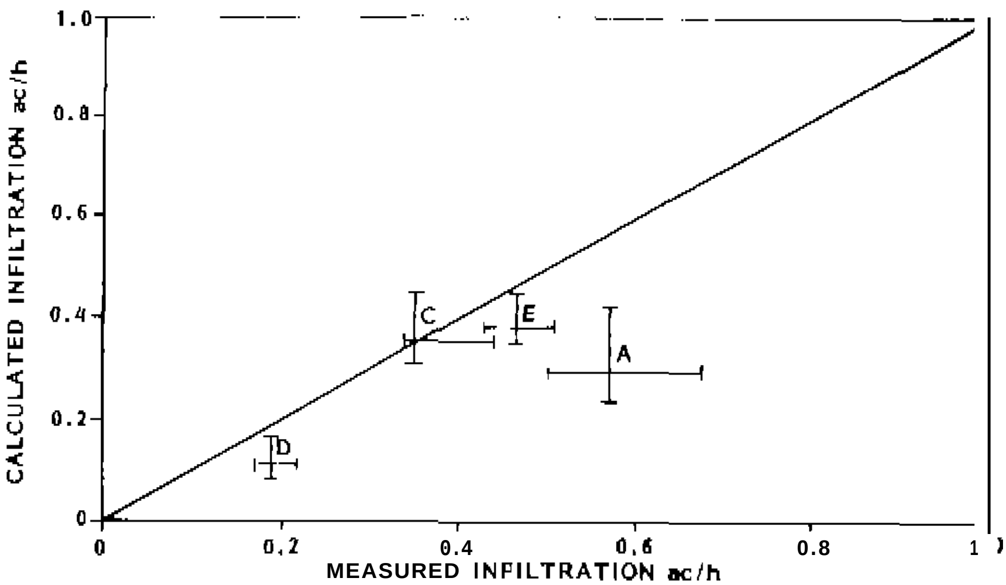

Figure 5.5 Mean measured and calculated infiltration in living spaces of buildings A to E

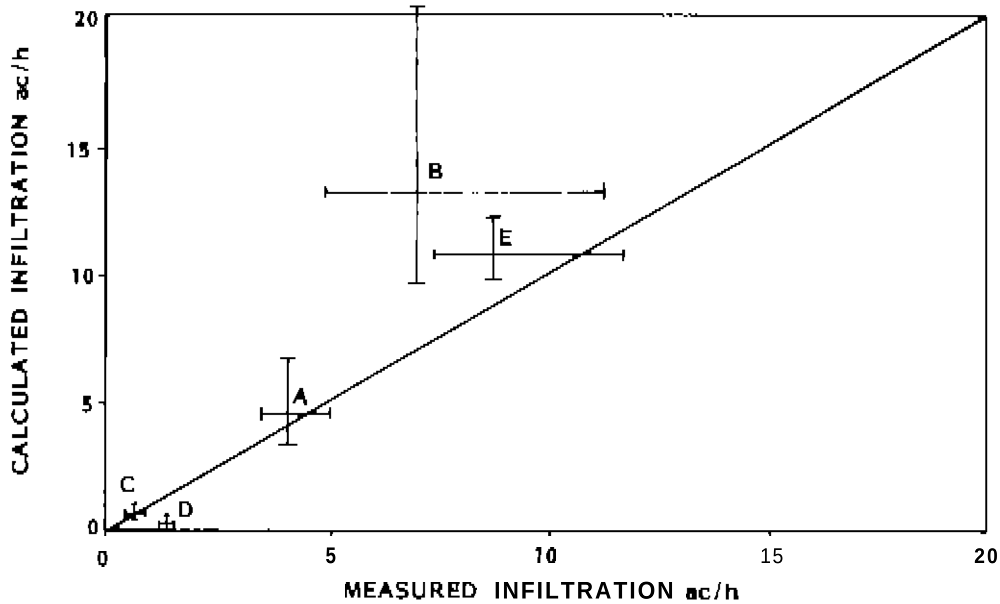

Figure 5.6 Mean measured and calculated infiltration in roof spaces of buildings A to E

Sensitivity to wind direction

It was generally noted that calculated infiltration rates were more sensitive to wind direction than the measured data. Figure 5.7 shows measured and calculated infiltration into the roof space of house C for a 2 m/s wind at roof height, plotted against Wind direction This less pronounced wind direction effect is considered to arise from wind direction changes during the experiment which effectively smooth over the wind direction dependence of infiltration air flows. Wind pressure coefficients averaged over a finite range of wind direction may therefore he more appropriate for modelling wind driven air flows averaged over extended periods of an hour or more.

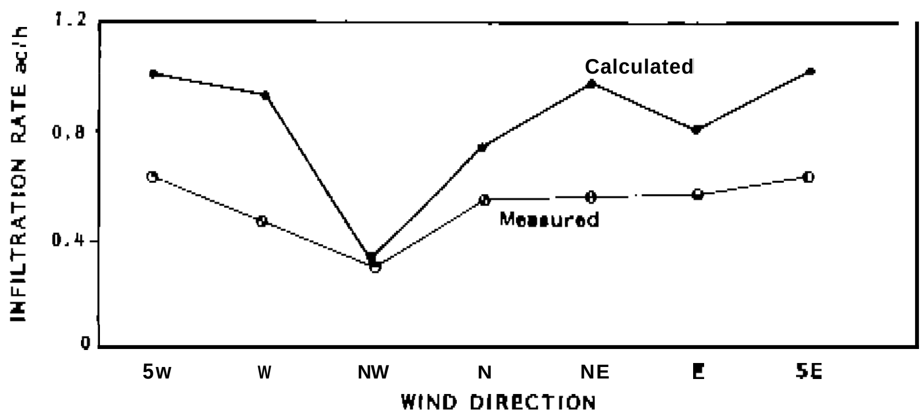

Figure 5.7 Measured and calculated infiltration rates into the roof space of house C for different wind directions.

Inter-zone air flows

Measured and calculated inter-zone air flows can be compared in the same way as zone infiltration rates above, however, it must be remembered that the calculated inter-zone flows depended more heavily on assumed leakage characteristics and that agreement between measured and calculated data is more a test of these assumpdons than a test of the model. Histograms of ERR for subfloor to living spacc, and living space to roof space air flows are given in Figures 5.8 and 5.9. They show a wider spread of ERR than was the case for infiltration air flows into the zones. For air flow between living and roof spaces, 90% of ERR values fall within cells centred on -1 to 1 but for air flow between subfloor and living space, the range of ERR containing 90% of the data is close to -3 to 2.

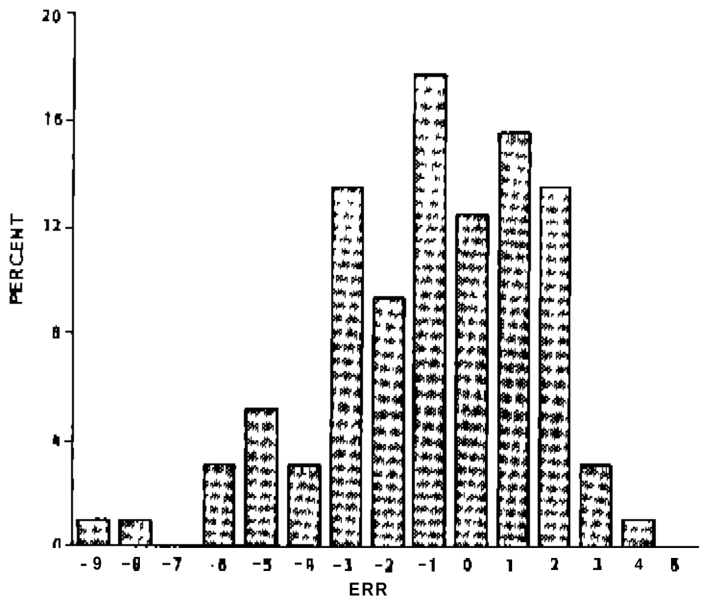

Figure 5.8 Histogram of ERR for subfloor to living space airflows

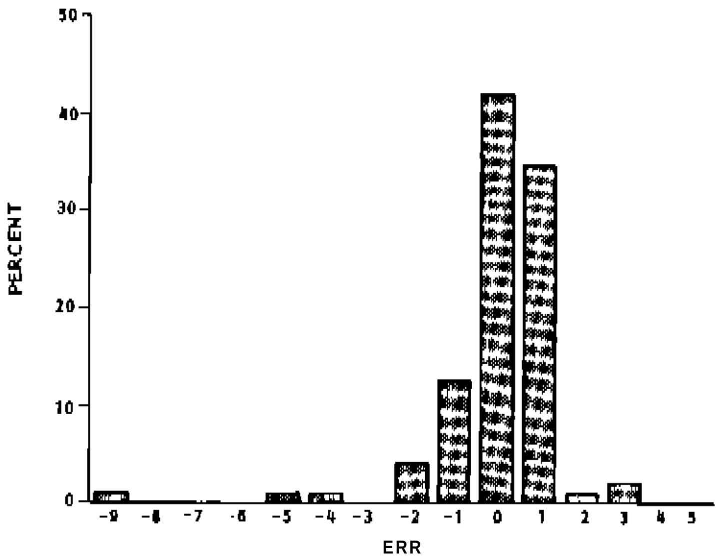

Figure 5.9 Histogram of ERR for living space to roof space air flows

An examination of the mean values of measured and calculated inter-zone air flows in Figures 5.10 and 5.11 shows no general trend to over or under estimation by calculation. Clearly though, measured inter-zone flow characteristics appear to be essential to achieving more satisfactory agreement between measured and calculated inter-zone air flows.

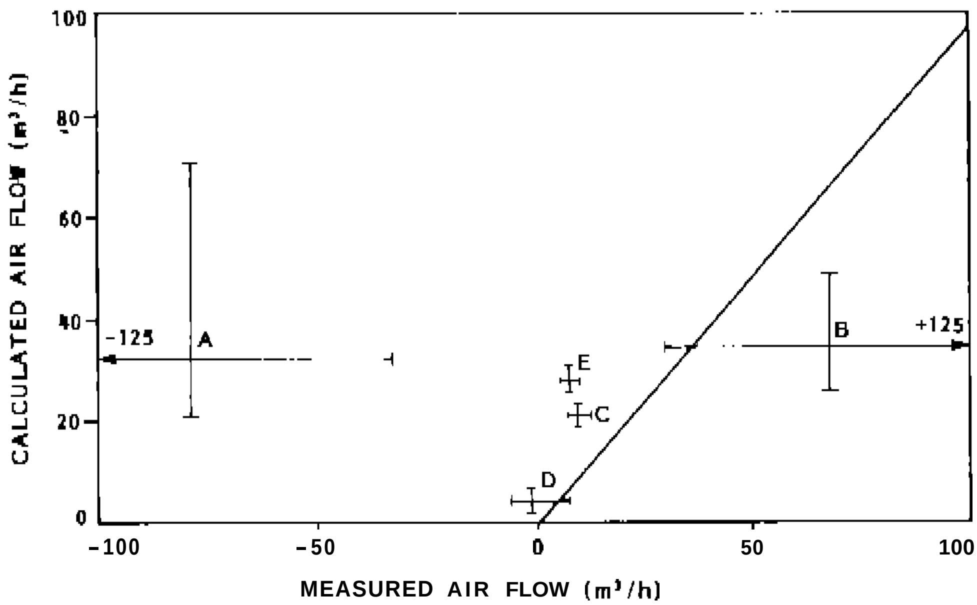

Figure 5.10 Mean values of measured and calculated air flows between subfloor and living space

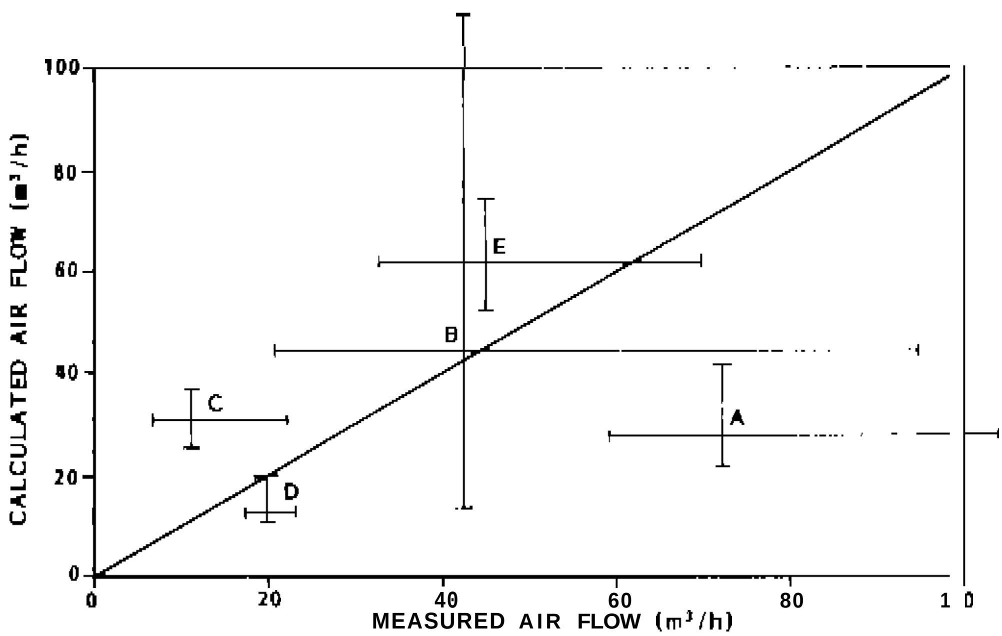

Figure 5.11 Mean values of measured and calculated air flows between living and roof spaces

Dlscusdon and Conclusions

The objective of thls numerlcal modelling exercise has been to examine the accuracy achieved in calculating **multi-cell** air flows using standard wind pressure coefficients **and** public domain software. It made use of the following resources:

1 Building geometry, wind exposure and measured **wind** and **air** temperature data for **a** selection of buildings in New Zealand

2 Wind pressure coefficients that have their origins in Europe.

3 A multi-zone air **flow** program **from NBS** in tho USA.

4 Approximately 300 sets of air flow data measured using a real time multi-tracer system in five New Zealand houses.

Infiltration and inter-cell flows between mbfloor, **living** space and roof **space** were calculated assuming that **building** leakage openings were uniformly distributed over the building surface. The results can be **summarised** as follows:

1 Infiltration rates **in** the roof space and **subfloor** construction cavitles were mostly well reproduced, with most calculations falling within **75%** of measured data and 30% to 40% falling **within 25%.**

2 Inter-zone air flows were sensitive to the leakage characteristicbut were often **well** reproduced from simple assumptions.

3 Calculated **air** flows ware generally more sensitive to wind direction than indicated **by** experiment.

4 A more testing validation of multi-zone calculation techniques will require **a** more dcteilcd distribution of measured leakage openings and measured pressure coefficients.

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Appendlx A Plans, locatlon and constructlon details of bulldlngs

This appendix llsts basic construction details for **each** of the **five** test buildings. It Includes plans. **n** description of wind **exposure,** and results of airtightness testlng of subfloor, living and roof zones.

A.1 Physlcnl **detalls** ***of*** Bulldlng A

Locatlon: Porlrua, **20** km **north** of **Wellington** New Zealand.

Terrain: The building **was** located in **a** developed subdivision but on slightly higher ground than immediate surrounding buildings. It was moderately exposed to **winds from** all directions and the subfloor vents were not generally shielded by vegetation.

Location of **meteorological statlon: The** ten metre mast was located 10m to the south of the building,

Construction **details:**

Basic **constructlon type: Single** storey detached **house** of light timber frame construction clad in concrete bricks. **The** floor was suspended above ground and **the** subfloor enclosed by a continuous concrete perimeter wall with standard ventilators cast In place. **The** concrete tile roof had **a** bitumen impregnated kraft paper underlay and **was** supported by timber **trusses.**

Roof: There were gable ends to the N and S and **the** roof was pitched at **22** degrees.

Roof ventilatlon: There were no purpose-made ventilation openings and no **obvious** single large openings.

Chimney **flues: Nil**

Ceiling: Continuous paper-coated **gypsum** plasterboard.

External cladding: Concrete brick veneer.

Internal wall **lining:** Paper-coated gypsum plasterboard, painted or wallpapered.

Subfloor ventilation: There were 16 standard ventilators located mid-height in **the** foundation perimeter wall.

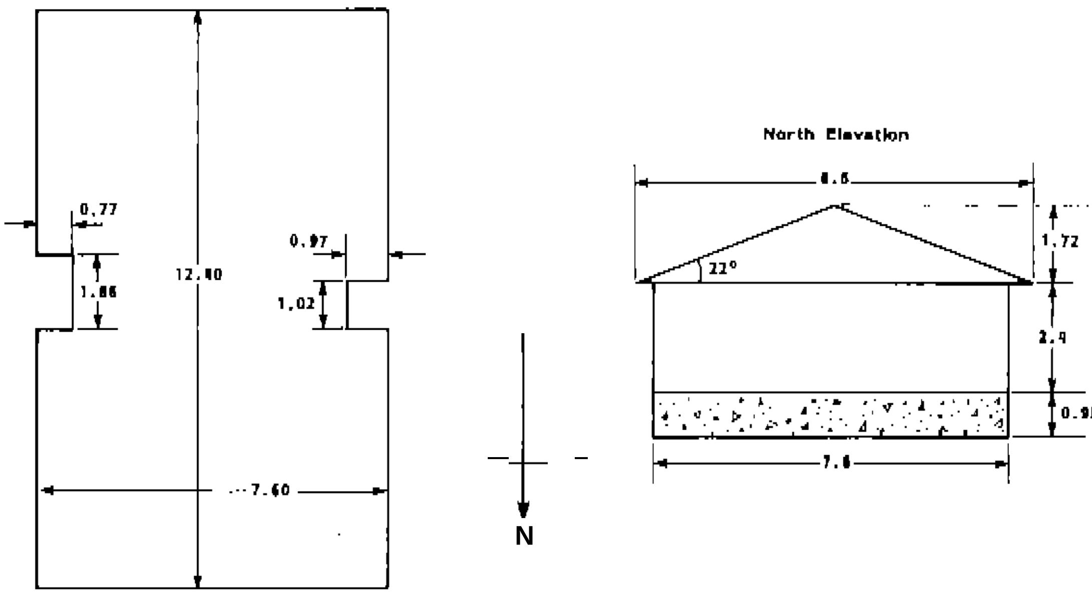


Figure A.1 Plan and dimensions of Building A

Airtightness test details:

The airtightness of the roof space, living space and subfloor volume were made by fan depressurization and best fit coefficients and exponents for the exponential flow equation derived. This data is listed in Table A.1 below.

Table A.1 Airtightness details of Building A

	Volume m^3	Coefficient	Exponent
Subfloor	83	0.33	0.6
Living space	213	0.074	0.64
Roof space	76	0.35	0.61

A.2 Physical detalls of Building B

Location: Pukerua Bay, 30 km north of Wellington New Zealand.

Terrain: Building B was located in a developed subdivision with houses surrounding all but N,NE directions. Ground to the N,NE fell away, leaving the house particularly exposed to winds from these directions. From all other directions it was sheltered by low rise buildings and vegetation.

Location of meteorological station: The ten metre mast was located within 10m to the N of the building.

Construction details:

Basic construction type: This single storey detached house of light timber frame construction was clad in weatherboards. The floor was suspended above ground and tho subfloor enclosed by a continuous concrete perimeter wall with standard ventilators cast in place. The galvanised steal roof had a bitumen impregnated kraft paper underlay and was supported by timber trusses.

Roof: A pitched roof of 10 degrees slope with gable ends to the NW and SE.

Roof ventilation: There were no purpose-made ventilation openings and no large single leakage openings.

Chimney flues: A single chimney connected to a freestanding fire place. All leakage openings into the living space were sealed for the duration of measurements.

Ceiling: Low density fibreboard ceiling tiles throughout most of the house.

External cladding: Fibre cement weatherboards

Internal wall lining: Paper-coated gypsum plaster board, painted or wallpapered.

Subfloor ventilation: There were 16 standard ventilators cast mid-height into the foundation perimeter wall.

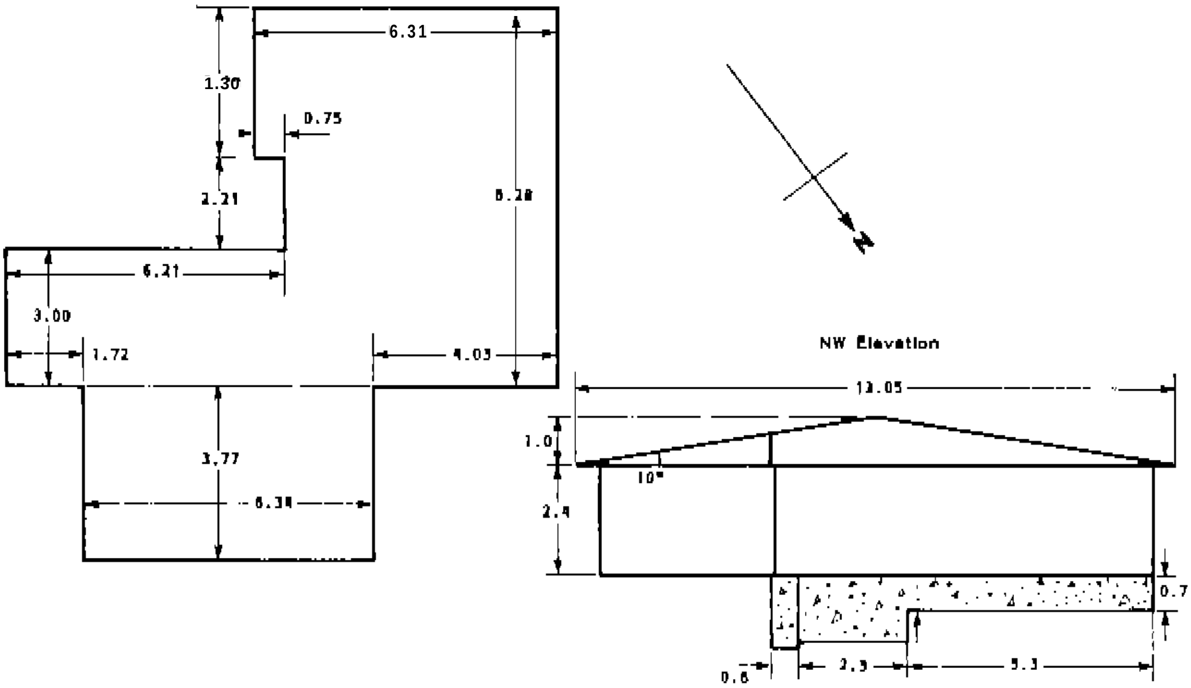


Figure A.2 Plan and dimensions of Building B

Airtightness test details:

The airtightness of the roof space, living space and subfloor volume were made by fan depressurization and best fit coefficients and exponents for the exponential flow equation derived. This data, is listed in Table A.2 below.

Table A2 Airtightness details of Building B			
	Volume m^3	Coefficient	Exponent
Subfloor	65	0.280	*0.5*
Living space	210	0.034	*0.89*
Roof space	71	*0.33*	*0.54*

A.3 Physical details of Building C

Location: Upper Hutt, 30 km northeast of Wellington New Zealand

Terrain: A developed residential area with houses to the NE, NW and SW. There were trees around most of the perimeter rising above roof height. Subfloor vents were shielded by shrubs planted close to the perimeter wall.

Location of meteorological station: The ten metre mast was located 10 m to the NW of the building.

Construction details:

Basic construction type: Building C was a single storey detached house of light timber frame construction clad in weatherboards. The floor was suspended above ground and the subfloor enclosed by a continuous concrete perimeter wall with standard ventilators cast in place. The long run galvanised steel roof had a bitumen-impregnated kraft paper underlay and was supported by timber trusses.

Roof: The roof had gable ends to the NW and SW and was pitched at 32 degrees.

Roof ventilation: There wcrc no purpose-made ventilators into the roof space and no obvious leakage openings due to workmanship defects.

Chimney flues: There was ono gas fire flue which was sealed for the duration of measurements.

Ceiling: A mixture of low density fibre board tiles and continuous paper-coated gypsum plasterboard.

External cladding: Timber weatherboards.

Internal wall lining: Paper coated gypsum plaster board painted or wallpapered.

Subfloor ventilation: There were 15 standard ventilators cast mid-height into the perimeter well.

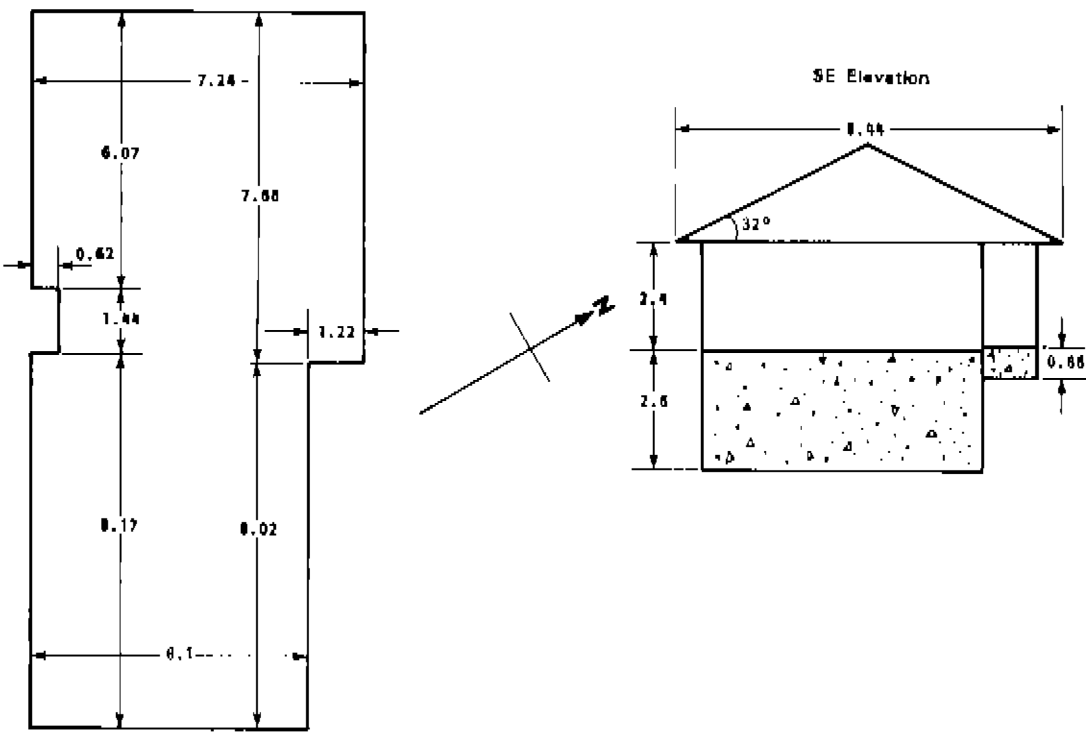


Figure A.3 Plan and dimensions of Building C

Airtightness test details:

The **airtightness of the** roof **space,** living **spaca and subfloor volume were made by fan depressurization and best fit coeffldents and exponents for the exponential flow equation derived. This data is listed in Table A.3.**

Table A.3 Airtightness details of Building C			
	Volume m^3	Coefficient	Exponent
Subfloor	58	0.137	0.64
Living space	234	0.084	0.64
Roof space	128	0.104	0.84

A4 Physical details of **Building** D

Location: Whitby, 20 km north of Wellington, New Zealand.

Terrain: Located in a residential subdivision with rising ground to the NW and falling ground to the SE. The building **was** particularly exposed to winds **from** W,SW,S,SE,E and sheltered from **NE,N,NW** winds. There **was** little vegetation around ventilation openings around all but the NW of the building.

Location of meteorological **station:** The ten metre mast was located 10 m to the **NW** of the building.

Construction details;

Basic construction type: Building **D** was **a** single storey detached house of light timber frame construction clad in weatherboards. The floor was suspended above ground and the subfloor enclosed by **a** continuous concrete perimeter wall with standard ventilators **cast** in place. The long run galvanised steel roof had a bitumen-impregnated heft paper underlay and was supported by timber trusses.

Roof: The roof had gable ends to the **SW** and NW and is pitched at 26 degrees.

Roof ventilation: There **were** no purpose made ventilation openings into the roof space and no obvious openings due to workmanship defects.

Chimney **flues: Nil**

Calling: Continuous paper-coated **gypsum** plaster board.

External **cladding:** Weatherboards.

Internal wall **lining:** Paper-coated **gypsum** plaster board, painted or wallpapered.

Subfloor ventllation: There were **15** standard **vents cast** mid-height into the foundadon perimeter wall.

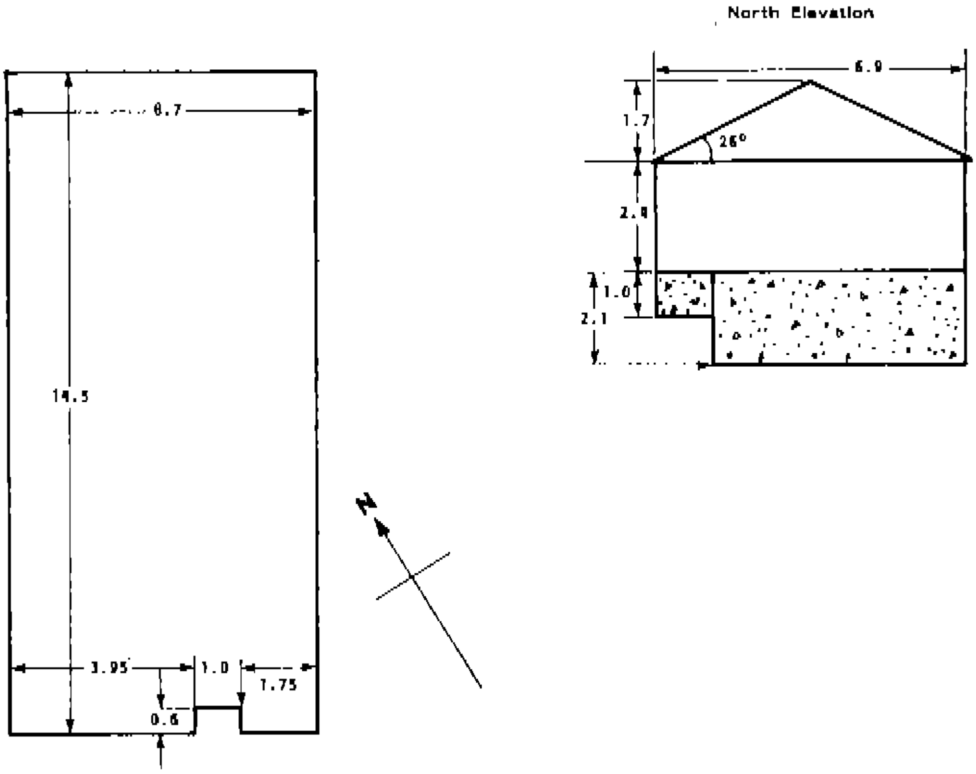


Figure A.4 Plan and dimensions of Building D

Airtightness test details:

The airtightness of the roof **space, living space and subfloor volume were made by fan depressurization and best fit coefficients and exponents** for **the exponential flow equation derived. This data is listed in the Table A.4 below.**

Table A.4 Airtightness details of Building D			
	Volume m^3	Coefficient	Exponent
Subfloor	73	0.15	0.86
Living space	242	0.016	0.85
Roof space	86	0.060	0.93

A.5 Physical details of Building E

Location: Kaitoki, 40km northeast **of** Wellington New Zealand

Terrain: Building E was located in a rural area but with low rise building within two house heights. In this case the subfloor vents were not shielded by vegetation. The ground rose to the SE and fell away to the N. It was well sheltered from E,SE,S,SW,and W winds and more exposed to wind from NW,N,NE directions.

Conatructlon **details:**

Basic construction **type:** A single storey detached house of light timber frame construction clad in concrete bricks. The floor was suspended above ground and the subfloor enclosed by a continuous concrete perimeter wall with standard ventilators cast in place. The concrete tile roof had a bitumen impregnated kraft paper underlay and was supported by timber trusses.

Roof: The roof had gable ends to the SW and NW and was pitched at 18 degrees.

Roof ventilation: There were no purpose-made ventilation openings into the roof space and no obvious openings due to workmanship defects.

Chimney flues: There were two chimneys connected to wood burning stoves. All leakage openings into the living and roof spaces were sealed for the duration of measurements.

Ceiling: Continuous paper-coated gypsum plaster board

External **cladding:** Concrete bricks.

Internal wall **lining:** Paper-coated gypsum plaster board painted or wallpapered.

Subfloor Ventilation: There were 15 standard vents cast mid-height into the foundation perimeter wall.

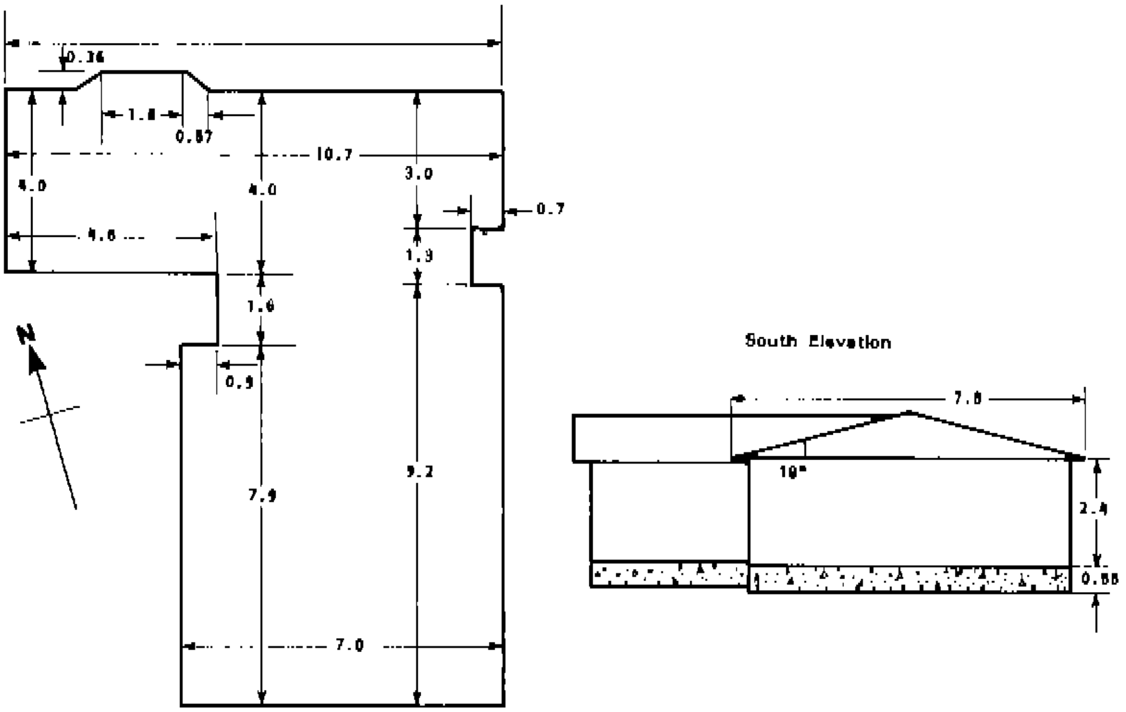


Figure A.5 Plan and dimensions of Building E

Airtightness test details:

The airtightness of the roof space, living space and subfloor volume were made by fan depressurization and best fit coefficients and exponents for the exponential flow equation derived. This data is listed in Table A.5 below.

Table A.6 Airtightness details of Building E			
	Volume m^3	Coefficient	Exponent
Subfloor	52	0.37	*0.5*
Living apace	229	0.049	*0.7*
Roof space	69	0.35	0.6

Appendlx B Detailed air flow modelling results

B.1 Building A

This concrete brick building with concrete tile roof was located in a residential area on slightly higher ground than surrounding houses. It was modelled as four internal and sixteen external nodes as shown in Figure B.1.1.The leakage path parameters are given In Table 13.1.1.

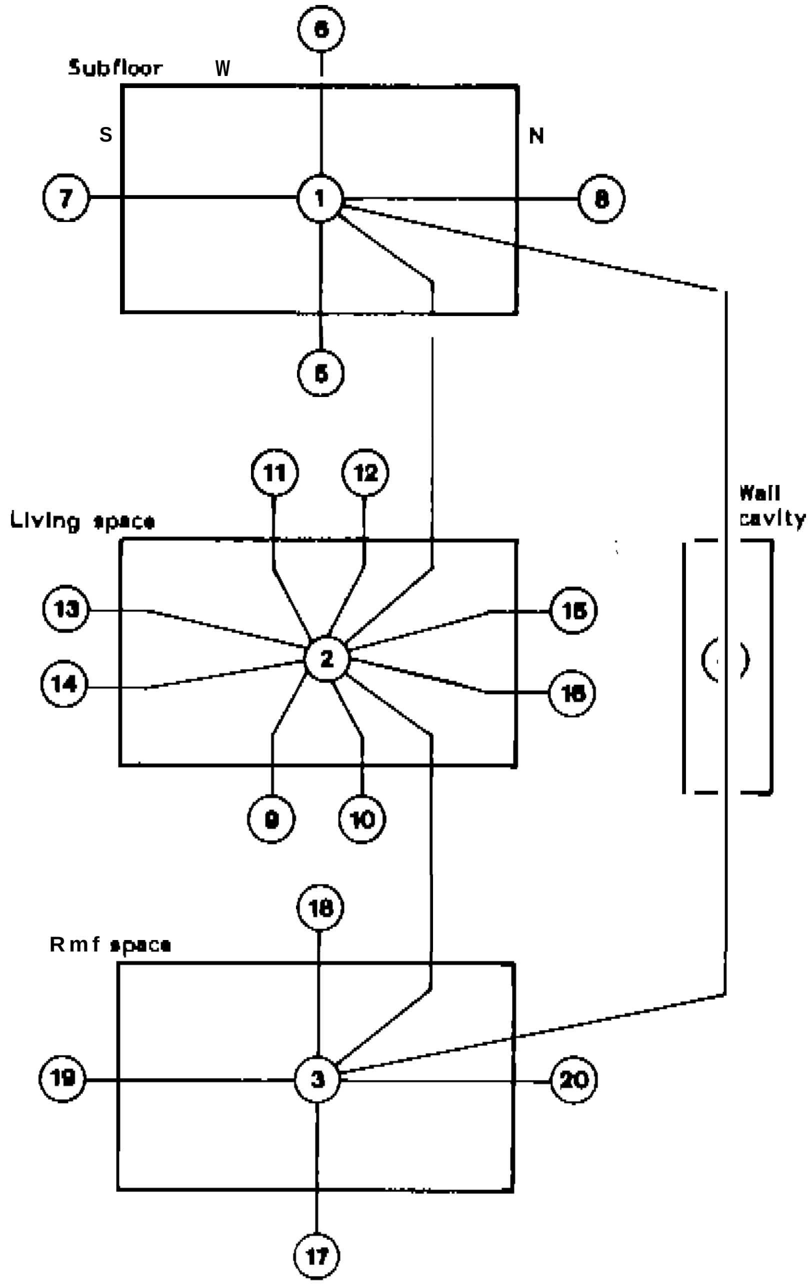


Figure B.1.1Nodal diagram for Building A

Table B.1.1 Leakage path parameters for Building A

Nods Number	Nods	Leakage Site	Orientation	K	N	Height m
1	6	Subfloor wall	E	0.12	0.81	0.5
1	6		W	0.12	0.61	0.6
1	7		S	0.06	0.61	0.6
1	0		N	0.06	0.61	0.5
2	9	Living space	E	0.007	0.64	1.6
2	10	Exterior wall	E	0.007	0.64	2.8
2	11		W	0.007	0.64	1.6
2	12		W	0.007	0.84	2.8
2	13		S	0.003	0.64	1.6
2	14		S	0.003	0.64	2.8
2	15		N	0.003	0.64	1.6
2	18		N	0.003	0.84	2.8
3	17	Roof - pitch	E	0.12	0.62	4 3
3	18	- pitch	W	0.12	0.62	4.3
3	19	- gable	S	0.016	0.82	4.3
3	20	- gable	N	0.015	0.62	4.3
1	2	Floor		0.018	0.64	1.0
2	3	Ceiling		0.018	0.84	3.4
1	4	Wall cavity		0.1	0.62	1.0
4	3	Wall cavity		0.1	0.62	3.4

Wind pressure coefficients applied in building A *are* given in Table B.1.2. Because the building was on higher ground than surrounding buildings it was given the semi-sheltered pressure coefficients of Table 4.2. Bullding A had a concrete tile roof, and leakage openings were assumed to be distributed uniformly over the pitched and gable end surfaces.

Table B.1.2 Wind pressure coefficients for Building A

Node	Wind direction N	NE	SE	S	SW	W	NW
Subfloor							
5	-.2	-.12	-.12	-.2	-.38	-.3	-.38
6	-.2	-.38	-.38	-.2	-.12	.06	-.12
7	-.2	-.32	.15	.18	.15	-.3	-.32
8	.18	.15	-.32	-.2	-.32	-.3	.15
Wall							
9.10	-.6	.25	.25	-.5	-.8	-.7	-.8
11.12	-.5	-.8	-.8	-.6	.26	.5	.26
13,14	-.35	-.6	.2	.6	.2	-.9	-.6
15.16	.6	.2	-.6	-.35	-.6	-.9	.2
Roof							
17	-.7	-.7	-.7	-.7	-.6	-.5	-.6
18	-.7	-.6	-.6	-.7	-.7	-.7	-.7
19	-.35	-.6	.2	.6	.2	-.9	-.6
20	.6	.2	-.6	35	-.6	-.9	.2

Results of simulations are given in Figures B.1.2 to B.1.4 for infiltration Into the three zones indicating that reasonably good agreement has been achieved using standardised wind pressure coefficients. Infiltration into the roof space was accurately reproduced hy the model with very few points falling outside the arbitrary 25% limits. Infiltration predictions for the living space were generally between 0.1 to 0.2 ac/h lower than measured data. One possible reason for this is suggested by the air transfer rate between subfloor and living space which was lower than measured.

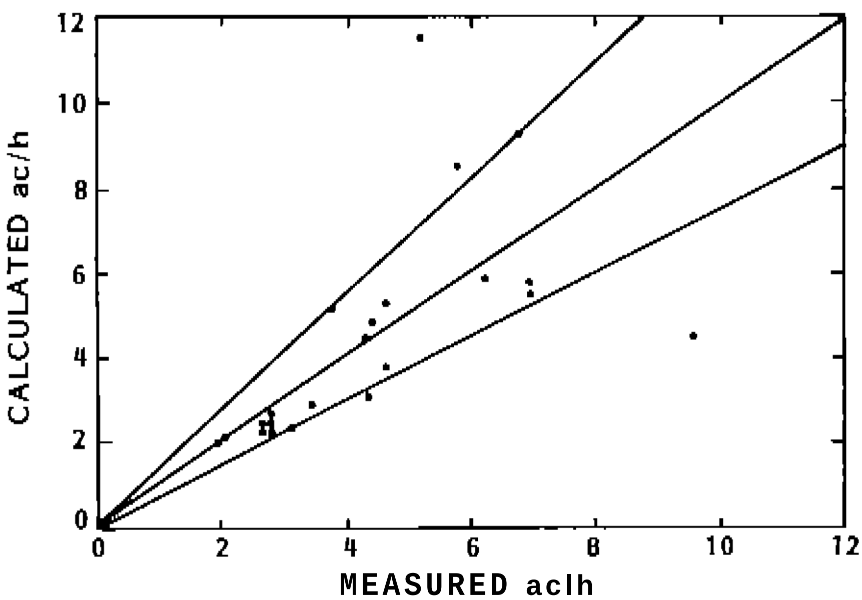


Figure B.1.2 Roof space infiltration in Building A

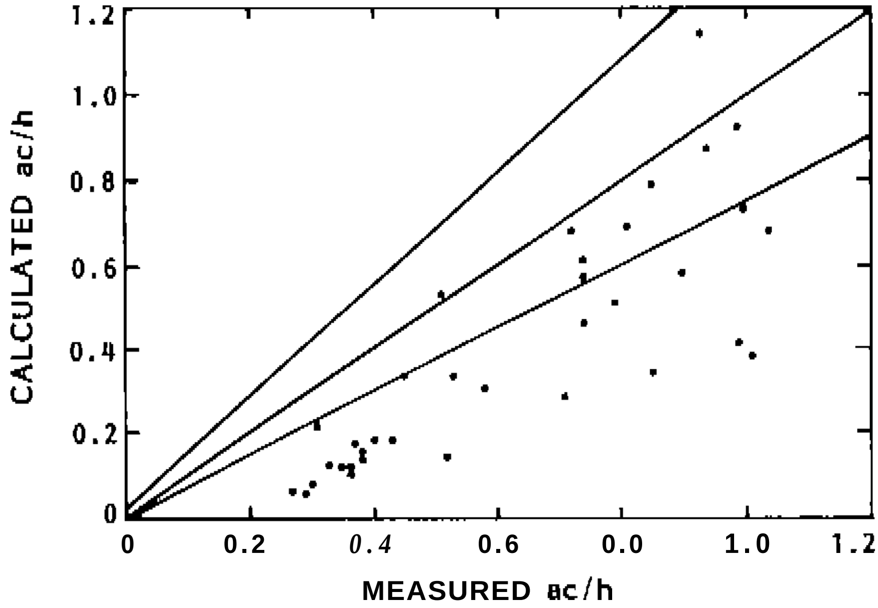


Figure B.1.3 Living space infiltration in Building A

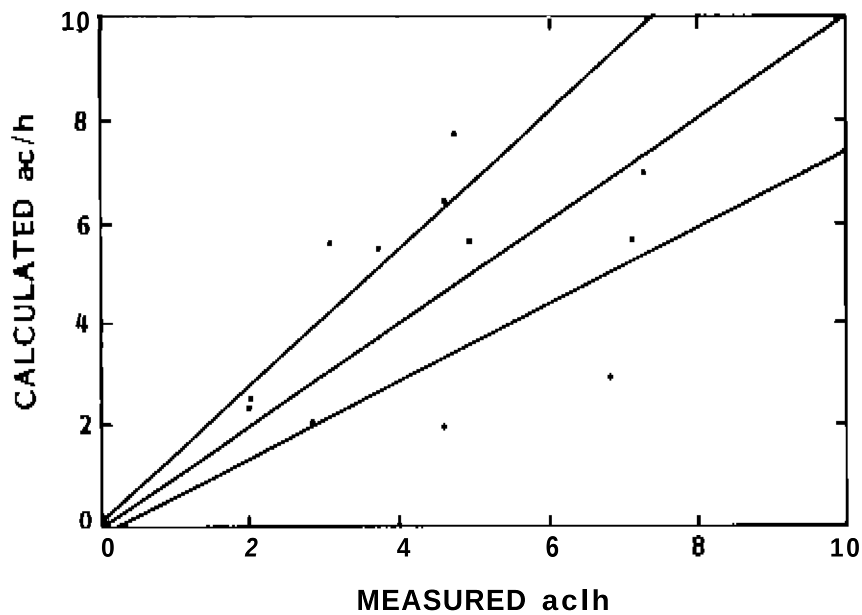


Figure B.1.4 Subfloor Infiltration in Building A

Inter-zona flows are compared in Figures B.1.Sand B.1.6.There is insufficient experimental data for a comparison of subfloor to roof space air flows in this particular building. Calculated air flow rates between living space and roof space were in the correct direction but approximately half the measured values. Subfloor to living space air flows were lass well reproduced. Air flows in both the subfloor to living and living to subfloor directions were measured experimentally, with the latter being the dominant flow. This is indicative of mora complicated time varying pressures than have been modelled. Differences between mean measured and calculated flow rates, however, suggest a lower mean subfloor pressure coefficient may have been mora appropriata for this building.

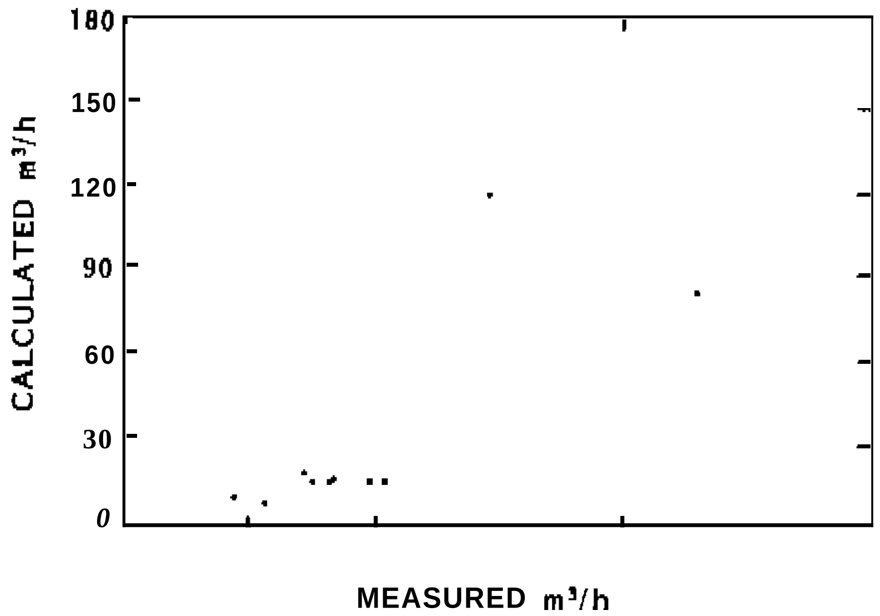


Figure B.1.5 Living space to roof space air flows

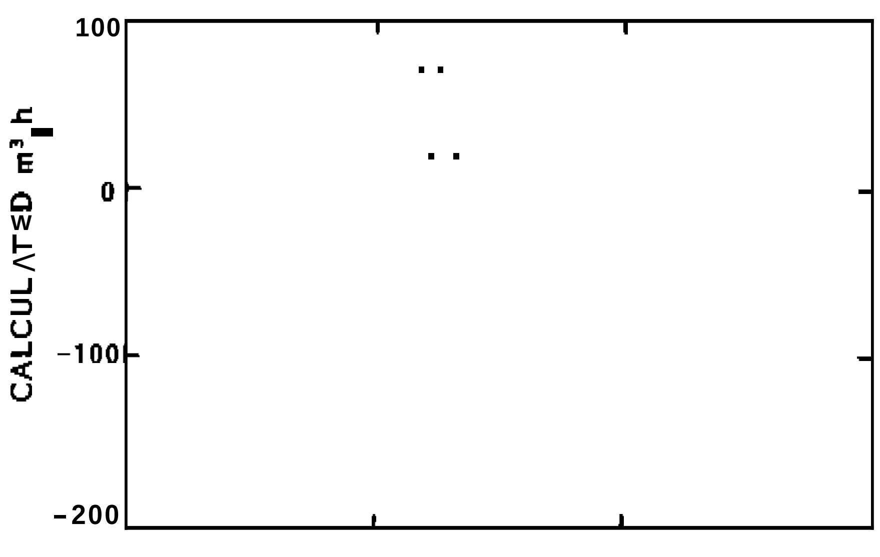


Figure B.16 Subfloor to living space air flows

B.2 Building B

This weatherboard clad single storey house was located in a residential environment and was sheltered by houses around much of its perimeter. It was exposed to winds from the N,NE but there was no experimental data with wind from these directions. Subfloor vents were shielded by shrubs planted close to the perimeter wall. Because direct air flows between subfloor and roof space were generally small in weatherboard clad houses, building B has been modelled as three internal zones and sixteen external nodes as represented in the nodal diagram in Figure B.2.1. Leakage path parameters are given in Table B.2.1.

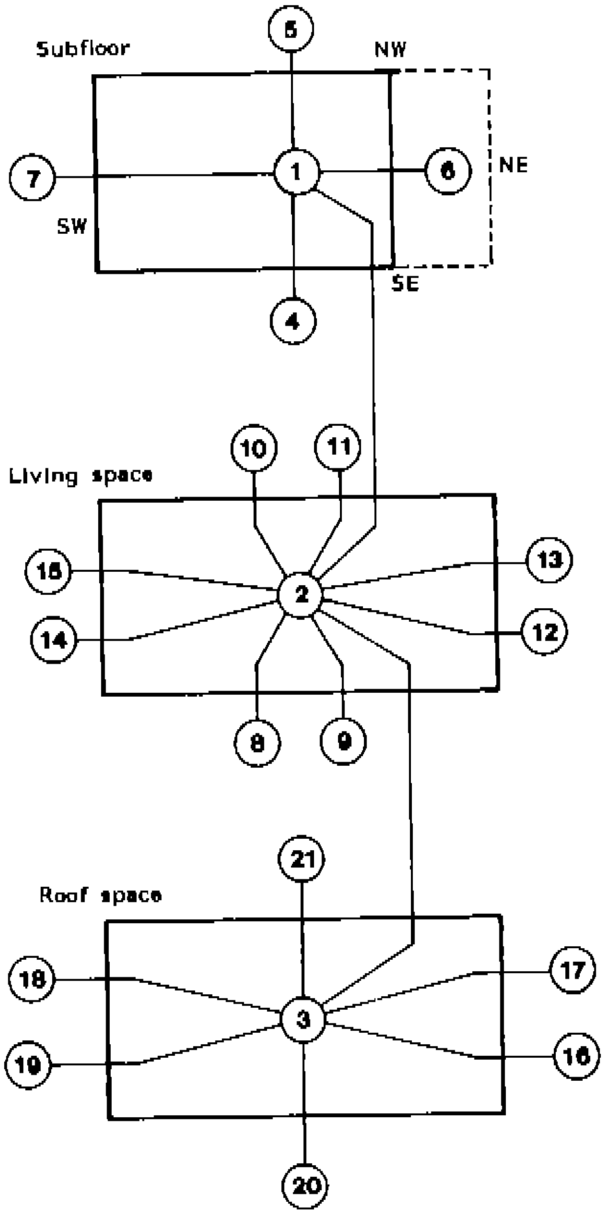


Figure B.2.1 Nodal diagram for Building B

Table B.2.1 Leakage path parameters for Building B

Node Number	Node	Leakage site	Orientation	K	N	Height m
1	4	Subfloorwall	SE	0.070	0.6	0.3
1	5		NW	0.078	0.6	0.3
1	6		NE	0.037	0.6	0.3
1	7		SW	0.037	0.5	0.3
2	8	Living space	SE	0.0033	0.7	1.2
2	9	Exterior wall	SE	0.0033	0.7	2.4
2	10		NW	0.0033	0.7	1.2
2	11		NW	0.0033	0.7	2.4
2	12		NE	0.0016	0.7	1.2
2	13		NE	0.0016	0.7	2.4
2	14		SW	0.0016	0.7	1.2
2	16		SW	0.0016	0.7	2.4
3	16	Roof-edge	NE	0.07	0.54	3.6
3	17	- pitch	NE	0.07	0.54	3.6
3	18	- edge	SW	0.07	0.54	3.0
3	19	- pitch	SW	0.07	0.64	3.0
3	20	- gable	SE	0.02	0.64	3.0
3	21	- gable	NW	0.02	0.54	3.0
1	2	Floor		0.0087	0.7	0.6
2	3	Ceiling		0.0087	0.7	3.0

Wind pressure coefficients applied in building B are given in Table B.2.2. They are the coefficients used for sheltered buildings given in Table 4.1. Leakage openings into the roof space were considered to be area-weighted to pitched and gable end surfaces. The component assodated with the larger pitched roof sections has been divided equally between leakage openings at the roof edge and openings distributed over the roof surface. The former have been assigned the pressure coeffldents of adjacent walls and the latter, pressure coefficients appropriate to a 10 degree pitch roof.

Table B.2.2 Wind pressure coefficients for Building B						
Node	Wind direction					
	E	NW	SE	S	SW	W
Subfloor						
4	-.15	-.15	0	-.15	-.15	-.15
5	-.15	0	-.15	-.15	-.15	-.15
6	0	0	0	0	0	0
7	-.15	-.15	-.15	0	0	0
Wall						
8,9	-.12	-.3	.06	-.12	-.2	-.38
10,11	-.38	.06	-.3	-.38	-.2	-.12
12,13	.15	-.3	-.3	-.32	-.2	-.32
14,15	-.32	-.3	-.3	.15	.18	.15
Roof						
16	.15	-.3	-.3	-.32	-.2	-.32
17	-.46	-.49	-.49	-.46	-.41	-.46
18	-.32	-.3	-.3	.15	.18	.16
19	-.46	-.49	-.49	.46	-.41	-.46
20	-.12	-.3	.06	-.12	-.2	-.38
21	-.38	.06	-.3	-.38	-.2	-.12

Results of simulations are given in Figures B.2.2 to B.2.3 for infiltration Into the subfloor and roof space, There was insufficient experimental living space infiltration data for a useful comparison with calculations. Reasonably good agreement has been achieved in the subfloor using the sheltered set of pressure coefficients. Infiltration into the roof space were a little higher than measured.

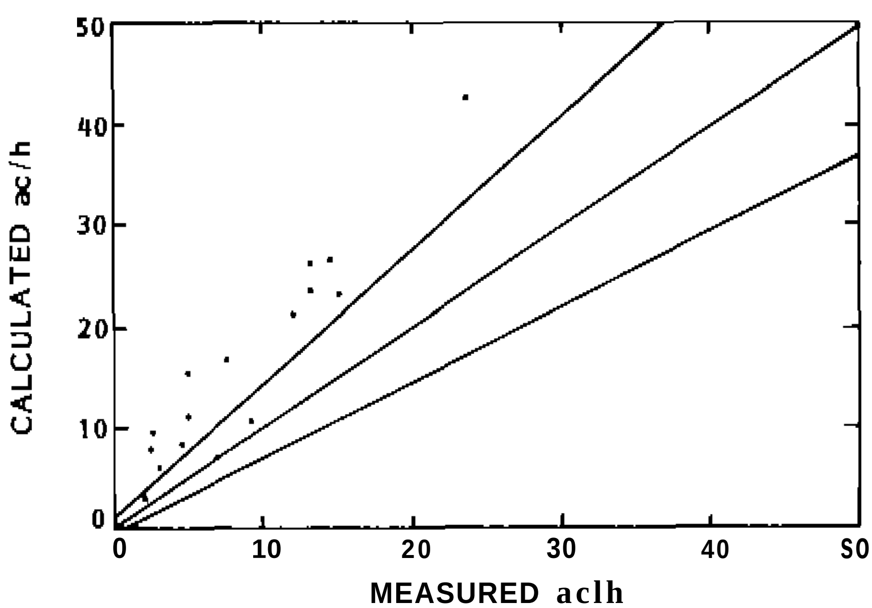


Figure B.2.2 Roof space infiltration In Building B

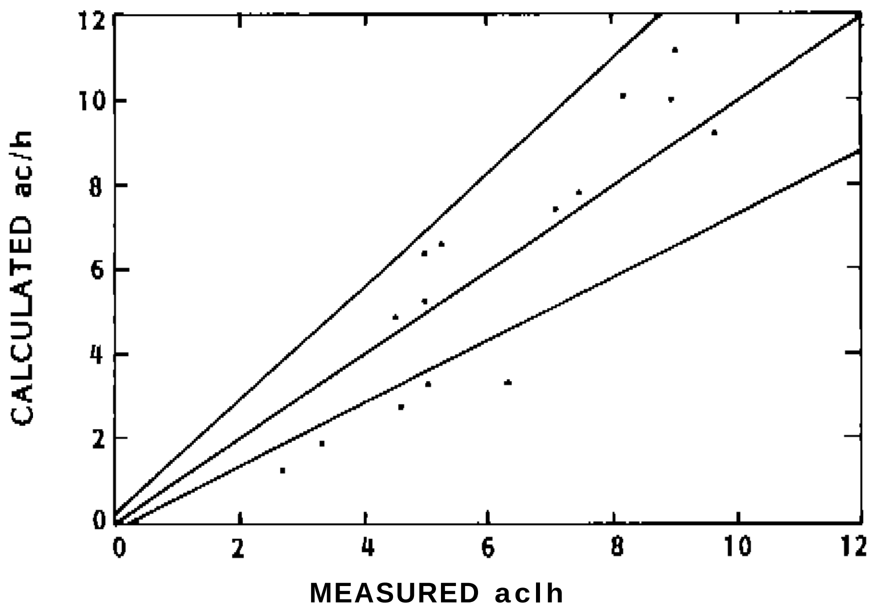


Figure B.2.3 Subfloor infiltration in Building B

Inter-zone flows are compared in Figures B.2.4 and B.2.5. Air flows between living spacc and roof space were well reproduced with few data points falling outside the arbitrary 25% limits. Air flows between the subfloor and living spaces were less well reproduced. The measured flows ware more variable than those calculated.

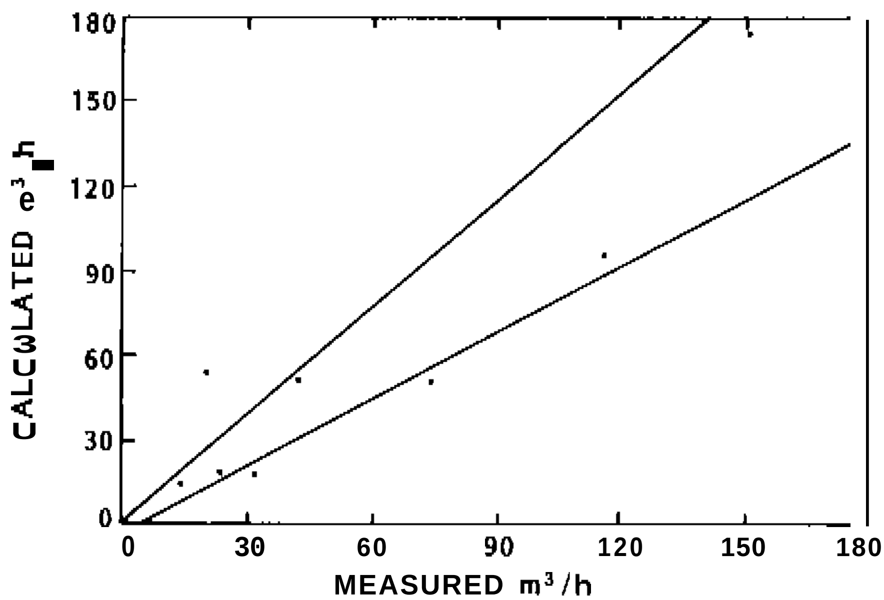


Figure B.2.4 Living space to roof space air flows in Building B

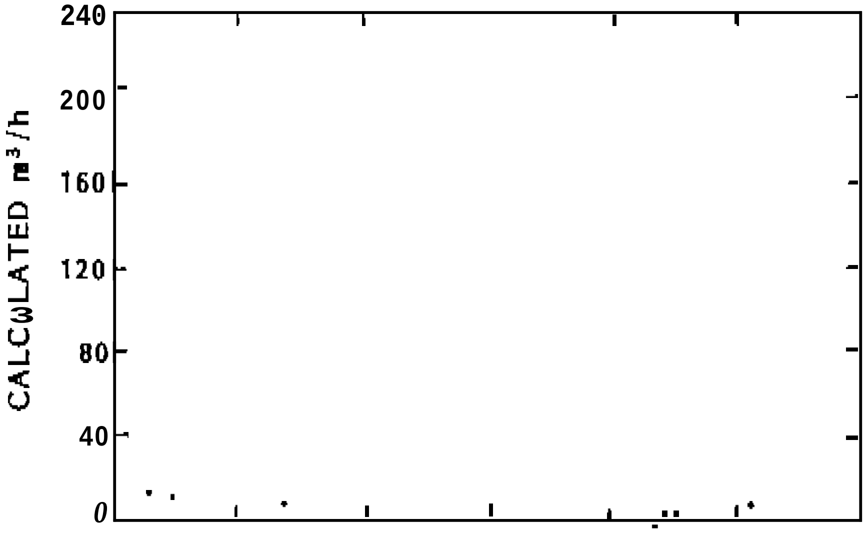


Figure B.2.5 Subfloor lo *living space air flows in Building B*

B 3 Building C

This weatherboard clad single storey house was located in a residential environment and was sheltered by trees and houses around its entire perimeter. Subfloor vents were also well shielded by shrubs planted close to the perimeter wall. The building was modelled as three internal and sixteen external nodes which are represented in Figure B.3.1. Leakage path parameters are given in Table B.3.1.

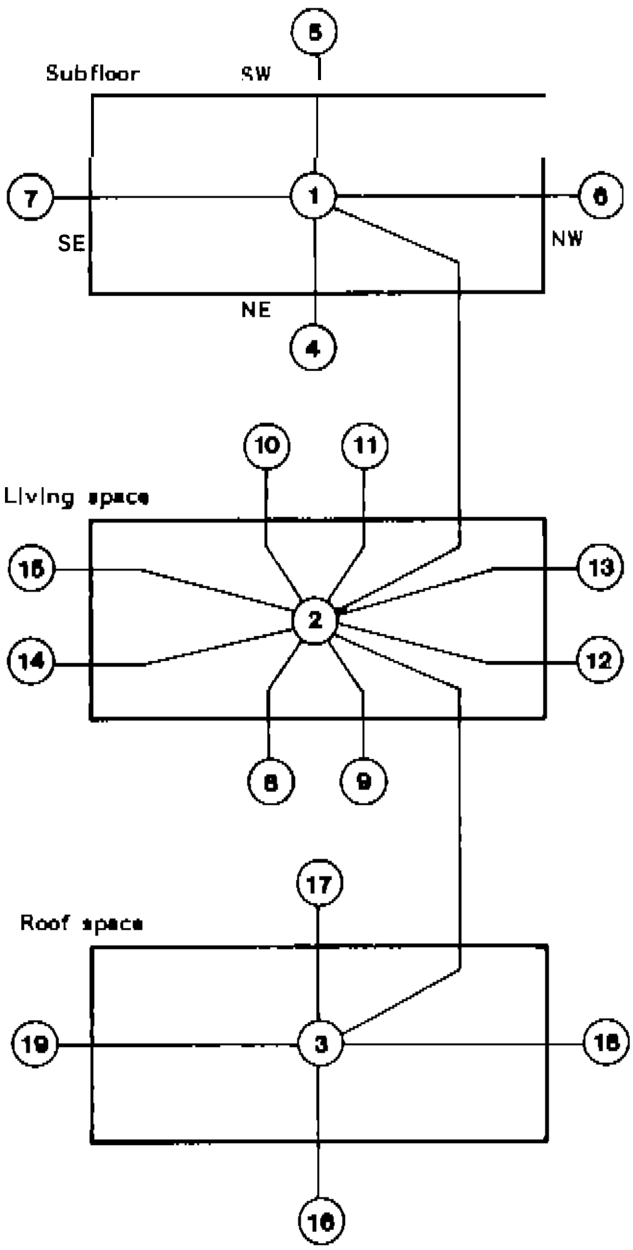


Fig B.3.1 Nodal diagram for Building C

Table B.3.1 Leakage path parameters for Building C

Node Number	Nods	Leakage site	Orientation	K	N	Height m
1	4	Subfloor wall	NE	0.048	0.55	0.3
1	6		SW	0.048	0.55	0.3
1	6		NW	0.021	0.66	0.3
1	7		SE	0.021	0.55	0.3
2	a	Living space	NE	0.011	0.66	1.2
2	8	Exterior wall	NE	0.011	0.65	2.4
2	10		SW	0.011	0.65	1.2
2	11		SW	0.011	0.65	2.4
2	12		NW	0.036	0.65	1.2
2	13		NW	0.005	0.65	2.4
2	14		SE	0.005	0.65	1.2
2	15		SE	0.036	0.65	2.4
3	16	Roof - pitch	NE	0.049	0.64	4.3
3	17	- pitch	SW	0.049	0.84	4.3
3	18	- gable	NW	0.003	0.64	4.3
3	19	- gable	SE	0.003	0.64	4.3
1	2	Floor		0.011	0.65	0.6
2	3	Ceiling		0.011	0.65	3.0

Wind pressure coefficients applied in building C arc given in Tahle B.3.2. They arc the pressure coefficients for a sheltered building given in Tabla 4.1. Leakage open-ings into **the roof space wcrc considered to lie mostly at the perimeter of the roof and were given the same pressure coefficients as adjacent walls.**

Table B.3.2 Wind pressure coefficients for Building C

Node	Wind direction							
	N	NE	E	SE	9	SW	W	NW
Subfloor								
4	-.15	0	-.15	-.15	-.15	-.15	-.15	-.15
6	-.15	-.15	-.15	-.15	-.15	-.15	-.15	-.15
6	0	-.15	-.15	-.15	-.15	-.15	0	0
7	-.15	-.15	0	0	0	-.15	-.15	-.15
Wall								
8,9	-.12	.06	-.12	-.2	-.38	-.3	-.38	-.2
10,11	-.38	-.3	-.38	-.2	-.12	.06	-.12	-.2
12.13	.15	-.3	-.32	-.2	-.32	-.3	.15	.18
14,15	-.32	-.3	.15	.18	.16	-.3	-.32	-.2
Roof								
16	-.12	.06	-.12	-.2	-.38	-.3	-.38	-.2
17	-.38	-.3	-.38	-.2	-.12	.06	-.12	-.2
18	.15	-.3	-.32	-.2	-.32	-.3	.15	.18
IQ	-.32	-.3	.15	.18	.15	-.3	-.32	-.2

Results of simulations arc given in Figures B.3.2 to B.3.4 for infiltration into the subfloor, living and roof space zones. In the roof space there is clear indication of wind direction sensitivity not seen in the experimental data. This is discussed more fully in section 5 with a graph illustrating the sensitivity of calculated and measured infiltration to wind direction. Infiltration rates calculated for the NW direction where the main leakage openings were given the same pressure coefficient, fall mostly within 25% of the measured data. For other wind directions, where the pressure coefficients for the main roof pitches were significantly different. the roof space infiltration and the living **space** to roof space flow rate were higher than measured. Pressure coefficients around -.25 would have been more suitable for this particulaly sheltered roof. Similar wind direction sensitivity Is seen in the subfloor and living space data although generally reasonable agreement was achieved with experimental data,

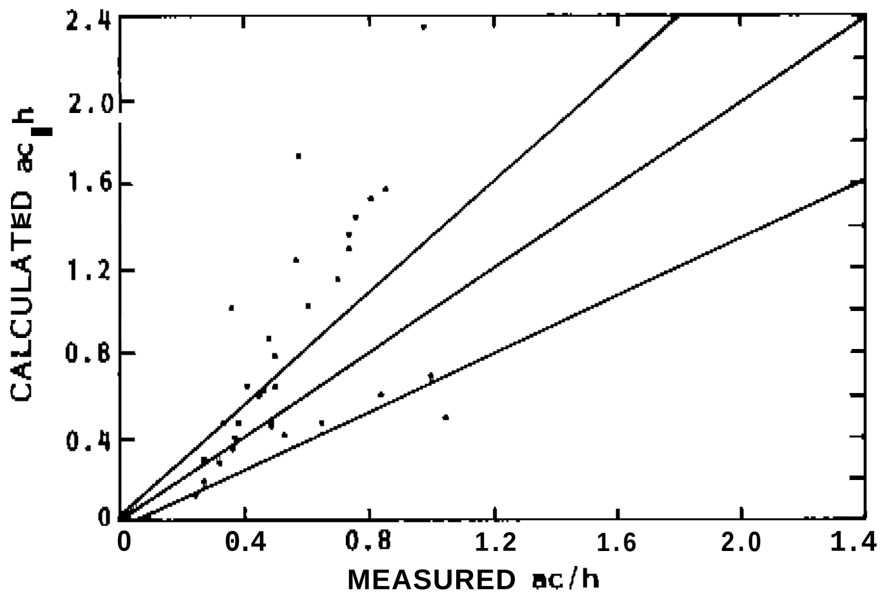


Figure B.3.2 Roof space infiltration in Building C

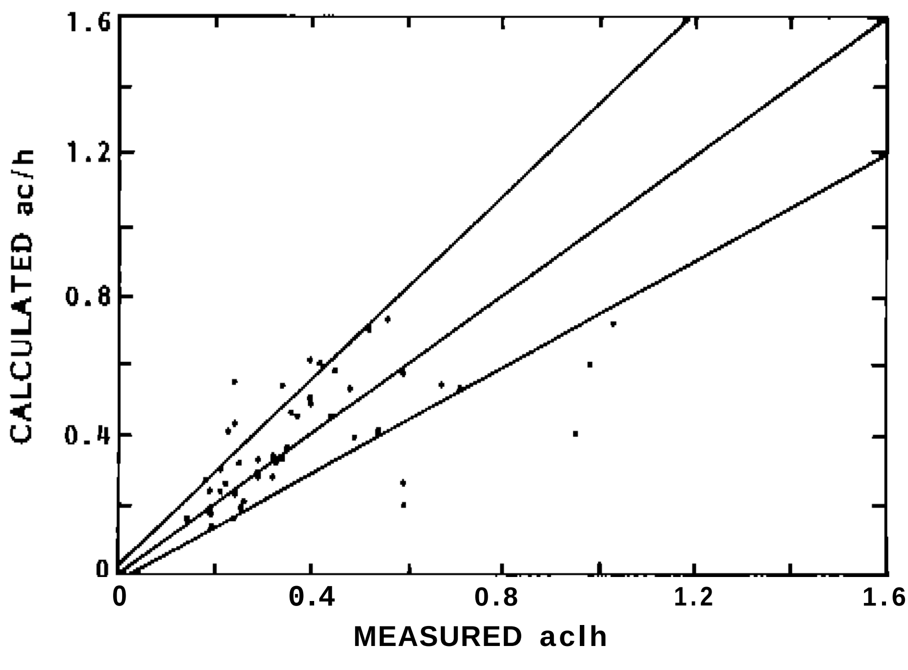


Figure B.3.3 Living space infiltration in Building C

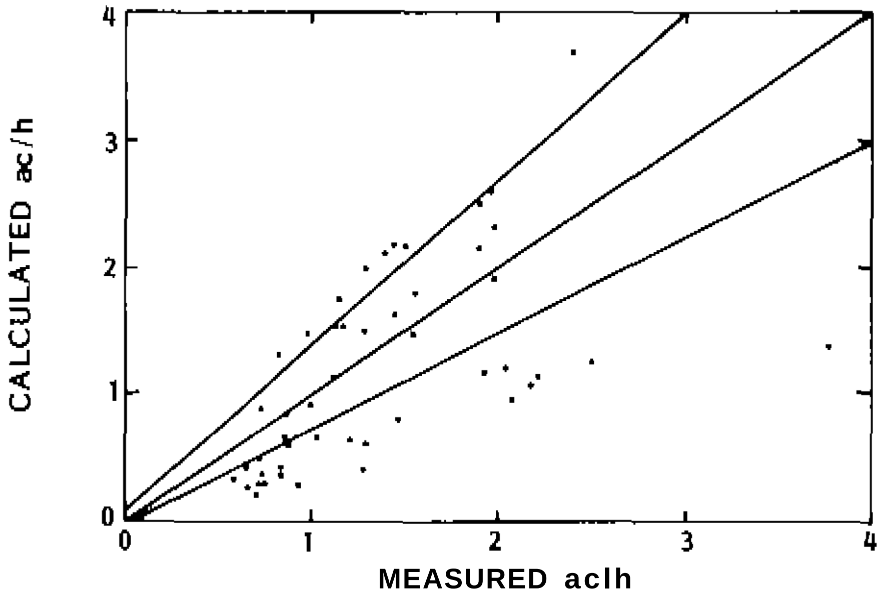


Figure B.3.4 Subfloor Infiltration in Building C

Inter-zone flows **are** compared **in Figures B.3.5 and B.3.6 indicating that In genaral the calculated** flow **rates were higher, and less varlable than measurements. In most cases the calculated airflow directlon was correct, suggesting that adjusting the pro-**portion of **leakage opening assigned to the ceiling and floor could achieve** reason-

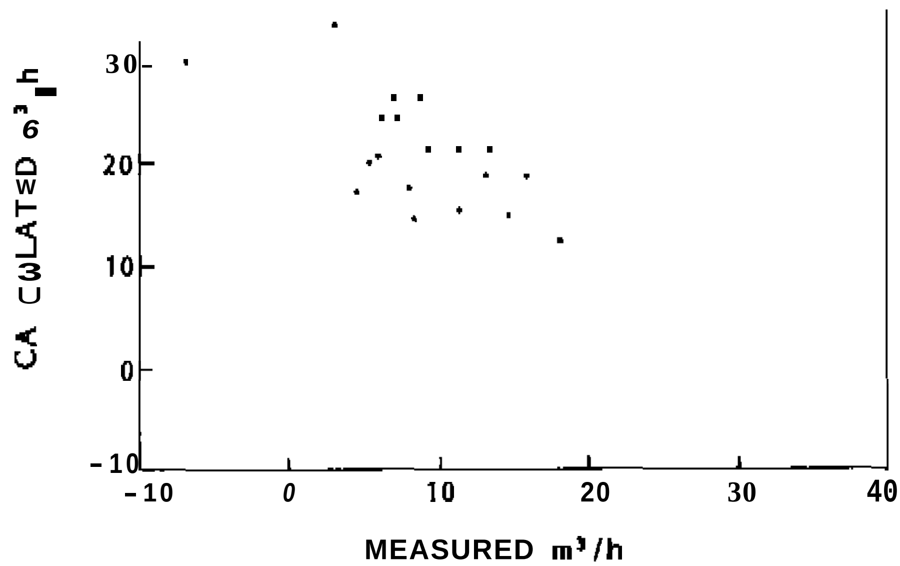


Figure B.3.5 Subfloor to living space air flows

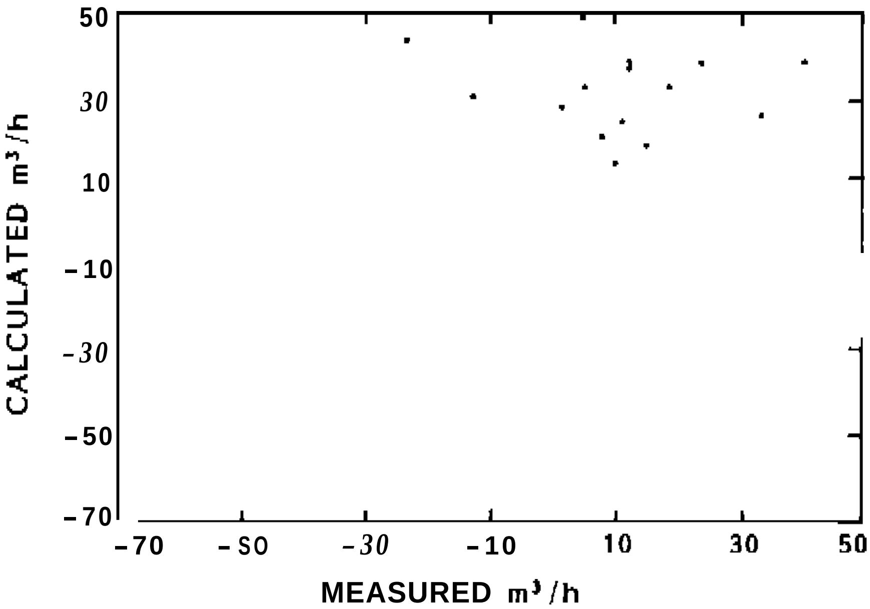


Figure B.3.6 Living space to roof space air flows

B.4 Building D

This weatherboard clad single storey house was located in a residential environment and sheltered by trees, houses and rising ground from NE,N,NW winds and exposed to winds from other directions. It was modelled as three internal and sixteen external nodes are shown in Figure B.4.1. The leakage path parameters are given in Table B.4.1.

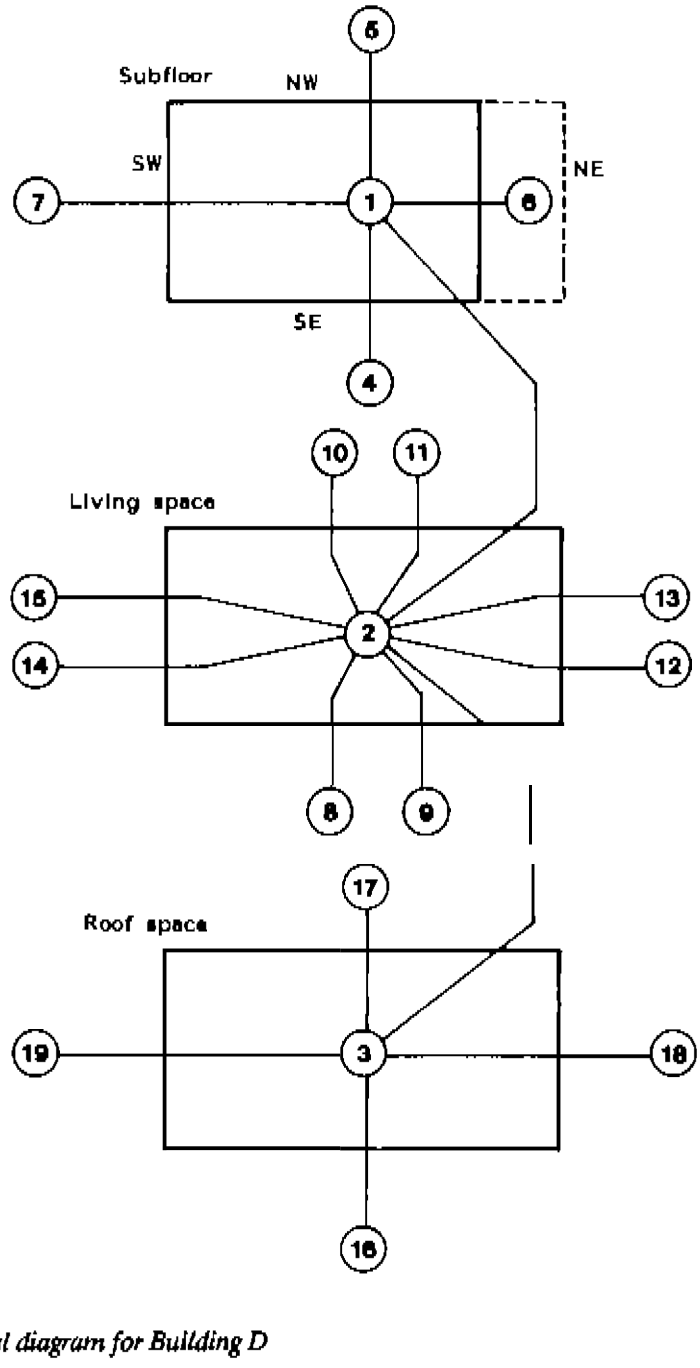


Figure B.4.1 Nodal diagram for Building D

Table B.4.1 Leakage path parameters for Building D

Node Number	Node	Leakage site	Orientation	K	N	Height m
1	4	Subfloor wall	SE	0.053	0.84	0.3
1	6		NW	0.053	0.84	0.3
1	6		NE	0.023	0.84	0.3
1	7		SW	0.023	0.84	0.3
2	8	Living space	SE	0.0018	0.85	1.2
2	9	Exterior wall	SE	0.0018	0.85	2.4
2	10		NW	0.0018	0.85	1.2
2	11		NW	0.0018	0.86	2.4
2	12		NE	0.0008	0.86	1.2
2	13		NE	0.0008	0.86	2.4
2	14		SW	0.0008	0.85	1.2
2	16		SW	0.0008	0.86	2.4
3	16	Roof - pitch	SE	0.027	0.93	3.7
3	17	- pitch	NW	0.027	0.93	3.7
3	18	- gable	NE	0.003	0.93	3.7
3	19	- gable	SW	0.003	0.83	3.7
1	2	Floor		0.0041	0.85	0.6
2	3	Ceiling		0.0041	0.86	3.0

Wind pressure coefficients applied in building D *are* given in Table B.4.2. The building was reasonably exposed to prevailing winds and was assigned wind pressure coefficients from Table 4.2. Suhfloor vents on the NE side were inside a garage and have been given a pressure coefficient of zero. There was no experimental air flow data with wind from the sheltered quarter. Leakage openings Into the roof space were **considered** to lie mostly at the perimeter of the roof and were given the same pressure coefficients as adjacent walls.

Table B.4.2 Wind pressure coefficients for Building D

Node	E	SE	S	SW	W
Subfloor					
4	-.12	.08	-.12	-.3	-.15
5	-.38	-.3	-.38	-.3	-.15
6	0	0	0	0	0
7	-.32	-.3	.15	.06	0
Wall					
8,9	.25	.5	.25	-.5	-.38
10.11	-.8	-.7	-.8	-.5	-.12
12,13	.2	-.9	-.6	-.35	-.32
14,15	-.6	-.9	.2	.6	.15
Roof					
16	.25	.5	.25	-.6	-.38
17	-.8	-.7	-.a	-.5	-.12
18	.2	-.9	-.6	-.35	-.32
					15

Results of simulations are given in Figures B.4.2 to B.4.4 for infiltration into the three zones, indicating that reasonable agreement was achieved in the living space and subfloor. In the roof space the calculated infiltration rates were lower than measurement for the prevailing SW wind dlrectlon. Irrespective of whether wall or sloping roof pressure coefficients were assigned to the major leakage openings on the NW and SE roof surfaces, they are similar in value and calculated infiltration rates arc very much lower than measured.

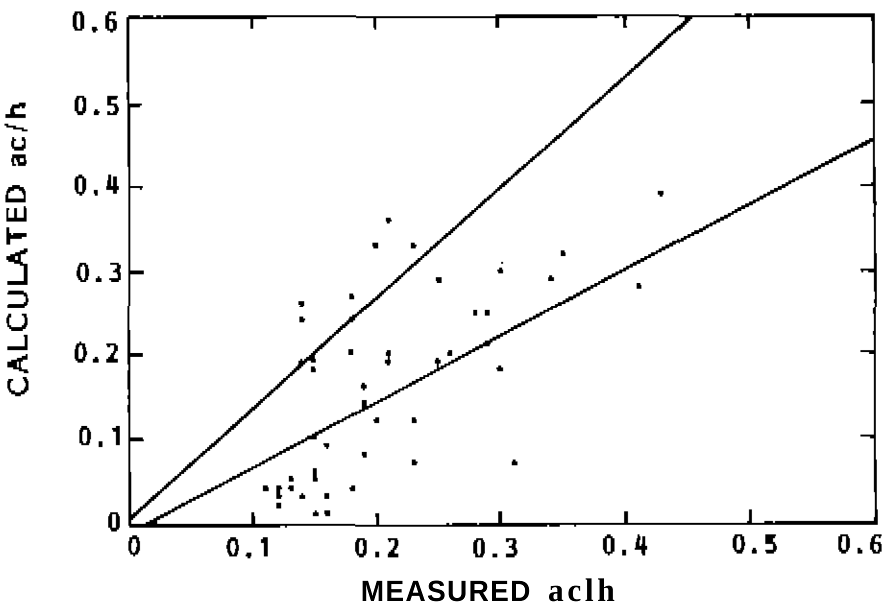


Figure B.4.2 Living space infiltration in Building D

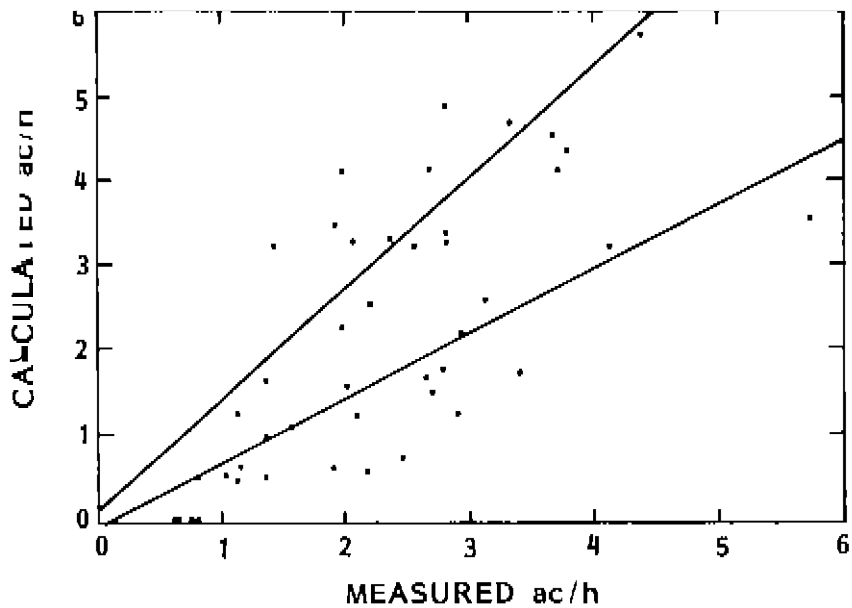


Figure B.4.3 Subfloor infiltration in Building D

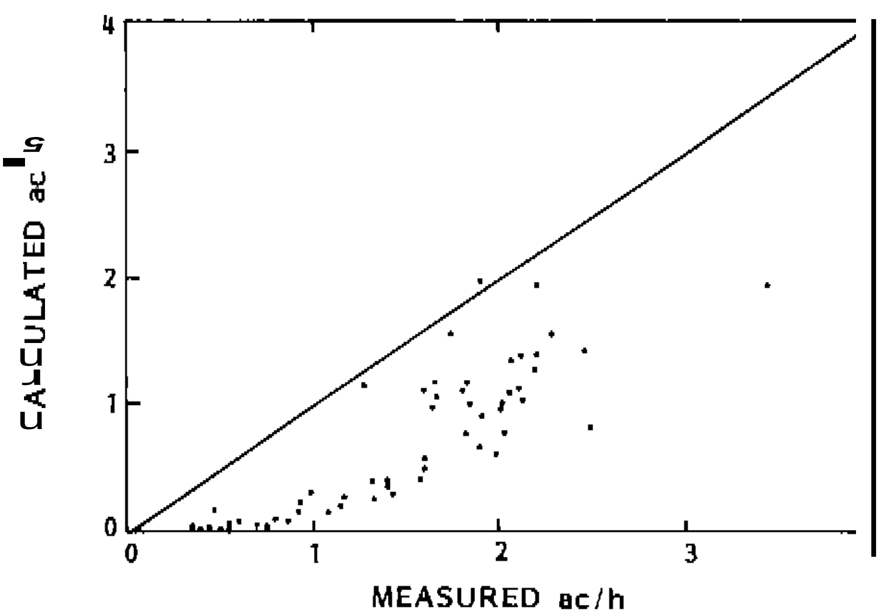


Figure B.4.4 Roof space infiltration in Building D

Inter-zone flows are compared in Figures B.4.5 and B.4.6 indicating that inter-zone air flow rates based on simple area-weighted leakage characteristics have given a similar mean air flow between living space and roof spaca. Subfloor to living space air flows have not been well reproduced. They are similar to the subfloor to living space air flows in building A in that the calculated data is much less variable than measurement.

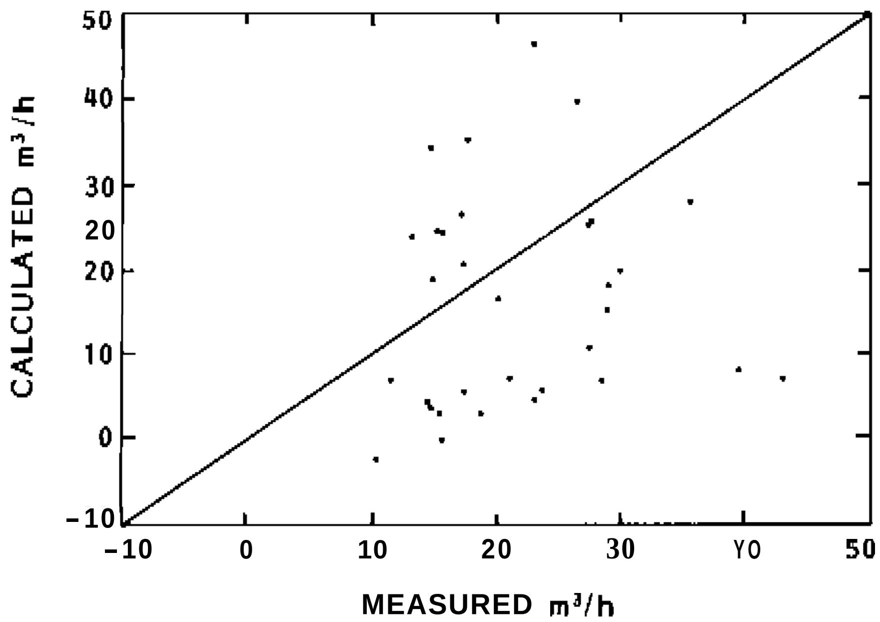
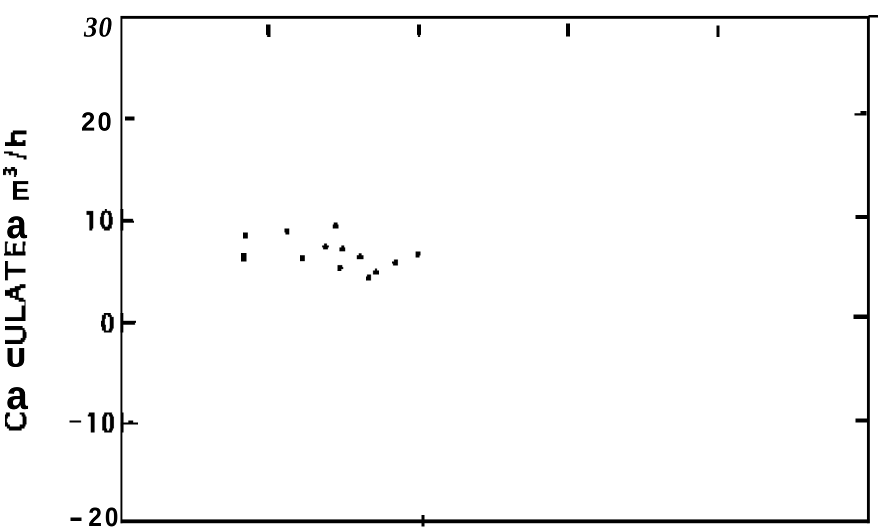


Figure B.4.5 Living space to roof space air flows for Building D



B.5 Building E

This brick clad single storey house was located in a rural environment but was sheltered by trees. rising ground and low sheds around much of the perimeter. It was more exposed to NE,N,NW winds but these were infrequent during the experimental period.

The three zones, together with an arbitrary wall cavity zona connecting subfloor to roof space, are represented as a nodal diagram in Figure B.5.1 and the leakage path parameters are given in Table B.5.1.

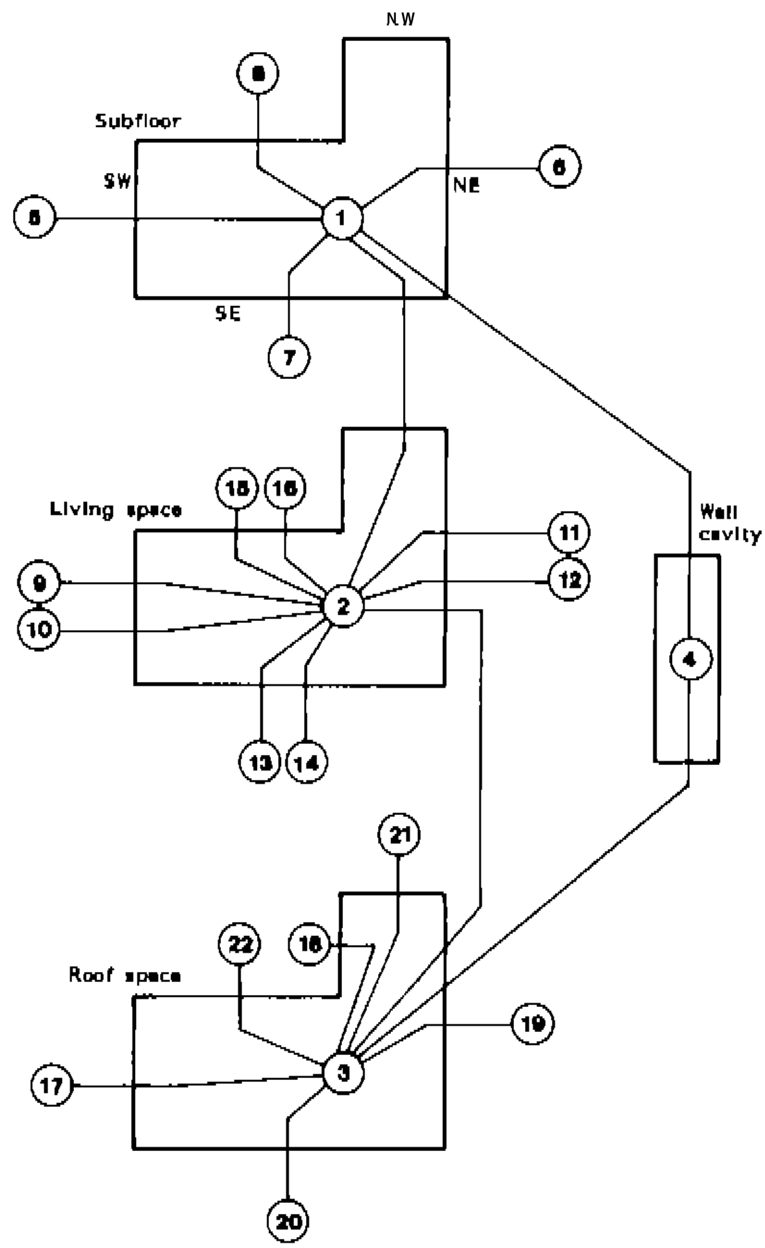


Figure B.5.1 Nodal diagram for Building E

Node Number	Node	Leakage site	Orientation	K	N	Height m
1	5	Subfloor wall	SW	0.08	0.5	0.3
1	6		NE	0.073	0.6	0.3
1	7		SE	0.088	0.6	0.3
1	8		NW	0.088	0.5	0.3
2	Q	Living space	SW	0.0034	0.7	1.2
a	10	Exterior wall	SW	0.0034	0.7	2.4
2	11		NE	0.0031	0.7	1.2
2	12		NE	0.0031	0.7	2.4
2	13		SE	0.0038	0.7	1.2
2	14		SE	0.0030	0.7	2.4
2	15		NW	0.0038	0.7	1.2
2	16		NW	0.0038	0.7	2.4
3	17	Roc gable	SW	0.013	0.6	3.6
3	18	- pitch	SW	0.032	0.6	3.6
3	19	- pitch	NE	0.067	0.6	3.8
3	20	- pitch	SE	0.117	0.6	3.8
3	21	- gable	NW	0.006	0.6	3.6
3	22	- pitch	NW	0.096	0.6	3.6
1	2	Floor		0.012	0.7	0.8
2	3	Ceiling		0.012	0.7	3.0
1	4	Wall cavity		0.05	0.6	0.3
4	3	Wall cavity		0.05	0.6	3.0

Table B.5.1 Leakage path parameters for Building E

Wind pressure coefficients applied to building E are those listed in **Table** 4.1 **for** a sheltered building. For the external nodes the pressure coefficients are listed in Table **B.S.2.**

								TaMe B.5.2 Wlnd pressure coefflclents lor Bullding E
Node				Wlnd dlrectlon				
	N	NE	E	SE	8	SW	W	NW
Subfloor								
5	-.15	-.16	-.15	-.15	0	0	0	-.15
6	0	0	0	-.15	-.15	-.15	-.15	-.15
7	-.15	-.16	-.15	0	-.15	-.15	-.15	-.15
8	-.15	-.15	-.15	-.15	-.15	-.15	-.15	0
Wall								
9,10	-.32	-.2	-.32	-.3	.is	.18	.15	-.3
11.12	.is	.18	.15	-.3	-.32	-.2	-.32	-.3
13.14	-.38	-.2	-.12	.06	-.12	-.2	-.38	-.3
15.18	-.12	-.2	-.38	-.3	-.38	-.2	-.12	.06
Roof								
17	-.32	-.2	-.32	-.3	.15	.18	.15	-.3
18	-.46	-.49	-.46	-.41	-.46	-.49	-.46	-.41
19	-.46	-.49	-.46	-.41	-.48	-.49	-.46	-.41
20	-.46	-.41	-.46	-.49	-.46	-.41	-.46	-.49
21	-.12	-.2	-.38	-.3	-.38	-.2	-.12	.06
22	-.46	-.41	-.46	-.49	-.46	-.41	-.46	-.49

Results of simulations arc given in Figures B.5.2 to B.5.4 for infiltration Into the three zones, indicating that reasonably good agreement has been achieved using standardised wind pressure coefficients. Infiltration into the roof space was accurately reproduced hy the model with very few points falling outside the arbitrary 25% limits. Infiltration predictions for living space and subfloor were also reasonably satisfactory.

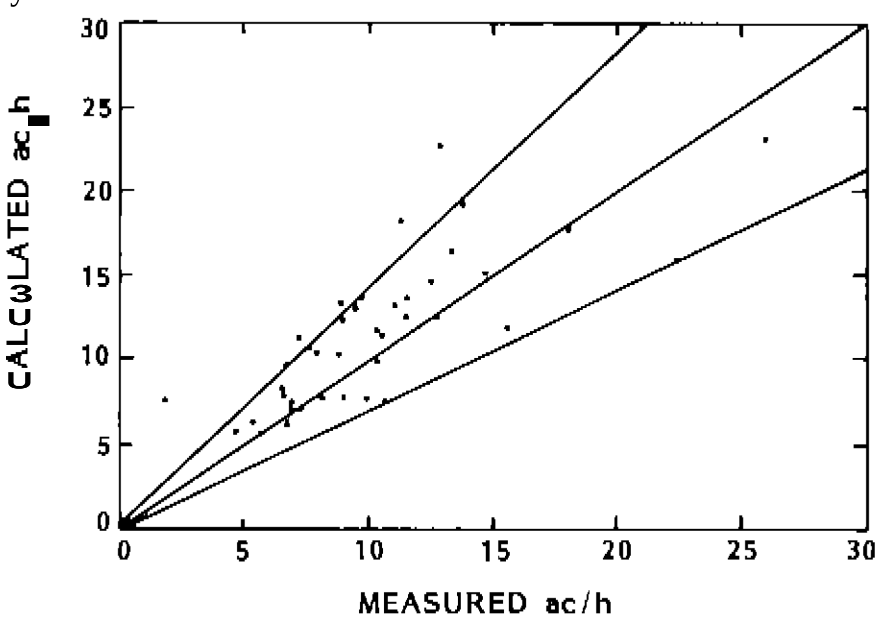


Figure B-5.2 Roof space infiltration in Building E

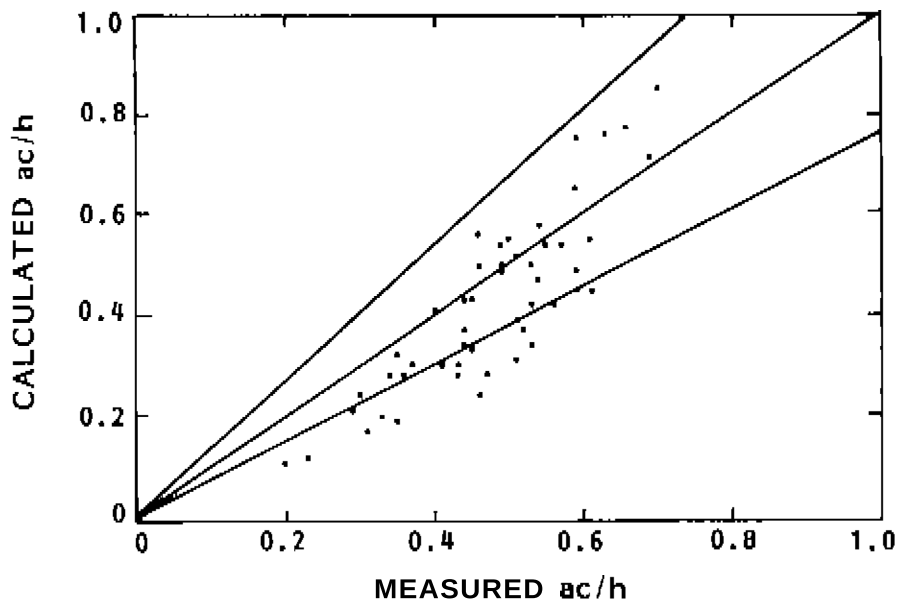


Figure B.5.3 Living space infiltration in Building E

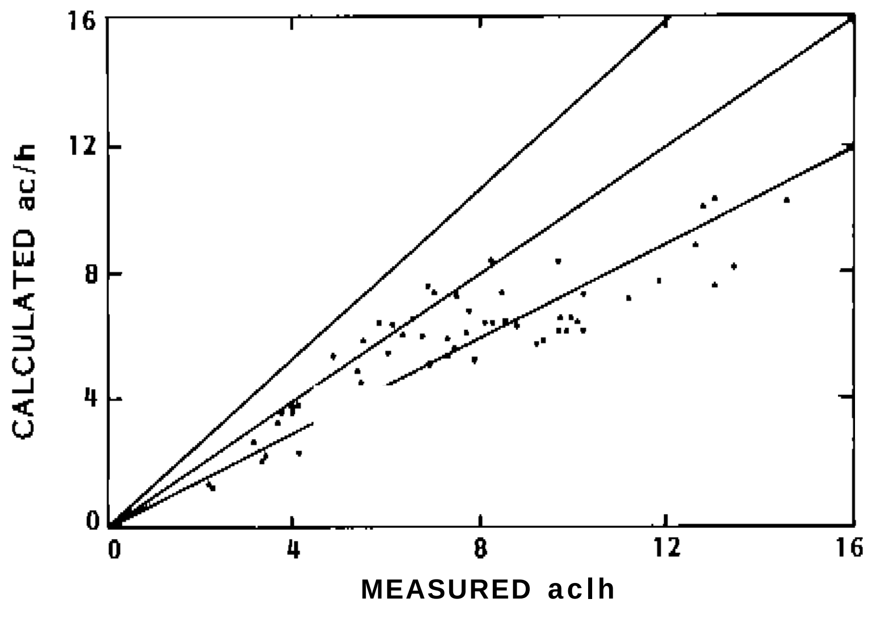


Figure B.5.4 Subfloor infiltration in Building E

Inter-zone flows are compared in Figures B.5.5 to B.S.7 indicating that the assumed inter-zone air flow characteristics havc given reasonable agreement with air flows measured between living space and roof space and between subfloor and roof space. Air flows between subfloor and living space were less well reproduced, indicating that the subfloor may have been rather more airtight than assumed.

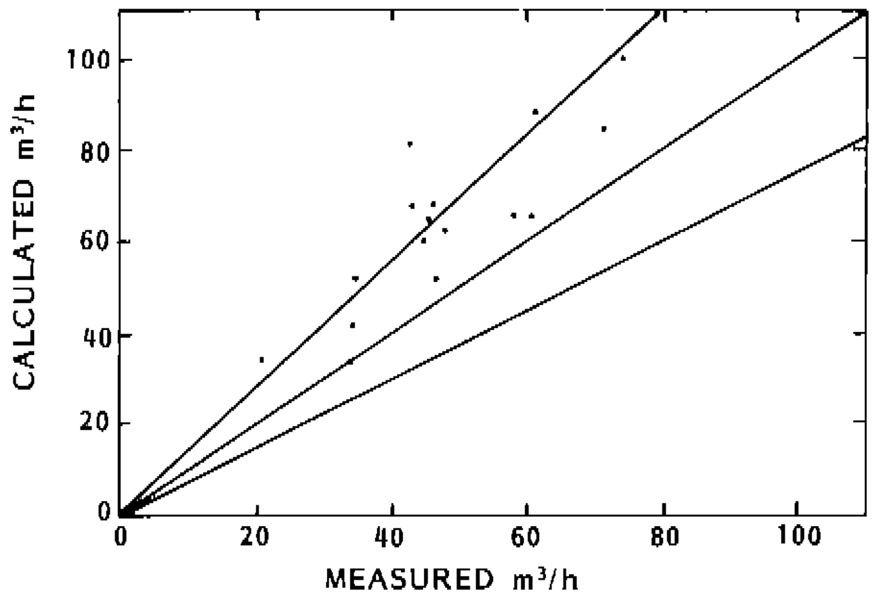


Figure B.5.5 Living space to roof space air flows for Building E

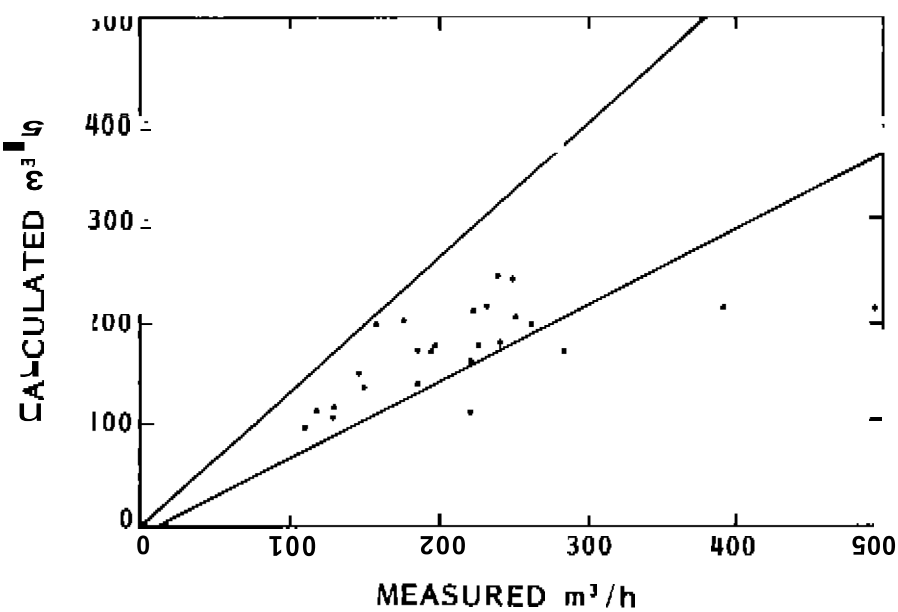


Figure B.5.6 Subfloor to roof space air flows for Building E

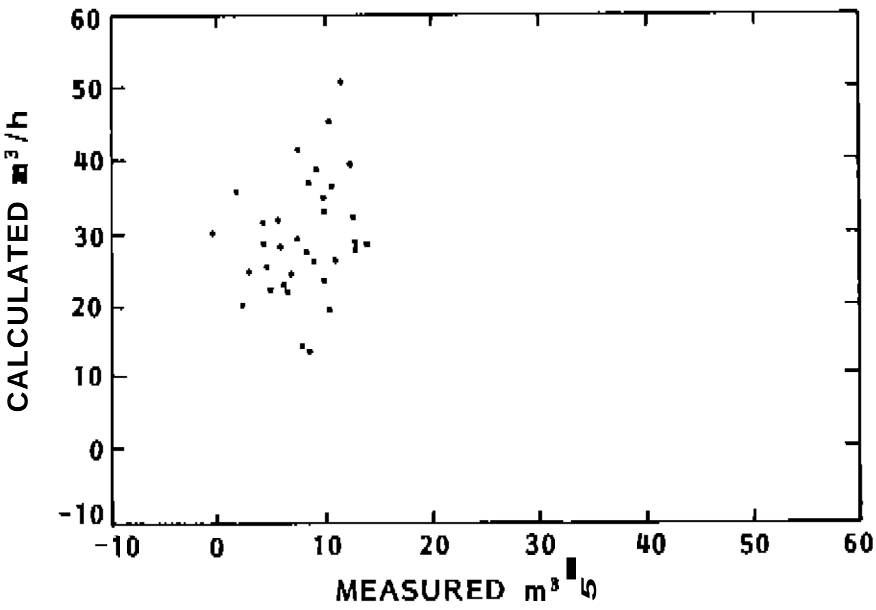


Figure B.5.7 Subfloor to living space air flows in Building E

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