CONDENSATION, HEATING AND VENTILATION IN SMALL HOMES

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BRE has investigated condensation in recently built 1-bedroom and bedsit homes in the UK. The study revealed significant condensation problems and gave an indication of the factors related to condensation: ventilation devices (particularly a passive ventilator in the bedroom, a mechanical ventilator in the kitchen and/or bathroom, or an air brick in any inner hall or landing); air movement (via stairs); heating (particularly the heating period and using bottled gas) and insulation. These factors were more important than occupant behaviour and "energy consciousness". It seems therefore that ventilation and heating facilities which depend on occupant behaviour are generally used effectively. The most important occupant characteristics were the number and age of occupants.

INTRODUCTION

Our study was concerned with owner occupied 1-bedroom and bedsit homes, built 1980-1985. Many such homes have been built, incorporating modern standards of insulation and ventilation and usually (though not always) a heating system. There had been anecdotal reports of condensation problems in such homes, which is surprising since the homes already have features proven in general to be effective measures against condensation. It was therefore of interest to investigate why such problems occur.

Condensation can occur in any type of dwelling, but there may be causes and solutions specific to small homes or the lifestyle and behaviour of their occupants. Condensation occurs when ventilation, insulation and heating are inadequate in the context of the moisture production in the dwelling. Even with adequate provision for these, full and proper use may not be made of them, and the design of the home may not promote full and proper use (e.g. ventilation and heating may conflict). Without better understanding of the interaction between building design and occupant behaviour, further application of standard solutions may be ineffective.

The main aim of the study was to identify the factors that contribute to condensation, thus providing the basis for suggesting remedies. We also investigated occupant perception of the seriousness of condensation and the correlation between subjective and objective measures.

METHOD

An interview was conducted at 383 homes (66% of valid contacts) in 5 regions of the UK (London, Havant, Leeds, Manchester, Dundee). All homes were over 1 year old, since newer homes may still be drying out from construction and the residents would not have experienced a full year in the dwelling. Sampling was based on information from Local Authorities in the 42 regions with the highest numbers of the required homes. 15 regions were chosen to represent a range of climates and a postal survey carried out to provide sampling data. The 5 regions were then chosen to represent a cross-section of dwelling types and climatic conditions.

A questionnaire provided data on condensation and mould, demographic details; pattern of home occupancy; dwelling size and structure; insulation; heating system and controls; heating behaviour and thermal comfort; fuel type and consumption; provision and use of ventilation; infiltration; air movement; knowledge of energy use and conservation; clothes drying and ratings of the home and home area. The following measures of condensation were used.

1. Respondents rated the seriousness of condensation on a scale from 1 (Not at all a problem) to 7 (A very serious problem), and rated how worried they were about condensation, on a 4-point scale: Very Much (1), Quite a Lot (2), A Little (3), and Not Worried (4).

2. MOULD. Interviewers rated (in each room) any mould which could be observed during the interview, from 1 (No mould) to 6 (Continuous areas of mould in cold spots and elsewhere). For most analyses, we defined a new variable, "MOULD" (the mean rating for all rooms).

3. COND. Respondents stated whether, during the winter, they had noticed any of a list of 8 signs of condensation (see Table 1). The sum of positive responses by each respondent (plus 1 to avoid zero scores) defines a new variable, "COND", a self-reported but relatively objective assessment of condensation problems, on a scale from 1 to 9.

RESULTS AND DISCUSSION: PREVALENCE OF CONDENSATION PROBLEMS

MOULD was the most objective measure of condensation problems, but it measured only one sign of condensation, and only problems which could be observed during the interview. We therefore used COND as the principal measure of condensation. COND correlates strongly with MOULD (accounting for 96% of the variance in MOULD, based on mean MOULD at each level of COND) and ratings of seriousness of condensation (80% of variance).

Table 1 shows the frequency of each sign of condensation. There does appear to be a problem which merits further attention. There were few homes with severe mould (only 4% had more than small patches), but the majority had condensation beyond windows steaming up. 32% of respondents

Table 1. Frequency of Various Condensation Problems.

	n	%
None	45	12
Misted mirrors/windows	327	85
Pools of water from windows	241	63
DAMP: Walls	63	16
Furniture and carpets	24	6
Clothes	14	4

	n	%
DAMAGE TO: Plaster	52	14
Woodwork	58	15
Mould	136	36

were worried very much or quite a lot by condensation and there was a significant correlation between COND and an overall rating of the home ($r=-0.314$, $p< 0.001$).

RESULTS AND DISCUSSION: FACTORS AFFECTING CONDENSATION

Statistical data are given separately at the end of this section.

Demographic Variables

MOULD was lower in pensioner households than other households. COND was also lowest for pensioners, followed by younger single-person households two-person households and households with a child. Presumably more people produce more moisture. This effect did not depend on the pattern of occupation of the home, suggesting that total moisture production is more important than the period during which the moisture is produced.

There was no evidence in our data on why pensioner households should have fewer condensation problems. COND was not significantly affected by social class, sex, keeping pets, previous housing experience, length of time in present home or expected duration of stay in that home.

Size of Dwelling

The size and type of dwelling were correlated, houses being the largest and bedsits the smallest, with flats having a wide intermediate range. Homes larger than 46.5m^2 had significantly lower COND than smaller homes and this effect is in addition to the effect of dwelling type. The number of rooms in the dwelling did not affect COND.

Moisture Production

Bottled gas heating is dealt with under heating and insulation. There was

no effect of cooking fuel. Drying clothes in the bathroom was associated with less mould in the bathroom. It may be that clothes are dried in the bathroom only if it is warm and well ventilated.

Ventilation, Infiltration and Air Movement

Passive or mechanical ventilators did not affect mould in individual rooms, except the bathroom where having a mechanical ventilator reduced mould. COND was lower if there was a passive ventilator in the bedroom, a mechanical ventilator in the kitchen or an air brick in an inner hallway or landing. Having any kind of ventilator in any other room, and the pattern of use of windows and ventilators, did not affect COND.

COND was higher where respondents said draughts made them feel uncomfortable. This was not related to indoor temperature. There was no effect on COND of having draught strip on doors or windows, or having a second external door. COND was lower for respondents who said the windows and ventilators provide enough cooling in summer and enough fresh air.

COND was highest if the stairs went from hall/landing to living room, lowest with the reverse arrangement, and intermediate if the stairs went from hall to landing or there were no stairs. This is probably due to heat transfer to bedrooms and is therefore another advantage of houses.

Heating and Insulation

The lowest COND was found with storage heaters in houses, followed by other electric heating, natural gas, storage heaters in flats/bedsits and bottled gas heating the highest COND. There was no difference in COND between homes with central heating and those with individual heaters. In larger homes this would be surprising, but in small homes there is relatively little advantage of central heating, so long as there is adequate heating in each room.

Homes heated all day had lower COND. There was no effect of the length of time the respondent typically spent out of the home before turning the heating down or off, the relative temperature of the bedroom and living room, the compass orientation of the main room or bedroom or the position of the heat source in each room. There was also no effect of room temperature or subjective ratings of temperature on COND or MOULD for the whole sample or for respondents who said that the temperature at the time of the interview was typical of the time of day and year.

COND was lower in homes with double glazed windows or external doors, filled cavity walls (or dry lining) or 100mm or more of loft insulation. There was no effect of floor type (suspended timber vs solid), but COND was lower in homes with carpet throughout than in homes with partial carpeting. The type of curtains had no significant effect on COND.

There was not a significant effect of total heat loss once floor area was taken into account. This suggests that, in the context of the type of homes studied, heat loss across individual components (which would affect surface temperature) is more important than total heat loss.

Occupant Knowledge, Expectation and Behaviour

There was a significant effect of having taken measures to reduce condensation: COND was **higher** if more measures had been taken. Thus, the greater the condensation problem, the more likely the occupants are to respond with remedial measures, but success is generally less than 100%. There was no effect of whether respondents said they would have expected to have had problems with condensation in a home like theirs. COND is not correlated with the thought the respondents put into energy conservation and heating costs when buying the home.

Statistics for Significant Effects

Mean values are given in square brackets, followed by t-test or analysis of variance statistics.

COND:
Household. Pensioner(s) [2.2] Younger single person [3.1] 2 persons [3.8, n=146] With a child [4.4] $F=5.45$, $df=5,375$, $p<0.01$
Over 46.5m² [2.4] Smaller [3.6] $F=21.14$, $df=1,376$, $p<0.001$
Passive ventilator in bedroom? Yes [2.9] No [3.5] $F=6.40$, $df=1,381$, $p<0.02$
Mechanical ventilator in kitchen? Yes [3.1] No [3.5] $F=3.93$, $df=1,381$, $p<0.05$
Air brick in inner hallway or landing? Yes [2.6] No [3.4] $F=4.32$, $df=1,381$, $p<0.05$
Draughts cause discomfort? Yes [3.9] No [3.2] $t=3.56$, $df=381$, $p<0.01$
Windows and ventilators provide enough cooling in summer? Usually [3.3] Sometimes [3.2] No [4.2] $F=4.95$, $df=2,371$, $p<0.01$
Windows and ventilators provide enough fresh air? Usually [3.2] Sometimes [4.1] No [4.5] $F=11.86$, $df=2,377$, $p<0.001$
Stairs. Hall to living room [4.5] Living room to landing [2.8] Hall to landing [3.6] $F=12.64$, $df=2,168$, $p<0.001$ No stairs [3.5].
Heating. Storage (houses) [2.3], Other electric [2.9], Natural gas [3.7] Storage (flats/bedsits) [3.8] Bottled gas [4.7] $F=12.31$, $df=4,368$, $p<0.001$
Heating period. All day [2.8] Part of day [3.5] $F=5.47$, $df=3,361$, $p<0.01$
Glazing. Double [2.3] Single [3.7] $t=7.10$, $df=381$, $p<0.001$
External doors. Single glazed [3.4] Double glazed [1.7] Wood [3.5] $F=11.00$, $df=2,380$, $p<0.001$
Walls. Filled cavity walls or dry lining [3.0] Unfilled cavity [3.6] Insulation not known [3.2] Timber framed [3.7] $F=4.43$, $df=5,261$, $p<0.001$

Loft insulation. Over 100mm [3.1] 100mm [3.3] Under 100mm [4.6] F=6.59, df=2,122, p<0.002
Fitted carpet: throughout [3.1] partial [3.6] F=7.22, df=1,336, p<0.01
Measures taken to reduce condensation. 0 [2.9] 1 [3.7] 2 [4.6] 3+ [5.3] F=33.18, df=3,379, p<0.001
MOULD:
Pensioners [1.05] Other households [1.19] t=2.01, df=380, p<0.05
Clothes dried in bathroom [1.0] Elsewhere [1.2] F=5.13, df=1,354, p<0.025
Mechanical ventilator in the bathroom? Yes [1.1] No [1.3] F=6.16, df=1,363, p<0.02

In order to check the impact of atypical households on the results, all analyses which gave a significant effect were repeated with cases removed if the household included pensioners (n=23) or children (n=12), if there was any use of bottled gas for heating (n=29) and if the home was constructed prior to the 1982 improvement of insulation standards in Building Regulations (n=37). The same factors were correlated with COND.

CONCLUSIONS

There is clearly a problem to be addressed: nearly two thirds of the homes surveyed had condensation at least enough to cause pools of water on the window sill, and one in six homes had signs of damage caused by condensation. The problems are not necessarily severe in individual homes, but are likely to become worse over time if no action is taken.

The factors which contribute to condensation problems are related to the building, the occupants, and building factors which are only effective to the extent that they bring about appropriate behaviour (e.g. the heating system and ventilators which are controlled by the occupant). In fact, ventilation behaviour has little effect on condensation levels, once the provision of ventilation is taken into account. Similarly, variation in heating behaviour and attitudes to energy have relatively little effect (except use of bottled gas and all-day heating).

It therefore seems to be worthwhile providing facilities which depend on occupant behaviour since they are on the whole used effectively. The main areas in which behaviour seems to be of significance are moisture production and longer-term factors such as the number and age of occupants and modifications to the dwelling.

The findings of this study are based on a cross-sectional survey, not the assessment of individual cases, therefore the findings cannot be applied directly to individual cases. For example, it should not be concluded that advice about reducing condensation is of no value: we have only shown that variation in behaviour in this particular population is not a major contributor to variation in condensation. The results do even so provide guidelines for identifying the likely causes of condensation problems and for establishing design principles for small homes.