ATTRIBUTING THE BLAME - A CASE STUDY OF MOISTURE DAMAGE IN HOUSING

W. Porteous

Introduction

The writer was engaged as an expert witness by a solicitor acting for a building company. The building company was the respondent to a claim by the building owner (the plaintiff) that his house had been built by the company with a standard of thermal insulation that failed to meet the building by-law requirements in force at the time of construction. Furthermore, the plaintiff claimed that damage to the interior of the house had resulted from the inadequate standard of insulation and that the considerable cost of rectifying the damage and installing the proper standard of insulation should be met by the respondent building company.

The house was built in 1989 by the building company which catered for the lower-cost end of the market and had done so successfully for some years. Examination of the drawings (one A2 sized sheet and one A4 supplementary plan including minor changes to the 'standard' plan) and the specifications revealed an adequate provision of facilities and obvious attention to the requirements for structural strength and other minimum requirements of the building by-laws of the time. As the writer was engaged as an expert witness by the legal representatives of the building company, access to the building was a matter for the home owner to allow. In the event access was not granted. Consequently the writer was obliged to rely on photographs of the visible damage to the interior together with the plans and specifications supplied by the building company.

It was acknowledged by all parties that the house had been tenanted for some years prior to the owner commencing proceedings against the building company. The damage to the interior of the house was alleged by the owner to have occurred during the tenants' occupation of the building. It appears that it may have been complaints from the tenants that alerted the owner to the damage. Faced with costs of several thousands of dollars to make good the interior of the house the owner sought to recover those costs from the building company, alleging on his Statement of Claim that the damage was caused by the builders' failure to insulate the building in accordance with the plans and specifications and the building by-law requirements in force at the time of construction.

Dr William Porteous
Victoria University of Wellington

In support of the owner plaintiff's claim against the building company the plaintiff supplied a copy of a site visit report (Ref 1) written in 1993 which reported on an investigation of mould and condensation problems in the house. The report was produced by building scientists from the Building Research Association of New Zealand (BRANZ). The BRANZ report included photographs of the damage to the interior which were the only pictorial evidence available to the respondent building company.

The BRANZ report described the insulation installed in the house as follows:

> "<u>Insulation</u>
> The floor is insulated with perforated aluminium foil.
> The walls are insulated with gib-foil.
> The ceiling is insulated with macerated paper and although there is gib foil lining on the ceiling there is no insulation value gained from the foil as the macerated paper covers the reflective surface. The thickness of the macerated paper insulation is only about 20 mm thick in parts and some places have none."

and later in the report:

> "Cause of the Problem
> There is insufficient ventilation provided during the colder months to remove the moisture from inside the house.
> There is insufficient heating in the house which meant that surfaces are cold and moisture in the air will readily condense.
> There is inadequate insulation in the walls and ceiling and if there is any heat inside the house it is readily lost through the structure.
> The heavy condensation on the windows, which is a result of insufficient heating, ventilation and insulation, is causing the MDF reveals to swell and disintegrate."

and still later in the report:

"Insulation
The existing insulation of the walls and ceiling does not meet the requirement of the New Zealand Standard Codes of Practice for insulation NZS4218P valid at the time the house was constructed."

The questions to be decided

Clearly there were two essential matters to be decided:

a)Had the walls and ceiling been insulated in accorance with the New Zealand Standard Codes of Practice for insulation valid at the time the house was constructed?
b)What were the causes of condensation, mould and associated moisture damage in this property?

The plans and specifications for the house showed clearly that it was a 'Type A' construction dwelling as defined in NZS4218P.

Table 1 - Permitted Combinations for Type A Construction

Part of thermal envelope	Combinations of minimum standard total thermal resistances (m^2 C/W)		
Roofs	1.9	2.6	3.0
Walls	1.5	1.2	1.0
Floors	0.9	0.9	0.9

Source: NZS 4218P:1977

Standard of Insulation - Compliance with NZS4218P:1977

Dealing first with the question of the standard of insulation in the house, it is necessary to consult the New Zealand Standard NZS4218P:1977 (Ref 2) which it was not contested was the standard with which compliance was necessary. Indeed the specifications for the house required compliance with NZS4218P:1977, which presented the minimum thermal insulation requirements for residential buildings in New Zealand. Table 1 of this standard is set out above.

Floor insulation

The building company's plans bore the note "double sided perforated foil under floor 100 mm sag - trim around nogs" The BRANZ report confirmed that the perforated foil was installed (see above) and made no criticism of the insulation method, material, or installation. It therefore seemed reasonable to assume that the house floor insulation system complied with NZS4218P:1977 (Table 1) and would have exhibited a thermal resistance level of $0.9m^2$ C /W.

Walls insulation

The plans bore no note about thermal insulation of the walls, but the specifications included a clause:

> "Insulation
> Insulate in accordance with NZS4218P, NZ4214 and BRANZ Paper C1 1978. The Builder reserves the right to substitute materials of equivalent thermal value as and when deemed necessary without notification or consultation."

It may be helpful to interpose here the information that while NZS4218P:1977 prescribes the required minimum thermal resistance of building elements it does not state how those values may be obtained. BRANZ Paper C1 1978 is required for that latter purpose since it contains annotated sketches of various common forms of wall, floor and roof construction used in New Zealand housing, along with the calculated thermal resistance of each form of construction.

Methods of determining the total thermal resistances of parts of buildings

NZS4214:1977 [Ref 3] deals with and is thus the theoretical underpinning of results published in NZS4218P:1977 and in BRANZ Paper C1. NZS4214:1977 is intended for use when less common forms of construction are proposed in which case the thermal resistance is calculated form first principles.

As mentioned above the BRANZ report noted perforated foil under-floor insulation. BRANZ Paper C1 1978 [Ref 4] contains a sheet labelled F1 which clearly suggests a thermal resistance of up to 1.5 could be obtained by this method. As already noted only 0.9 was required by NZS4218P:1977.

The BRANZ report confirmed that the walls were insulated with gib-foil (see above): Gib-foil is a 9.5 mm thick gypsum-plaster board with a thick paper facing to the interior of the house and an aluminium foil backing facing towards the wall cavity. It is a variation of an identical board, with paper facings on each side, which is easily the most popular interior wall lining material used in New Zealand. Gib-foil went out of production as recently as early 1995.

In 1989 the fixing of Gib-foil was a common and accepted method of providing both a wall lining and wall insulation in one operation.

Table 1 of NZS4218P allows for a combination of thermal insulation values for floors, walls and ceilings which includes 0.9 for floors and 1.0 for walls.

Interestingly, the BRANZ report C1 1978 to which the building specifications for the house referred (see above) provides a construction guide to the thermal resistance values achieved by using various different forms of wall construction. Sheet W11 of the document depicts the form of construction used in the plaintiff's house (fibre-cement weatherboards, timber studs, and Gib-foil wall lining) and declares it to have a thermal resistance of 0.9. This value is below that required by NZS4218P:1977. At first glance it would appear that the plaintiff had evidence that the building company had failed to comply with NZS4218P:1977. Further investigation revealed that BRANZ Building Information Bulletin 217 Thermal Insulation of Houses published in September 1979 [Ref 5], included a Table 2 which suggests that the wall system used in the house, would have had a thermal resistance of 1.0 and would thus have complied with NZS4218P:1977. The fact that the latter document attributed a value of 1.0 to the wall system and that Gib-foil was being extensively used as the sole wall insulation material in many houses being built at the time may be reasonable grounds for supposing that the builders thought they were complying with NZS4218P:1977 especially as both the documents specifically refer to NZS4218P.

Ceiling Insulation

Reference to Table 1 in NZS4218P:1977 shows that a complying thermal resistance value required for a ceiling, when the values for floor and walls are 0.9 and 1.0 respectively, would be 3.0.

As outlined above, the building company's specifications provided for the house to be insulated in accordance with NZS4218P:1977, NZS4214 and BRANZ Paper C1:1978. Furthermore the plans for the house bore the note "135 mm layer macerated paper in ceiling." The BRANZ report confirmed that there was some macerated paper installed in the ceiling but criticised the inadequate thickness observed in places and the fact that some areas of the ceiling were not covered with macerated paper.

BRANZ Report C1: 1978 contains a sheet labelled C10 which illustrates a roof insulation system of the type specified for the house. It states that a 100 mm thick layer of macerated paper can provide a thermal resistance of 2.8 while a 150 mm thick layer can provide a thermal resistance of 4.1. It is clear from these figures that a 135 mm thick layer of macerated paper, as specified for the plaintiffs' house, could have provided a thermal resistance well above the 3.0 required to comply with NZS4218P:1977.

The building company's solicitors were able to contact the contractor who had installed the macerated paper. The contractor stated that the quantity of insulant required to create a uniform layer of 135 mm thickness is approximately 2.5 kg/sq metre. His records showed that he had installed twenty 10 kg bags of insulant on the ceiling of the house.

20 x 10 kg bags = 200 kg ÷ 2_ kg/sq metre = 80 sq metres. That is, enough insulant was installed to provide a layer 135 mm thick on a ceiling area of 80 .0 sq metres . The ceiling area of the house was measured and found to be 80.19 sq metres so it appears that the layer of insulation at the time of installation was very close to 135 mm thick.

The discovery (by BRANZ) in 1993 that the macerated paper insulation was absent on some patches of the ceiling and only 20 mm thick in some others is not necessarily puzzling. When it is first installed, macerated paper is very light, dry and finely shredded. After some time macerated paper tends to settle as it gradually absorbs moisture from the air, a process which can take several years. Further, it is quite common for wind currents to cause movement of macerated paper. The writer has observed several instances where this has occurred. Such movement is common in roofs where air currents can enter the cavity between the ceiling and the roof. The plaintiff's house has a galvanised corrugated steel roof. It is common for wind to enter the ceiling space through the gap between the guttering and the edge of the corrugated steel.

There is no obvious means of avoiding the problem of movement of macerated paper by wind currents during the early period following installation. Regular inspections of the ceiling as part of general house maintenance are one method of ensuring an adequate thickness of macerated paper is maintained. The wind currents do not cause the macerated paper to disappear, but tend to cause it to accumulate on one side of the ceiling space. Generally it can be raked back into place quite easily.

A further cause of movement, compression or other disturbance of insulant of this type is storage of items in the ceiling or movement of people treading or kneeling on the material.

The cause of the deficiencies of the insulation layer in the ceiling observed by the BRANZ site report was never clearly established. The owner appears to have assumed that the original installation was at fault and that there could be no other explanation.

In summary then, the walls and ceiling of the house appeared to have been insulated in accordance with the meaning and intent of NZS4218P:1977 at the time it was built.

Causes of Condensation, Mould and Associated Moisture Damage

The necessary preconditions for condensation and other moisture problems of the kind experienced in the plaintiffs's house are [Ref 6]:

(a) a source of moisture
(b) inadequate ventilation
(c) inadequate heating

Source of Moisture

The normal daily human activities of breathing, bathing, washing and cooking cause approximately 7 to 12 litres of moisture to be released into the air inside a house each day [Refs 7 & 8]. The operation of an unvented clothes dryer dramatically increases the amount of water released into the inside of the house. (In its Points of Defence the building company alleged that the occupants of the house had operated "clothes dryers or similar appliances inside the dwelling without adequate ventilation").

Inadequate Ventilation

The only way of removing or lowering the moisture content of the air inside a house is by providing adequate ventilation, or alternatively, by using a dehumidifier. Ventilation allows dryer air from the exterior to replace the wet air inside. A BRE recommendation [Ref 9] suggests:

> "to prevent condensation there should be sufficient ventilation even in well heated houses; the ideal rate is somewhere between 0.5 and 1.5 air changes per hour ..., ... with less ventilation than this, the RH rises sharply regardless of heat input or insulation levels".

The plaintiff's house was of modern construction with no flue to allow natural ventilation and with precision - made tightly closing metal joinery which precludes significant air leakage. The BRANZ report noted that the only means of ventilating the house was by opening the windows.

Inadequate heating

The areas worst affected by moisture damage were the south and south-east bedrooms, which were also the rooms to receive the least benefit from any solar heat gain. Condensation and mould problems are very common in bedrooms, which typically suffer from a lack of heat, but which are usually occupied for long periods of time by either one or two people [Ref 10]. Condensation occurs when moisture laden air is cooled and its moisture carrying capacity is reduced [Ref 11]. Conversely, air warmed by heating has a greater capacity to carry moisture than does cold air.

Insulation

Insulation itself does not heat a house. Insulation merely slows the rate of loss of whatever heat is present. Insulation does not itself cause moisture to appear. Insulation does not provide ventilation. The BRE Guide confirms that introduction of thermal insulation alone will not increase temperatures unless the room is heated, either directly or indirectly [Ref 12]. It goes on to state that thermal insulation has hardly any effect on temperatures in rooms which are unheated, for example unheated bedrooms [Ref 13].

In the light of these facts it is clear that the plaintiff's claim that inadequate thermal insulation was to blame for the condensation, mould and general moisture damage cannot be sustained. The fine point as to whether the house was insulated to required New Zealand Standards or not was thus of much less significance than the plaintiff was claiming.

The Moisture Damage

Because window glass frequently presents the coldest surface to air-borne moisture in a room, condensation is most frequently found on the inside surface of windows. Further, it will occur in that location regardless of the extent of the thermal insulation is the roof, walls and floor.

The condensed moisture on windows commonly drains down onto the sills. The BRANZ report referred to ponding of condensed water on the medium density fibre-board (MDF) sills. From the sills the water overflowed down the interior wall surface. The photographs in the BRANZ report showed that the water-staining on the walls was not a recent single occurrence but the result of repeated wetting over an extended period of time. It is difficult to believe that the occupiers did not notice the ponding on the sills and the overflow down the walls.

Conclusion

The application of principles of building science and the use of some judgement based on experience of other similar cases suggests that the plaintiff's claims were unreasonable on the facts available. It is far from certain that the thermal insulation as installed was below the standard required by the building contract and the New Zealand Standard. More to the point, the damage suffered by the plaintiff cannot be attributed to a deficiency in thermal insulation. This was a case where compliance with the principles of good building science was not achieved because features of the design and the mode of operation of the house militated against compliance.

This appears to have been a situation where the tenant occupants created moisture in the morning and evening by their usual daily activities (breathing, showering, cooking, washing and drying clothes). While the occupants were at work the house was left unoccupied all day with all the windows shut for security reasons, so that there was little ventilation. In the absence of adequate heating the moist air cooled, and the moisture it contained condensed on cold glass south wall surfaces. The condensate pooled and ran down the walls, a repeated occurrence which the tenant occupants either did not notice or did not report to their landlord until the damage was well advanced.

Studies in the United Kingdom have established that privately rented properties have a far higher incidence of moisture problems than owner-occupied or even local authority rented properties [Ref 14]. Whether the same studies in New Zealand would produce similar results is a matter for conjecture. It is clear that in the plaintiff's building the ignorance of the principles of building science apparently demonstrated by the occupants frustrated the intent of the building code to provide a dry warm habitation for them. It could be argued that, technically, the plaintiff would have been much more justified in claiming against the tenants for their actions, (or lack of actions) than against the builder.

Footnote

For reasons connected with the financial state of one of the parties in the action, the arbitration hearing did not take place and the action by the plaintiff was discontinued.

References

1. Building Research Association of New Zealand, *Report on Mould and Condensation Problems in House,* Judgeford, 1993. **(Note: This report is not in the public domain but confidential to the parties in dispute).**
2. Standards New Zealand, *Provisional New Zealand Standard NZS4218P:1977 Minimum Thermal Insulation Requirements for Residential Buildings*, Wellington, 1977.
3. Standards New Zealand, *New Zealand Standard NZS4214:1977 Methods of Determining the Total Thermal Resistances of Parts of Buildings*, Wellington, 1977.
4. Building Research Association of New Zealand, *Paper C1 A Construction Guide to Home Insulation* (Second Edition), Judgeford, April, 1978.
5. Building Research Association of New Zealand, *Building Information Bulletin 217 Thermal Insulation of Houses*, Judgeford, September, 1979.
6. Garratt, J., Nowak, F., *Tackling Condensation: A Guide to the Causes of, and Remedies for, Surface Condensation and Mould in Traditional Housing*., Watford, England, Building Research Establishment, 1991.
7. Ibid, pp.18,19.
8. Ministry of Public Building Works, *Condensation in Dwellings*, London, HMSO, 1970 -71.
9. See 6 above.
10. Ibid, p 12.
11. Ibid, p 7.
12. Ibid, p 6.
13. Ibid, p 29.
14. Ibid.

Table 2 - Thermal Resistance of Common Forms of Construction

Description	Uninsulated	With foil or Gib foil	With 75 mm fill insulation
Roofs		**m^2 C/W**	
Timber framed, steel roofing	0.4	0.6	1.6
Timber framed, tiled	0.3	0.5	1.5
Walls			
Timber framed, bevel-backed weatherboard	0.7	1.0	1.7
Timber fr., masonry veneer, with building paper	0.5	0.8	1.5
Timber fr., masonry veneer, with no building paper	0.25		
200 mm concrete block	0.3	0.9	
200 mm insulated concrete block	0.5	1.1	
Floors (suspended)			
Particle board or T&G	0.4		
Particle board + underlay & carpet	0.8		
Particle board foil insulated, bare	0.9-1.5		
Particle board foil insulated, carpeted	1.3-1.9		

Source: BRANZ Building Information Bulletin 217 Thermal Insulation of Houses).