MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HIKINA WHAKATUTUKI

Determination 2016/057

Regarding the performance of a concrete floor slab and foundation with respect to moisture transmission to a house at 5 Main Road, Redcliffs, Christchurch

Summary

This determination concerns the construction of a concrete floor slab and foundations without a damp proof membrane. The determination considers whether the authority was correct to issue the code compliance certificate in respect of compliance of the concrete floor slab with Clause E2 External Moisture, and Clause B2 Durability.

1. The matter to be determined

1.1 This is a determination under Part 3 Subpart 1 of the Building Act 2004[1] ("the Act") made under due authorisation by me, John Gardiner, Manager Determinations and Assurance, Ministry of Business, Innovation and Employment ("the Ministry"), for and on behalf of the Chief Executive of the Ministry.

1.2 The parties to the determination are:

- the owner of the house, the Rule Family Trust ("the owner"), who applied for the determination, acting via Southern Response Earthquake Services Limited[2] ("the insurer")
- Christchurch City Council ("the authority"), carrying out its duties as a territorial authority or building consent authority
- the designer of the house and licensed building practitioner[3] D Joyce ("the designer")
- the builder and licensed building practitioner[4], B Rakena ("the builder")
- the chartered professional engineer who designed the foundations, J Kirk ("the engineer") who is deemed to be an LBP[5] and therefore a party.

1.3 The authority issued a code compliance certificate for the then 1-year-old house in 2015. This determination arises because the owner claims that the authority failed to ensure the building work complied with certain clauses[6] of the Building Code (Schedule 1, Building Regulations 1992). The owner's concerns regarding

[1] The Building Act, Building Code, compliance documents, past determinations and guidance documents issued by the Ministry are all available at www.building.govt.nz or by contacting the Ministry on 0800 242 243.
[2] Southern Response, formerly AMI Insurance Limited, is a Crown-owned company with a Board of Directors appointed by the Crown as sole shareholder.
[3] Licensed Building Practitioner Number BP114445
[4] Licensed Building Practitioner Number BP111213
[5] Chartered Professional Engineers under the Chartered Professional Engineers of New Zealand Act 2002 are treated as if they were licensed in the building work licensing class Design 3 under the Building (Designation of Building Work Licensing Classes) Order 2010.
[6] In this determination, unless otherwise stated, references to sections are to sections of the Act and references to clauses are to clauses of the Building Code.

compliance of the building work relate to the weathertightness of the floor slab to the house, taking into account the lack of a damp proof membrane ("DPM") installed directly under the floor slab.

1.4 The matter to be determined[7] is therefore the authority's exercise of its powers of decision in issuing a code compliance certificate for the house. In deciding this matter, I must consider whether the floor slab as installed complies with Clause E2 External Moisture and Clause B2 Durability of the Building Code. The floor slab includes the components of the system (such as the site contours, the concrete floor slab, the concrete block foundation wall, the hard fill and DPM) as well as the way components have been installed and work together.

1.5 This determination is limited to the installation of the foundations and floor slab as outlined above and does not consider any other building elements or aspects of the Building Code or the Act.

1.6 Evidence considered in this determination includes a number of reports provided to the insurer and the authority. In making my decision, I have considered the:

- submissions of the parties
- reports of the building surveyor engaged by the insurer to report on the floor slab ("the building surveyor")
- report of the building consultant engaged by the authority ("the consultant")
- reports of the independent experts ("the first expert" and "the second expert"), commissioned by the Ministry to advise on this dispute
- the other evidence in this matter.

2. The building work

2.1 The building work consists of the concrete floor slab of a single-storey detached house which replaces a house damaged during the Canterbury earthquake sequence[8]. The property is in the Foundation Technical Category 2 Zone ("TC2")[9] and is considered land subject to lateral spread.

2.2 The foundations are specifically engineered concrete and concrete block foundations and floor slab. The engineer required the entire concrete foundation to be installed on two layers of 0.25mm thick polythene sheet.

2.3 Construction above slab is generally conventional light timber frame with uPVC wall claddings, aluminium joinery, and profiled metal roofing with roof overhangs of about 600mm overall.

2.4 The installed floor coverings/finishes are:

- carpet to bedrooms including wardrobes, and living / dining areas
- ceramic tiles kitchen, bathroom, and toilet
- bare concrete to the garage.

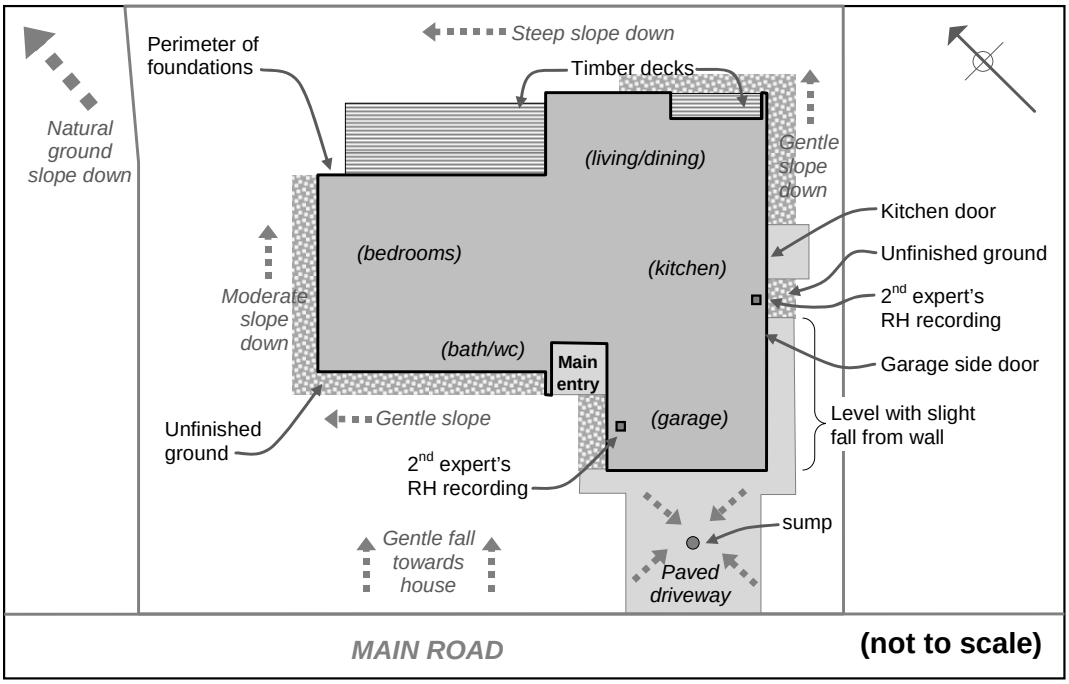
[7] Under sections 177(1)(b) and 177(2)(d) of the Act

[8] The Canterbury Earthquake Sequence includes the 'Darfield Earthquake' of 4 September 2010 with a moment magnitude of 7.1, followed by a series of aftershocks that included a 6.3 magnitude shake on 22 February 2011.

[9] As described in the '*DBH Residential Foundation Technical Categories, Southern Area*' plan information dated 16 November 2011 published by the Ministry.

2.5 The site is north-sloping, with the garage and main entry facing southwest toward the street. At the time of the experts' inspections, landscaping had not been completed and ground contours were approximately as shown in Figure 1:

Figure 1: Site plan



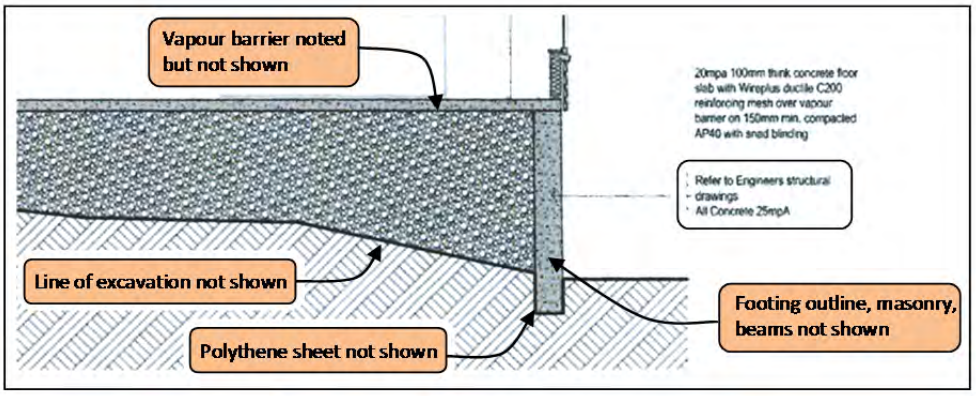
3. Background

3.1 The consent documentation

3.1.1 The authority issued building consent no. BCN/2013/2518 for construction of the house on 16 October 2013.

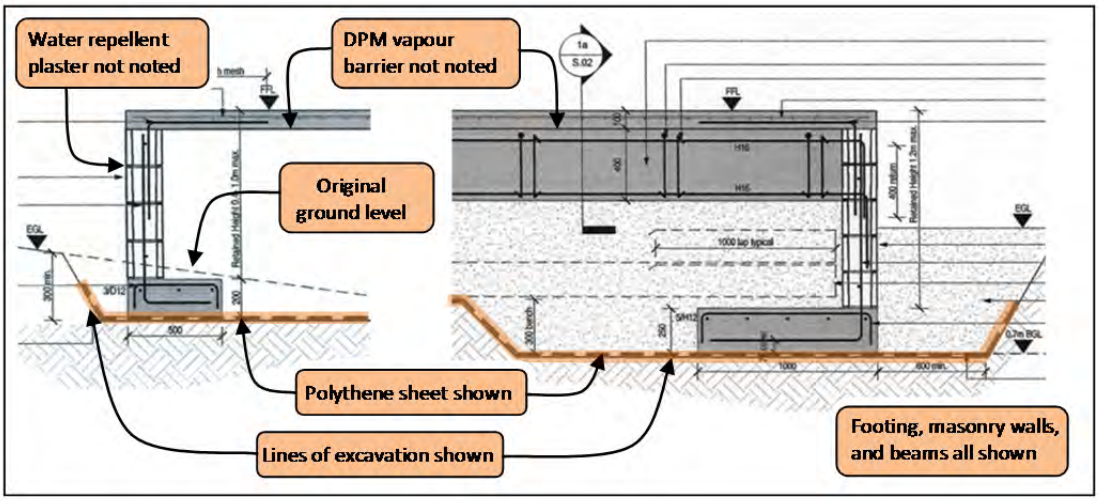
3.1.2 The consent drawings prepared by the designer called for a DPM immediately beneath the reinforced concrete floor slab and referred to the structural drawings for the foundations as shown in Figure 2:

Figure 2: Foundation detail in architectural drawings with my notes added



3.1.3 According to the builder, the designer's drawings were 'extremely vague' and clearly referred to the engineering drawings: as well as providing details, the engineering drawings 'called for a double layer of polythene to extend past the building line' (as shown in Figure 3).

Figure 3: Foundation detail in engineering drawings with my notes added



3.2 The foundations and floor slab

3.2.1 Construction commenced in March 2014 and the design engineer monitored the construction of the foundations and floor slab. The authority also carried out inspections during construction, including of the foundations and floor slab from March to May 2014.

3.2.2 It appears the builder followed the engineering drawings, and foundation boxing and floor plan footprint were lined with two layers of polythene with lapped and taped joints at junctions and the polythene extended beyond the building line.

3.2.3 Photographs taken during construction show:

- on 16 April 2014; footings and masonry perimeter wall in place, with polythene edges visible and ready for lapping
- prior to base course installation; foundations, starter rods, and polythene over the floor area taped at the foundation junction, with ground levels sloping gently toward the northeast and appearing similar to the engineer's detail
- prior to first pre-pour inspection; slab reinforcing in place and base course installed to the perimeter of the foundation walls, with no polythene visible.

3.2.4 Base course, floor slab boxing and reinforcing were installed, and the authority carried out a pre-pour inspection on 21 April 2014, by which time the polythene under the foundation was concealed. The inspection record noted the lack of a DPM under the floor slab and directed the builder to 'ensure DPM installed to comply with consent and E2 of the Building Code'. A further pre-pour inspection on 23 May 2014 also failed.

3.2.5 The owner raised concerns about potential water penetrating through the perimeter foundation walls and causing moisture problems to the concrete floor. The engineer and housing company agreed that the double layer of polythene provided sufficient protection due to the deep water table and the 'highly permeable' nature of the hardfill under the slab and surrounding the perimeter foundations.

3.2.6 Following discussions and correspondence with the housing company and engineer, the authority agreed to accept the vapour barrier installation based on the engineer's confirmation and emailed the housing company on 26 May 2014 stating:

> Following review of the response and discussions with the Principal Building Official we can allow the detail if you confirm that;
>
> - the DPM was installed as per the Engineers design
> - the DPM design/installation is included on the Engineers PS4.

In an email to the housing company dated 27 May 2014, the engineer confirmed that 'we will be happy to cover the DPM on the PS4 as the construction is as per the structural drawings.'

3.2.7 The concrete was subsequently poured[10] and a framing inspection was recorded on 23 June 2014. The owner continued to express concerns that water could enter via the foundation wall. While acknowledging that the engineer said 'that water seepage into the house due to the lack of foundation waterproofing is very low risk', the owner noted that 'surely if the correct waterproofing was installed then there would be no risk?'

3.2.8 The house was closed in by November 2014 and the engineer issued a Producer Statement ("PS4") dated 10 March 2015 to cover construction review for:

> Design of Technical Category 2 (TC2) shallow foundations including entry post, masonry block retaining walls, deck foundations and balustrade with associated connections.

3.2.9 On 4 June 2015, the engineer issued a second PS4 for:

> Design of Technical Category 2 (TC2) shallow foundations including entry post; masonry block retaining walls, deck foundations and balustrade with associated connections, and the DPM membrane under the floor slab [my emphasis].

3.3 The authority carried out a final inspection of the house on 24 June 2015, which was recorded as a 'pass' and the housing company applied for a code compliance certificate on the same day. The authority issued the code compliance certificate on 21 July 2015.

3.4 The owner continued to raise concerns about the lack of a DPM directly beneath the floor slab along with other issues that are not matters considered in this determination.

3.5 The building surveyor's report

3.5.1 On 3 August 2015, the insurer engaged the building surveyor to 'undertake an independent survey and report' on the house. The surveyor inspected the house and provided a 'Construction Deficiency Report' dated 25 August 2015. The report noted that the scope of the engagement was to visually inspect the house and to provide an independent opinion.

3.5.2 The building surveyor reviewed the authority's property file and compared the foundation and slab installation shown in construction photographs to: the consent drawings; Clause E2 requirements; E2/AS1; NZS 3604; NZS 4229[11]; BRANZ *Good Practice Guide: Concrete Floors and Basements*, and BRANZ Bulletin 469 *Damp-Proof Membranes to Concrete Slabs.*

3.5.3 In regard to the concrete work, the building surveyor commented as follows:

- Photographs taken prior to the concrete pour show compacted fill below the reinforcing, with no DPM.

[10] A record post-dated 24 June 2015 of a pre-pour inspection retrospectively records a 'pass', although comments on the lack of the under slab DPM remained on record.
[11] NZS 4229:1999 Concrete masonry buildings not requiring specific design

- Sealed areas around the southwest garage and entry area finish from 30 to 65mm below the wall cladding and further backfilling has not been completed around the northwest, southwest and southeast foundation walls
- Completed backfilling will expose foundation walls to moisture entry through joints and voids into compacted fill under the floor slab, where it will not drain swiftly due to fill composition and the underlying DPM.
- The engineer's PS4 only covers specifically engineered items and is limited to compliance of the foundations with Clause B1.

3.5.4 The building surveyor concluded that the lack of an under slab DPM created the risk of a floor dampness problem once the backfilling was completed. Remediation would involve a specific waterproofing and drainage design.

3.6 The insurer forwarded the building surveyor's report to the authority and noted that the surveyor's report confirmed that the DPM was not installed directly beneath the floor slab.

3.7 The Ministry received an application for a determination on 2 February 2016. The Ministry sought further information from the builder to clarify why the DPM had not been installed under the floor slab.

4. The submissions

4.1 With the application for determination, the insurer provided copies of:

- the consent documentation and inspection records
- the building surveyor's report dated 25 August 2015
- various construction photographs of the concrete work
- correspondence between the parties and the engineer
- various other technical information, etc.

4.2 The authority made no submission in response to the application.

4.3 The builder's submission on 16 March 2016 responded to the Ministry's request for clarification as to why the DPM had not been installed beneath the floor slab. The builder described the confusion between the designer's and the engineer's drawings and how this had resulted in the engineer's details alone being followed (see paragraph 3.2.2), adding that the onsite inspector had 'told us if the engineer was to sign off the design then we could proceed.'

4.4 When the pre-pour inspection failed, the concrete pour had been postponed for some weeks and the builder moved onto other jobs. The housing company subsequently approved the pour without the builder's knowledge or presence on-site and the project manager told him of 'the engineer's approval and [how] they would sign it off at the end of the job in the producer statement.'

5. The first expert's report

5.1 General

5.1.1 As mentioned in paragraph 1.6, I engaged an independent expert to assist me. The first expert is a member of the New Zealand Institute of Building Surveyors and inspected the subject concrete work on 29 and 30 March 2016; providing a report dated 8 April 2016.

5.1.2 The expert noted that the scope of his report was to visit the property and to:

- describe the site topography in regard to surface water flow
- describe the as-built work in regard to surface water management
- carry out testing of the bare concrete slab in the garage.

5.1.3 The first expert noted that the house was complete at the time of his inspection, but 'landscaping was yet to be addressed'.

5.2 Topography and surface water drainage

5.2.1 The expert checked the site levels against a datum at the west corner of the garage (see Figure 1) and noted that:

- ground between the southwest elevation and the street lacks topsoil and currently slopes gently down toward the house
- ground levels against northwest wall fall more steeply towards north corner
- most ground to the southeast elevation is paved, with limited clearances to the finished floor level ("FFL") and a slight slope away from the wall
- ground levels to northeast elevation fall fairly steeply from about 1m below the FFL at the east corner towards the north corner
- the driveway slopes gently towards a sump in the middle of the drive.

5.2.2 The expert also noted that downpipe locations accord with the consent site plan and testing surface water drainage with a hose confirmed satisfactory operation.

5.3 Ground clearances

5.3.1 The expert measured clearances from the bottom of the cladding and FFL to adjacent ground or paving; comparing these with clearances noted in E2/AS1 Table 18:

Table 1: Ground clearances

Location		As measured	As per E2/AS1	Comment
SE kitchen door	FFL to paving	100mm	150mm	
SE garage/ kitchen	FFL to ground	135mm	225mm	Top soil yet to be added
Sth corner garage	FFL to paving	100mm	150mm	
SW entry	FFL to paving	115mm	150mm	

5.4 Floor slab moisture testing

5.4.1 The expert carried out non-invasive testing in two locations by taping the perimeter of a piece of polythene sheet to the concrete slab surface at the rear of the garage and in the wardrobe of bedroom 3. The sheet was removed 24 hours later and the expert could see no evidence of condensation moisture on the underside of the sheet.

5.4.2 The expert also carried out invasive moisture tests in 3 different locations by drilling 60mm into the floor and inserting humidity probes[12] into the holes to measure the equilibrium relative humidity ("ERH") within the slab. From a relative humidity at the start of the test of about 60%, expert noted that after 24 hours this rose to:

- 89% near the rear of the southeast exterior wall of the garage
- 92% within the wardrobes of bedrooms 1 and 2.

5.4.3 The expert attached an excerpt from BRANZ Bulletin 388[13] which noted that concrete 'slabs that have an ERH value of 75% or lower are considered to be in a safe air-dry condition. Slabs that have an ERH value of 80% or greater are generally considered being in a damp condition.'

5.4.4 The expert noted that the weather had been warm and dry for some weeks prior to and during his inspections and concluded that the invasive test results 'all indicated that the concrete floor slab still contained more moisture than would be expected nearly two years after pouring the concrete.' (See paragraph 6.3.3 for the second expert's alternative rationale for the moisture levels.)

5.4.5 The expert concluded that in his opinion the results of the testing indicates that:

> ...water is flowing onto the polythene slip layer from the perimeter of the building, then being drawn up through the compacted base course by capillary action where it is in direct contact with the concrete floor slab. The mandatory requirements of clause E2 have been breached.

5.5 Responses to the first expert's report

5.5.1 The first expert's report was forwarded to the parties for comment on 11 April 2016. The authority's and the insurer's comments are outlined in the following paragraphs.

The authority's response

5.5.2 The authority responded on 2 May 2016, noting that it had engaged a building consultant advisor to 'assist us with the technical aspects' of the determination.

5.5.3 The consultant reviewed the first expert's report and noted (in summary):

- BRANZ Bulletin 585 (April 2015) and other documents, including E2/AS1, require 75% RH maximum before laying floor coverings because floor coverings such as vinyl can impede further drying out of the floor slab. However this does not apply to breathable carpet and some overseas sources maintain that 90% RH is satisfactory for carpet.
- An RH of 90% equates to 3% moisture content for concrete, which is not high enough to affect soft floor coverings, particularly when timber floors can have an in-service moisture content of 18% to 20%.

[12] Using a Protimeter Moisture Measurement System (MMS) in Hygrometer Mode to measure the relative humidity of the air within the sealed hole, which reaches moisture equilibrium with the concrete

[13] BRANZ Bulletin 388 July 1999: *Site Measurement of Moisture in Timber and Concrete*. I note here that this bulletin was withdrawn on 1 March 2002. BRANZ Bulletin 585 June 2015: *Measuring Moisture in Timber and Concrete* refers to an RH of less than 75% at the time of laying fixed floor coverings as provided for in E2/AS1 and in Appendix A of AS/NZS 1884:2013 *Floor coverings – resilient sheet and tiles – installation practices*.

- The lack of moisture on the backs of taped polythene shows that there is no moisture passing from the slab into the building.

5.5.4 The consultant disagreed with the first expert's conclusion that water is flowing onto the slip layer and being drawn up to the slab, because (in summary):

- the expert has not shown that there are any areas where water can enter the slip layer
- the likelihood of capillary rise in the hard fill is low as the reason for using granular fill is so that moisture is not lifted by capillary rise
- any moisture within the base course itself will drain to the lowest point and the site has deep hard fill in all areas, with a minimum of 600mm
- the ground water table beneath the property is over 2.5m below the slip layer.

5.5.5 The consultant also disagreed with the first expert's conclusion that there was a breach of Clause E2.3.3, because (in summary):

- no building elements have been identified which 'may be subject to undue dampness or damage'
- tiled areas are not subject to deterioration and the timber framed walls are protected from the slab by a separate DPM layer
- if the carpet is the element referred to, a surface layer could be applied to the top of the slab to stop any moisture passage.

5.5.6 The consultant also suggested:

> ... the installation of drainage pipes to the low side of the building to ensure that in the unlikely event that moisture finds its way onto the slip layer it is able to freely drain rather than being able to build up under the slab.

The insurer's response

5.5.7 The insurer responded on 18 May 2016; providing comments from the building surveyor's on the consultant's response to the first expert's report. The insurer noted that the determination needed to answer the question:

> Does the dwelling comply with the Building Code including clause E2 (external moisture) in circumstances where a damp proof membrane has not been installed as required by the building consent.

5.5.8 The building surveyor reviewed the consultant's comments, and noted (in summary):

- The hard fill under the slab cannot fully drain like 100% metal fill as it is AP20 which will hold moisture and allow capillary rise.
- DPM under the timber framed walls only applies to external walls, as consent drawings show no DPM under internal partitions.
- Comments focus on whether current damage has manifested due to the slab not performing, but the real point which relates to future risks is overlooked.
- When the house is completed as per the consent, back filling will render the water table level irrelevant as moisture can enter the sides of the masonry foundation walls above the slip layer.

5.5.9 The insurer also added the following comments (in summary):

- The issue of the missing DPM is not limited to the specific questions that formed the basis of the expert's report.
- The issue is also not limited to whether moisture has migrated into the building at this time – it 'also relates to future risk of water ingress to the property.'

5.6 Following the above comments, the Ministry notified the parties on 3 June 2016 that it was seeking peer review of the first expert's report and the submissions received in response.

5.7 In an email to the Ministry dated 22 June 2016, the insurer noted that the owner had 'expressed concern regarding the extended timeframe associated with the requirement for further opinion and potential additional work in order to resolve the issues identified at the property.' The owner asked for the 'instruction/brief' to be circulated for review and the peer review be expedited 'to reflect the increasingly pressing circumstances of the family.'

5.8 On 30 June 2015, the parties were advised that the second independent expert had been engaged to carry out an assessment on site, review the first expert's investigations and to give an opinion on responses to the first report.

6. The second expert's report

6.1 General

6.1.1 As outlined above, following the responses to the first expert's report I engaged a second expert to assist me. The expert is a member of the New Zealand Institute of Architects. The expert inspected the house on 12 and 13 July 2016 and provided a report dated 2 August 2016.

6.1.2 The second expert noted that the scope of his report was to provide an opinion on the compliance of the concrete slab based on:

- a review of the available consent documents
- inspection of the house and site
- invasive moisture measurement of bottom plates in contact with the slab
- indirect measurement of the moisture content of the slab surface.

6.1.3 The expert was told that, while acknowledging the lack of current moisture problems, the owner is concerned about future performance based on the building surveyor's report showing that the slab 'was not built to code'. The owner's concerns are the future risks that moisture:

- will penetrate the foundation walls when topsoil and planting is carried out adjacent to the walls
- will wick up through the hardfill and reach the floor slab as the underlying slip layer polythene creates a 'swimming pool' effect by trapping water.

6.1.4 The term 'equilibrium relative humidity' or ERH is used in various documents as a proxy for the moisture content in the concrete slab. It measures the relative humidity of a pocket of air close to the concrete surface and the methodology was developed when there was no direct method of measuring concrete's moisture content.

6.2 Moisture investigations

6.2.1 The second expert noted that floor coverings and the garage concrete floor were 'all free from visual signs of current or past moisture ingress', with the concrete surface in the garage and bedroom 3 wardrobe 'free from cementitious salts which commonly occur' with wet concrete. The moisture content of five bottom plates to internal walls were measured and ranged from 15% to 17% compared to 16% for an external wall. The expert noted that these readings were low and likely to be about the peak of seasonal variation, given the measurements were taken in mid-winter.

6.2.2 The expert carried out two 'polythene tests' within the garage by taping the perimeter of a piece of polythene sheet to the garage slab surface at the east corner and near the southwest door. The sheet was removed 21 hours later and the expert could see no evidence of condensation moisture on the underside of the sheet.

6.2.3 The expert also used two data loggers[14] to record movements in relative humidity ("RH") within the garage slab near the southwest wall and at the east corner (see Figure 1). The expert noted that after 16 hours RH measurements ranged from:

- 71% to 82% adjacent to the south west wall (near unfinished soil)
- 73% to 79% near the east corner of the garage (near unfinished soil)

6.3 Analysis of results

6.3.1 The second expert noted that the maximum recorded RH of 82% equated to 2.1% moisture content ("MC") in the concrete slab, compared to 75% RH (1.8%MC) provided for in the Acceptable Solution (refer paragraph 5.5.3). The expert noted that the latter deals only with transient conditions for laying floor coverings, so although RH measurements were above 75%, that level is not a test for compliance with Clauses E2 and B2. Exceeding 75%RH 'does not mean the floor fails to comply' as moisture levels would need to be high enough to damage building elements to result in a breach of Clause E2.

6.3.2 The second expert noted there was a lack of guidance within E2/AS1 or elsewhere as to what is a safe in-service moisture level in concrete slabs, so other evidence of current and anticipated long term performance must be considered in order to assess compliance.

6.3.3 In regard to the recorded moisture levels, the expert considered that the moisture content of the slab is likely to be lower at other times of year and also lower over time, because:

- readings were taken in mid-winter when the relative humidity in Christchurch[15] ranged from 80% to 90%, meaning that the slab would have absorbed moisture from the air until it reached equilibrium, then when atmospheric RH drops the moisture in the slab will tend to drop accordingly
- the slab was laid direct on hardfill up to 1200mm deep which was placed over polythene, with exposed fill subject to heavy rain[16], meaning that the fill would have contained a large volume of trapped water that can only dry via the concrete slab and perimeter concrete block perimeter foundation walls

[14] Placed on the concrete surface, covered with tape then covered with an insulated box
[15] Measured at Christchurch Airport from 30 June to 14 July 2016
[16] NIWA records indicate 510mm of rain from March to June 2014 (with construction photographs showing exposed fill during that time)

- slab construction moisture may therefore still be drying out during summer months, well beyond the traditional rule of thumb of 25mm per month[17].

6.3.4 In regard to current performance of the floor slab, the second expert noted that:

- the physical condition of the floor and adjacent finishes showed no evidence of moisture damage and moisture readings in internal bottom plates were low
- all four polythene tests (two by the first expert and two by the second expert) showed that the slab surface moisture level was below dew point and would not condense; indicating that any vapour flows through the slab will not promote conditions leading to damage.

6.3.5 In regard to anticipated future performance of the floor slab, the second expert considered issues raised by the building surveyor and commented as follows (in summary):

- Any 'swimming pool effect' created by the polythene-lined excavation contour (see Figure 2) is limited to the northeast perimeter walls due to the site slopes. No investigations identified evidence that ponding actually occurs and there are no signs of efflorescence or moss growth at the base of the visible blockwork.
- The building surveyor believed that capillary rise in the hardfill is an issue, but there is no evidence of actual occurrence in the form of efflorescence on the concrete; such as at movement joints, hairline cracks, repairs etc.
- NZS 3604 defines granular fill material used as hardfill under slabs and notes as commentary[18] that capillary rise will only be a problem if fill is not properly graded. There is no evidence that the hard fill used was improperly graded.
- The building surveyor considered that the perimeter foundation wall will allow moisture to enter the hard fill. The architectural drawings note 'plaster foundation, add water repellent admixture to plaster', which is not yet done.

6.3.6 The expert also noted the use of foundations details in NZS 3604 where Commentary C7.5.4.1 notes that:

> NZS 3604 also recognizes that 'slabs work' without the requirement for an edge vapour barrier up the face of the external slab edge. In essence, they work because the differential vapour pressure does not exist since there is a free air surface.

6.3.7 In regard to future soil levels around the house, the expert stated:

> My conclusion is that raising the soil level around the house, but keeping it below the levels indicated in E2/AS1 figure 65 (225mm to soil, 150mm to paving) will comply with industry standards and is unlikely to cause undue dampness, particularly so if the foundation is plastered and treated with a water repellent admixture in accordance with the consent drawings.

[17] In contrast to the first expert's assumption in paragraph 5.4.4
[18] Commentary to paragraph 7.5.3.2

6.4 The second expert's conclusions

6.4.1 The second expert also reviewed the various reports and provided detailed comment based on his investigations, including the following (in summary):

- The omission of the DPM was clearly a mistake and contrary to the consent, but the effect of that omission 'is mitigated by the presence of a double polythene slip layer between the ground and the hard fill.'
- The slightly elevated moisture readings of the slab surface is likely due to the DPM omission and/or the wet hard fill drying out and relative humidity should be 'lower in warmer weather and to fall over time.'
- What is effectively relocation of the DPM to the underside of the hard fill is unlikely to result in failure to comply with the Building Code in normal circumstances.
- If the owner wishes to change the existing floor coverings and install 'timber, vinyl or similar fixed flooring in the near future', i.e. before the hardfill had dried out, paint-on DPM could be used.

6.5 The second expert's report was forwarded to the parties for comment on 2 August 2016.

6.6 Responses to the second expert's report

The authority's response

6.6.1 The authority responded to the second expert's report in an email to the Ministry dated 9 August 2016, which noted 'minor non-technical comments'. I have taken those comments into account as I consider appropriate.

6.6.2 In regard to the issue of the code compliance certificate, the authority included the following comments (in summary):

- It is not uncommon for minor variations to be agreed without a formal amendment to the building consent.
- The omission of the under slab DPM was recognised during an inspection on 23 May 2014 (see paragraph 3.2.4) and the email correspondence between the authority, the housing company and the engineer during May 2014 resulted in the DPM below the hard fill being accepted providing the engineer's producer statement included this (see paragraph 3.2.6).
- The engineer's producer statement was subsequently provided (see paragraph 3.2.9) and the change has been adequately documented as a minor variation, so the code compliance certificate was appropriately issued.

The insurer's response

6.6.3 The insurer responded to the expert's report in an email to the Ministry dated 24 August 2016. The submission included letters from the building surveyor dated 16 and 23 August 2016. The submission made the following points (in summary):

- The effect of the omission of the DPM is only partially mitigated by the polythene slip layer.
- Moisture levels will increase once site works have been completed and water table levels return to normal.

- The engineer is not 'entitled' to sign off work in relation to Clause E2.
- The foundation structure has a polythene sheet slip layer installed under it. The polythene can perform the role of a DPM when installed correctly.
- The lack of any moisture damage is because the owner 'has not installed any flooring system over the concrete floor as a result of concern that damage will occur to such systems'. (I note floor finishes have been installed, refer paragraph 2.4.)
- It was inappropriate for the expert to offer a repair solution.
- An enlarged photo was provided that appeared to show a joint in the polythene that was not taped.

7. The draft determination and submissions in response

7.1 A draft of this determination was issued to the parties for comment on 31 August 2016.

7.2 The authority responded by email on 6 September 2016, accepting the draft subject to a minor amendment regarding a Producer Statement PS4 – Construction Review issued by the engineer (refer paragraph 3.2.9).

7.3 The agent for the owner responded by email on 28 September 2016, noting that the owner did not accept the conclusions in the draft determination and submitting (in summary):

- The owner did not consider the risk of future moisture ingress had been adequately addressed, particularly once backfilling is completed and the ground contours altered.
- It has not been demonstrated that the slip layer of polythene was installed to the standard required 'for a product intended to perform as a DPM for the purpose of E2' and photographs indicate it was not installed in accordance with the drawing at Figure 3 (refer paragraph 3.1.3).
- The compliance of a DPM for the purpose of Clause E2 is a matter for the designer and not the engineer, 'who is not authorised to sign off on E2 compliance in respect of design'. The engineer's PS4 is limited to Clauses B1 and B2, and the authority should not have relied on this in respect of compliance with Clause E2.
- The draft determination did not provide adequate justification for the departure from the findings and conclusions of the building surveyor and first expert, in particular in respect to the results of the invasive moisture testing and the conclusions relating to moisture resulting from capillary action through the base course.
- The second expert's 'comparative' testing of his own garage floor slab is immaterial and the determination should confirm it has been disregarded.
- The authority's consultant has not inspected the property or undertaken any testing.
- The absence of DPM does not constitute a minor variation.

7.4 The designer, builder, and engineer made no response to the draft despite being reminded to do so.

8. Evaluating code compliance

8.1 General

8.1.1 In evaluating the design of a building and its construction, it is useful to make some comparisons with the relevant Acceptable Solutions, which will assist in determining whether this concrete slab installation is code-compliant. However, in making this comparison, the following general observations are valid:

- Some Acceptable Solutions cover the worst case, so that they may be modified in less extreme cases and the resulting alternative solution will still comply with the Building Code.
- Usually, when there is non-compliance with one provision of an Acceptable Solution, it will be necessary to add some other provision to compensate for that in order to comply with the Building Code.

8.1.2 An Acceptable Solution is a prescriptive design solution that provides one way, but not the only way, of complying with the Building Code. The concrete slab and foundation system does not comply in all respects with E2/AS1; and the work must therefore be considered as an alternative solution, entailing an assessment of the likely performance of the concrete slab within the context of this particular house.

8.2 Evaluation of the concrete slab for E2 and B2 Compliance

8.2.1 The approach in determining whether building work is weathertight and durable and is likely to remain so, involves the examination of the design of the concrete slab and foundations, the surrounding site contours, the design features intended to prevent the penetration of water and the concrete work as installed.

8.2.2 In considering the code-compliance of this particular concrete slab, I have taken account of the two experts' reports; together with other available evidence, including the reports from the insurer's building surveyor and the authority's consultant.

8.2.3 Taking account of the above evidence, I make the following observations on the circumstances that I consider relevant to assessing this particular concrete slab:

Table 2: risks and mitigating factors

Issue/risks	Particular circumstances (summary)	Conclusion
Slab recorded at up to 82%RH (2.1%MC) Risk of current moisture damage to building elements	• No guidance for safe in-service moisture content ("MC") for concrete slabs • Maximum level of 75%RH (1.8%MC) advised for timber/vinyl coverings (measured 82%RH is only 0.3% above) • No condensation during polythene tests • No evidence of concrete efflorescence, vinyl/carpet damage • Low MC recorded in bottom plates	Current moisture levels acceptable in the circumstances

Issue/risks	Particular circumstances (summary)	Conclusion
Slab recorded at up to 82%RH Risk of future moisture damage to building elements	• Mid-winter, with atmospheric RH for preceding period from 80% to 90% • Slab has been absorbing air moisture which will evaporate when air RH drops during warmer seasons • Hard fill wet when installed – could only dry through the slab and perimeter walls • Hard fill is deep in places so construction moisture is likely to be still drying out	Adequate in circumstances (moisture levels likely to remain acceptable and to drop gradually over time)
Water penetrating foundation walls when landscaping completed Risks moisture reaching slab	• No evidence of current or past moisture entering or exiting via concrete block foundation walls • Water table under site is very low • Although some paving is high, junctions sheltered under eaves with fall from walls • Some soil levels are high and could increase when topsoil added • No water repellent plaster installed to foundation walls.	Adequate in circumstances (if finished soil levels meet E2/AS1 and upper foundation walls treated with water repellent plaster)
Trapped water pools at lower foundations Risks moisture reaching slab	• If ponding were occurring, lower foundations would be wet for long periods • No moss/efflorescence etc to blockwork so no evidence ponding is occurring.	Adequate in circumstances (a very unlikely occurrence, should not affect compliance)
Capillary rise through hard fill. Risks moisture reaching slab	• Hardfill likely to be AP65 as specified, which should not contain clay. • No evidence that incorrect or improperly graded hard fill was used. • If properly graded AP65 used as fill, capillary rise very unlikely. • No efflorescence etc to concrete work, so no evidence capillary rise is occurring.	Adequate in circumstances (a very unlikely occurrence, should not affect compliance)

8.2.4 Taking account of the above, I have reasonable grounds to conclude that despite the lack of a DPM directly beneath the slab the concrete slab to this particular house will be satisfactory in these particular circumstances.

8.3 Discretionary precautionary measures

8.3.1 Notwithstanding that I have concluded that the concrete slab complies with the minimum requirements of the Building Code, I acknowledge the owner's concerns regarding possible future risks when landscaping is completed.

8.3.2 I also note the experts' comments on ground levels to the southern part of the house where landscaping is incomplete and the lack of waterproofing to the concrete block foundation walls in regard to those areas (see Table 1 and paragraph 6.3.7). In regard to areas already finished with paved surfaces, I am satisfied that the falls provided will satisfactorily drain surface water away from the perimeter foundations.

8.3.3 As well as ensuring that finished soil levels maintain the 225mm clearances specified in E2/AS1 Figure 65, the owner could consider additional precautionary measures to mitigate any unlikely future risks to the concrete slab via water penetrating areas at

the currently unfinished upper contours of the site. Such precautionary measures could include the following treatment:

- exposure of concrete block foundation walls between:
  - the driveway paving and the west corner
  - the short section between the southeast garage and kitchen doors
- coating the surface of these particular walls with an appropriate liquid-applied damp proof membrane
- installation of free-draining fill prior to the installation of top soil.

8.4 Conclusion

8.4.1 I consider that the various reports establish that the concrete slab was not installed in accordance with the consented architectural drawings and must therefore be assessed as an alternative solution. However, as shown in Figure 2 and Figure 3 the consent documentation is not consistent in regard to particular requirements for the slab and foundation.

8.4.2 The second expert's report and the other evidence provide me with reasonable grounds to conclude the concrete slab is currently weathertight and I am therefore able to conclude that the slab complies with Clause E2 of the Building Code.

8.4.3 The durability requirements of Clause B2 include a requirement for a floor slab to remain weathertight for a minimum of 50 years. Due to the mitigating factors that compensate for any shortcomings of the slab installation, I am also able to conclude that there are no defects likely to allow the ingress of moisture in the future. Consequently, I am satisfied that the concrete slab as installed complies with Clause B2 of the Building Code.

8.4.4 It is emphasised that each determination is conducted on a case-by-case basis. Accordingly, the fact that a particular concrete slab has been established as being code-compliant in a specific instance for a specific house, does not of itself mean that the same system will be code-compliant in other situations.

9. The decision

9.1 In accordance with section 188 of the Building Act 2004, I hereby determine that the concrete slab as constructed complies with Clause B2 and Clause E2 of the Building Code and confirm the authority's decision to issue the code compliance certificate.

Signed for and on behalf of the Chief Executive of the Ministry of Business, Innovation and Employment on 25 November 2016.

John Gardiner
Manager Determinations and Assurance