Determination 2023/015

Regarding the decision to issue a code compliance certificate for the construction of the foundation and floor slab of a vehicle storage and maintenance shed

2 to 6 Bidois Road, Fairy Springs, Rotorua

Summary

This determination considers the decision by an authority to issue a code compliance certificate for building work to construct a foundation system and floor slab for a new vehicle storage and maintenance shed. The determination also considers whether the building work complies with the building consent and Building Code, taking into account all the information now available.

Figure 1: The truck shed[1]

In this determination, unless otherwise stated, references to "sections" are to sections of the Building Act 2004 ("the Act") and references to "clauses" are to clauses in Schedule 1 ("the Building Code") of the Building Regulations 1992.

The Act and the Building Code are available at www.legislation.govt.nz. Information about the legislation, as well as past determinations, compliance documents (eg, acceptable solutions) and guidance issued by the Ministry, is available at www.building.govt.nz.

1. The matter to be determined

1.1. This is a determination made under due authorisation by me, Katie Gordon, National Manager Building Resolution, Ministry of Business, Innovation and Employment ("the Ministry"), for and on behalf of the Chief Executive of the Ministry.[2]

1.2. The parties to the determination are:

1.2.1. Fells Hotels Limited, the owner of the property who applied for this determination ("the owner")[3]

1.2.2. Rotorua Lakes Council ("the authority"),[4] carrying out its duties as a territorial authority or building consent authority.

1.3. I consider the following are persons with an interest in the matter:

1.3.1. WSP New Zealand Limited[5] ("engineer 1")

1.3.2. BSK Consulting Engineers Limited ("engineer 2").

1.4. This determination arises from a decision by the authority to issue a code compliance certificate[6] dated 18 September 2015.

1.5. The building consent (73400) relates to the specific engineering design and construction of timber pile foundations and reinforced concrete perimeter edge beam ("the foundation system"), and associated floor slab, for a new vehicle storage and maintenance shed ("the truck shed").

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[1] Image reproduced from Google Maps, accessed on 9 May 2022. View of the southwest corner of the truck shed.

[2] The Building Act 2004, section 185(1)(a) provides the Chief Executive of the Ministry with the power to make determinations.

[3] The building consent certificate and code compliance certificate issued by the authority, associated with building consent (73400), state different details for the owner (ie The Fell Family Trust). A record of title property search on 3 May 2022, for Lot 2 DP South Auckland 57826 identifier SA49C/931, states the registered owners are Fells Hotels Limited.

[4] The operating name of Rotorua District Council.

[5] Prior to 14 October 2019 this company was named Opus International Consultants Limited; the relevant building consent documentation in respect of this determination (eg the Producer Statement – Design [PS1] and Producer Statement – Construction Review [PS4]) was issued by a chartered professional engineer working for the company under its previous name.

[6] Section 95 of the Act.

1.6. The floor slab of the truck shed has been subject to settlement, and the perimeter edge beam has been in part raised upwards, causing an abrupt difference in finished levels across the construction. In addition, the as-built construction differed from the consented design. Consequently, the owner is of the view that the authority was incorrect to issue the code compliance certificate.

1.7. The matter to be determined[7] is the authority's decision to issue a code compliance certificate for building consent 73400.

1.8. In deciding this matter, I must consider whether the building work complied with the building consent.[8] If it does not comply with the building consent, then in considering whether the authority's decision should be confirmed, reversed, or modified, I will determine whether the building work complies with the Building Code, taking into account all the information now available.

1.9. I have also assessed the changes made to the building work and whether these could have been considered as minor variations to the building consent.[9]

Issues outside this determination

1.10. The determination will not discuss the decision made by the authority when it granted and issued the original building consent 73400.

1.11. The parties and engineer 1 have considered options for remediating the floor slab and whether this additional building work may require a building consent. These issues have no bearing on the decision by the authority to issue the code compliance certificate for building consent 73400 and have not been discussed further.

1.12. The determination will not discuss the separate building consent (authority reference number 73424) regarding the construction of the truck shed superstructure (steel portal frames and lightweight metal cladding) connected to and supported by the foundation system approved in building consent 73400.

1.13. The determination will not discuss the design and construction of the office building on the same property, and adjacent to the truck shed, that was approved under a separate building consent (authority reference number 73346).

2. The building work

2.1. The property is a predominantly flat site to the south-west of Lake Rotorua (see figures 1 and 2). Geotechnical information from engineer 1 (dated 23 May 2014) and the experts (see paragraph 5.1) about the ground conditions at the site indicate the presence of soft clays, gravel, soft diatomaceous silts, peat, soft organic rich layers, sands, and pumice soils.[10] Ground water was encountered between 1.5m to 2m below ground level.

[7] Section 177(1)(b) and (2)(d) of the Act.
[8] Section 94(1)(a) of the Act.
[9] Sections 45(4)(a) and 45A of the Act.
[10] Pumice is a volcanic rock that consists of highly vesicular rough-textured volcanic glass, which may or not contain crystals and is typically light-coloured.

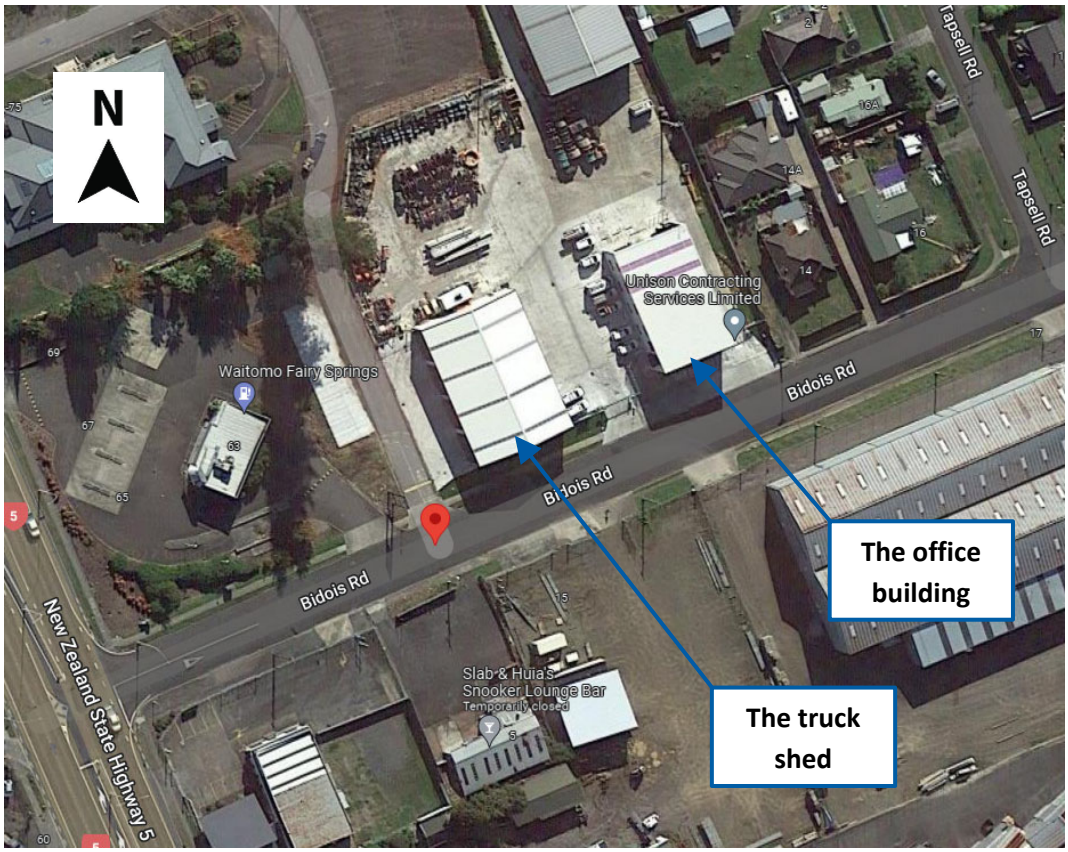

Figure 2: The truck shed, 2 – 6 Bidois Road, Fairy Springs, Rotorua[11]

2.2. The truck shed is an importance level 2 (IL2) building.[12] The annual probability of exceedance for ultimate limit states,[13] for a design working life of 50 years and an IL2 building, is 1 in 500 for wind and earthquake.[14]

2.3. The foundation system and floor slab are subject of a specific engineering design by two Chartered Professional Engineers (engineers 1 and 2). The design is detailed in three plans produced by engineer 2 (sheet numbers 1 to 3), dated January 2015. Revision 'A' of the plans was "issued for consent" on 5 February 2015.

2.4. The building consent application form (Form 2) stated the means of compliance was with Building Code Clause B1 Structure was 'NZS 3604'[15] and Verification Method 'B1/VM1'[16]. Part 9.0 'Foundations' of B1/VM1 states, "See B1/VM4". Paragraph 1.0.3 in B1/VM4, and associated 'comment', refers to Appendix B – 'Serviceability Limit State Deformations (Settlement)'.[17]

[11] Image reproduced from Google Maps, accessed on 9 May 2022.
[12] In accordance with Australian/New Zealand Standard, *AS/NZS1170.0:2002, Structural design actions Part 0: General Principles*, incorporating Amendment number 5 (September 2011), Tables 3.1 and 3.2.
[13] AS/NZS 1170.0.2002, item 1.4.10: Limit states, ultimate – "states associated with collapse, or with other similar forms of structural failure (this generally corresponds to the maximum load-carrying resistance of a structure or structural element but, in some cases, to the maximum applicable strain or deformation)".
[14] AS/NZS 1170.0:2002, Table 3.3 – Annual probability of exceedance.
[15] New Zealand Standard NZS 3604:2011 'Timber-framed buildings'.
[16] *Ministry of Business, Innovation and Employment Acceptable Solution and Verification Method for New Zealand Building Code Clause B1 Structure*, amendment 12, effective from 14 February 2014.
[17] This is an 'informative' appendix, and states in B1.0.2, "Foundation design should limit the probable maximum differential settlement over a horizontal distance of 6m to be no more than 25mm under serviceability limit state load combinations of AS/NZS 1170.0…".

2.5. The truck shed is approximately 30.5m long and 21m wide. It includes four "roller door rebates" evenly spaced along both long sides of the truck shed. See figure 1.

2.6. The foundation system approved in the building consent 73400 comprises of fourteen 23m long, 400mm diameter, H5 treated driven timber piles.[18] The piles are spaced evenly along both the short and long sides of the perimeter of the truck shed. Refer to figures 3 and 4.

2.7. In the consented design, the piles support a 500mm wide by 525mm deep reinforced concrete edge beam which extends around the perimeter of the truck shed. Refer to figure 3.

2.8. There is a 150mm thick reinforced concrete floor slab. This incorporates a 300mm deep thickening around the four edges of the slab. The floor slab is separated from the perimeter edge beam by an isolation joint (refer to figure 3).

2.9. The finished height of the floor slab is designed to be level with the top surface of the perimeter edge beam. Refer to figure 3.

2.10. The specification on plan sheet 1 of 3 stated all reinforced concrete material and construction shall comply with New Zealand Standards *NZS 3101:2006 Concrete structures standard* and *NZS 3109:2006 Concrete construction*.[19]

2.10.1. The specification did not state any project specific construction tolerances[20] to be achieved for the construction of the floor slab and perimeter edge beam. Therefore, in this determination, reference is made to *NZS 3109:1997 "Concrete construction"*, section 5.3 "Tolerances", table 5.2 "Tolerances for in situ construction". This allows for an acceptable deviation for the top of a foundation (slab) element to be plus or minus 12mm.

2.10.2. For flatness of departure from a 3m template, *NZS 3109:1997* table 5.2 refers to NZS 3114.[21] *NZS 3114:1987*, Table 3 "Tolerances for abrupt deviations or offsets and gradual deviations" states the "maximum abrupt deviation shall be 3mm for all classes of finish and use" and the maximum gradual deviation for an exposed concrete interior floor is 5mm.

2.11. The floor slab is supported on a 500m deep layer of proprietary expanded polystyrene units covered in a minimum 1mm thick flexible high density polyethylene membrane. Under these units is a variable depth of "pumice sand backfill compacted to 95 percent of maximum dry density at [an] optimum moisture content and less than 10 percent air voids in 200mm [maximum] layers", reinforced with two layers of a proprietary geotextile product used to strengthen soil. The consented design specified that the backfill was to extend between 4.2m to 5.6m beyond the perimeter of the

[18] Timber treated to hazard classification H5 is described in *New Zealand Standard NZS 3640:2003 Chemical Preservation of Round and Sawn Timber*.

[19] Engineer 2 refers to NZS 3109:2006, however, the correct reference is NZS 3109:1997, incorporating amendment 1 in August 2003, and amendment 2 in March 2004. Both NZS 3109:1997 and NZS 3101:Part 1:2006 are cited in *Ministry of Business, Innovation and Employment Acceptable Solution and Verification Method for New Zealand Building Code Clause B1 Structure*, amendment 12, effective from 14 February 2014; this was the version that was current when the building consent was granted and issued.

[20] Tolerances – limits specified for construction variation.

[21] New Zealand standard NZS 3114:1987 "Specification for concrete surface finishes".

truck shed, with the top surface sloped downwards and away from the "edge beam".[22] Refer to figure 3.

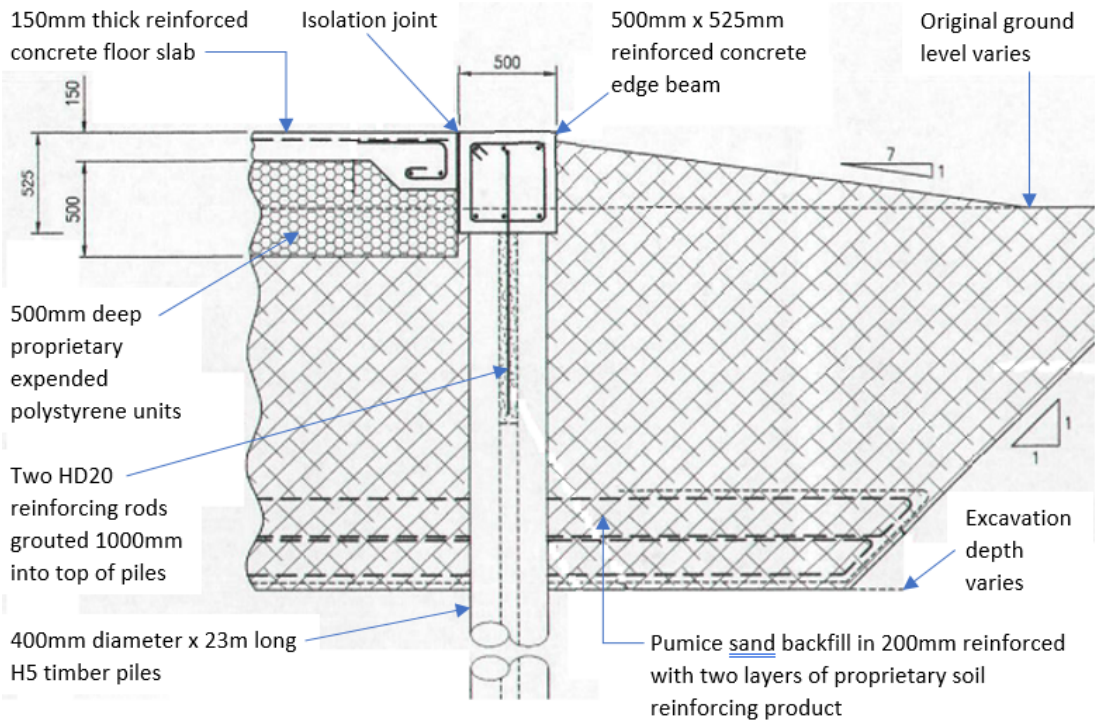

Figure 3: Foundation system and floor slab (not to scale)

(Note: Figure 3 is reproduced from engineer 2's plan sheet 3 of 3, section 4/1, "Details", amendment A, dated 5 February 2015. Dimensions are in millimetres unless stated otherwise).

2.12. The design was dependant on several inspections and testing to be conducted as specified on plan sheet 1 of 3:

2.12.1. Inspection and approval of the foundation soils is required by a geotechnical engineer or engineering geologist at the completion of the excavation. No backfill material shall be placed before approval of the excavation.

2.12.2. The proposed backfill must be approved by the engineer. The builder is to provide grading and standard compaction test results for the proposed material.

2.12.3. The proprietary high density polyethylene membrane and proprietary product used to strengthen the soil must be inspected and approved by the engineer before installation.[23]

[22] The designer's approved site plan BD 1.01 C dated 19 February 2015 indicates "new concrete yard paving" to three sides of the new truck shed, with "planting" along the fourth (south-east) side. However, the building consent plans from engineer 2 do not show the new concrete paving.

[23] The specification did not confirm which engineer was responsible for this inspection. In response to the draft determination, the owner was of the view engineer 1 had "supervisory responsibility" for this element of the building work.

2.12.4. In respect of the backfill material to be used, a site trial area compaction shall be carried out to determine the optimum layer thickness and number of passes required to achieve this target compaction.[24]

2.12.5. Compaction testing of the backfill shall be performed at a frequency of five evenly spaced tests per layer. If any of the test records a density of less than 95 percent of the maximum dry density, the builder must take the required remedial measures and re-test the area.

3. Background

3.1. Between 7 and 14 April 2014, engineer 1 conducted an initial "site walkover…to identify any geomorphic features that may impact on the development of the site", and undertook cone penetrometer tests and other geotechnical investigations.

3.2. On 23 May 2014[25], engineer 1 prepared a report for the owner in respect of a geotechnical assessment and foundation recommendations for the project ("the geotechnical report").[26] The report stated:

3.2.1. The exploratory holes have proved significantly different ground conditions exist between the eastern and western parts of the site.

3.2.2. The soils at the site have the potential to liquefy during a significant seismic event due to the grain size, density, strength, and high-water table (assessed at a depth of between 1.5m to 2m below ground level).

3.2.3. The estimates of settlement arising from liquefaction of the soils range from 35mm to 140mm across the site.

3.2.4. Settlement and liquefaction occur in the upper 6m of the soil profile.

3.2.5. Placing fill over the area of the truck shed, or removal and replacement of the upper parts of the soft soils, will result in long-term settlement of the underlying organic soils due to the increased weight of soil.

3.3. On 4 October 2014, engineer 1 undertook further geotechnical investigations and on 21 October 2014, excavated "three test pits" adjacent to the footprint of the proposed truck shed "to further appraise the…soils at the site".

3.4. On 24 October 2014, engineer 1 wrote to the owner and engineer 2 describing additional investigation and assessment required for the project. Engineer 1 identified that "the site is underlain by two distinct problematic soil types". The letter stated:

> The western part of the site beneath the proposed [truck shed] is underlain by organic soils (peat and organic silt / clay) at relatively shallow depths, with a thick organic soil layer also indicated to extend to 12 – 13m depth below the site. A deep

[24] The specification did not confirm who was responsible for undertaking, monitoring, and recording of the compaction testing.

[25] The date on the signature page is 23 May 2014, but all other pages of the report state the date of 5 May 2014 in the footer.

[26] Engineer 1 reference number 2-32352.00 G3212, issue 1.

> pile solution or the [proprietary expanded polystyrene] option may be suitable solutions for the [truck shed].

Engineer 1 recommended "a deep pile solution".

3.5. Between 27 November 2014 and 20 January 2015, engineer 1 and engineer 2 corresponded about the size, quantity, and depth of the timber piles.

3.6. On 20 January 2015, engineer 1 issued a letter to engineer 2, where they describe the recommended design for the truck shed foundations.

3.6.1. The foundation was to consist of fourteen 400mm diameter, 23m deep, timber piles.

3.6.2. The piles were connected to a "rigid perimeter beam pile cap at the surface", and "spaced to be directly under each point load applied by the building structure".

3.6.3. The reinforced concrete "floor slab must be completely disconnected from the perimeter beam and designed to support the live and static truck loading".

3.6.4. The building site was to extend "at least 1.0m in each direction beyond the building footprint" and was to be excavated "to a depth of at least 1.5m below [the] existing level and replaced with a pumice pit sand backfill material to slab level".

3.6.5. The backfill material was to be "compacted to 300kPa bearing capacity" and reinforced with a proprietary geotextile product.

3.6.6. "As a result of the piled foundation, and removal of the existing soil and replacement with pumice pit sand, much of the potential long-term differential settlement[27] risk has been reduced".

3.6.7. There remained a potential long-term issue for this site, namely, "potentially significant long-term creep settlement of the organic silt / clay material".

3.6.8. The construction drawings must include a requirement that all service connections to the truck shed must be designed to withstand up to 100mm vertical movement.

3.6.9. The construction drawings must include reference to specific inspections by the engineer and measures to be adopted if groundwater is encountered above the 1.5m depth of the excavation.

3.6.10. The letter included several attachments such as site investigation records dated 4 October 2014, including soil classifications, auger/scala penetrometer

[27] Meaning the downward movement of a building's foundation and/or floor slab due to the load of the building compressing the underlying soil layers and/or movement of the underlying soil itself. Downward movement of the building's foundation and/or floor slab that varies at different locations is termed differential settlement that can often lead to structural damage (as stated in Appendix D of the Ministry's *"Assessment, repair and rebuild of earthquake-affected industrial buildings in Canterbury"*, dated December 2014).

test reports dated 23 April 2014,[28] bearing capacity calculations and settlement estimates dated September 2014, 19 January 2015 and 3 February 2015, and plan sheets 1, 2 and 3, revision A, details and sections prepared by engineer 2 dated 5 February 2015.[29]

3.7. On 28 January 2015, engineer 1 provided to engineer 2 an updated fill design for the truck shed to increase the fill height. Engineer 1 noted there will be some differential settlement between the ramp and structure, and therefore recommended preloading.[30]

3.8. On 17 February 2015, engineer 1 issued a Producer Statement – Design ("PS1") with supporting documentation for site investigation and foundation design and specification for the "proposed truck storage shed" ("the original design and calculations").[31] The PS1 stated compliance with Clauses B1 Structure and B2 Durability and cross-referenced to engineer 2's plan sheets 1, 2 and 3, revision A, dated 5 February 2015. The schedule to the PS1 included the letter to engineer 2 dated 20 January 2015 which provided foundation design information for the truck shed.[32] The schedule also included bearing capacity calculations and settlement estimates.

3.9. On 19 February 2015, a building consent was sought for the "foundation [and] slab for [a] new proposed workshop shed". The owner used the services of an agent (Licensed Building Practitioner, design) for the purposes of obtaining the building consent and code compliance certificate for the project ("the designer").

3.10. Building consent 73400 ("the building consent") was granted by the authority on 12 March 2015 and issued on 13 March 2015 for the construction of the timber pile foundation and reinforced concrete edge beam and floor slab for the truck shed. The building consent appears to have been issued by the authority on the grounds:

3.10.1. the compensated slab design was deemed sufficient to limit the effects of primary (consolidation) settlement, but not secondary (creep) settlement

3.10.2. the piled support to the perimeter edge beam was deemed sufficient to limit the settlement therein so it was able to be accommodated by the building superstructure

3.10.3. any secondary (creep) settlement occurring in the future would not be such as to the make the building floor system non-functional

meaning overall compliance with the performance requirements of Clauses B1 Structure and B2 Durability would be achieved.

[28] Tests conducted 14 April 2014.

[29] I note the date of the letter of 20 January 2015 pre-dates several of the attachments appended to it.

[30] I note, from the information received as part of the application for determination, it appears the ground was not subject to preloading prior to the construction of the floor slab and foundation system.

[31] The PS1 was signed by a Chartered Professional Engineer, practice field: geotechnical engineering.

[32] The PS1, the associated schedule, and letter dated 20 January 2015 from engineer 1, are all included in the authority's approved building consent file for 73400.

3.11. The building consent was issued subject to several "conditions" and "endorsements", these included (but were not limited to):

3.11.1. Three inspections were to be conducted by the authority:

(1) Siting, footings, foundations (location relative to the boundary to be confirmed, steel reinforcing in place and supported).

(2) Concrete floors (damp-proof membrane laid, steel reinforcing placed and supported, and any pipes lagged).

(3) Final inspection when all building work is completed.

3.11.2. "The applicant shall comply with the recommendations of the geotechnical report…" and a "producer statement [confirming] compliance is to be submitted to [the authority] on completion of this work".[33]

3.11.3. "A suitably qualified person shall be retained by the owner to certify the minimum bearing capacity for the foundation design has been met" and issue an associated Producer Statement – Construction Review (PS4).

3.11.4. "A suitably qualified engineer is to confirm that any preparatory site works has been undertaken as [a] controlled operation and that any filling that will support the building foundations has been adequately compacted. The engineer shall also consider any implications within the cut ground including but not limited to; slope stability…and consideration of any changes to the foundations sub grade soils…".

3.11.5. A granular base being laid under the floor slab.

3.12. On 31 March 2015, engineer 1 issued a new Producer Statement – Design (PS1) to the owner along with amended plans and specifications (plus supporting documentation) for the "proposed truck storage shed".[34] The PS1 stated the design complied with Clauses B1 Structure and B2 Durability as an alternative solution.

The PS1 referred to updated plans titled "Proposed Truck Shed, Foundation and Slab Plan…Sheets 1 to 3 [revision] D".[35] A schedule accompanying the PS1 in respect of the "revised design" included:

3.12.1. confirmation of "reduced pile lengths from 23 m to 14 to 16 m" and 300mm in diameter

3.12.2. copies of site investigation records

[33] For the purposes of this determination, I have assumed this relates to a Producer Statement – Construction Review ("PS4").

[34] The PS1 states it was issued to the owner, to be supplied to the authority. However, this is contrary to the owner's submission to the application for determination which states the design changes were issued by engineer 1 to the designer, engineer 2, and the "building and piling contractors" on 1 April 2015. No evidence has been provided to confirm the PS1 dated 31 March 2015, plus supporting documentation, was issued to the authority.

[35] The schedule attached to the PS1 refers to revision D of the plan sheets being dated January 2015. This appears to be incorrect. Revision D of the plan sheets is dated 31 March 2015.

3.12.3. bearing capacity calculations and settlement estimates

3.12.4. pile axial capacity calculations

3.12.5. copies of plan sheets 1 to 3 revision D

3.12.6. confirmation that the cross-sectional dimensions of the perimeter edge beam were now to be 600mm wide x 525mm deep (as stated on revision D of plan sheets 2 and 3)

3.12.7. another copy of the letter from engineer 1 to engineer 2 dated 20 January 2015

3.12.8. data sheets titled "Pile capacity (versus) Depth – 300mm [and] 400mm driven wood piles" for each of the test locations assessed by engineer 1

3.12.9. another copy of the "settlement checks" for the floor slab and expanded polystyrene fill material calculation sheets dated 3 February 2015.

3.13. On 8 April 2015, engineer 1 observed the "pile driving and installation".

3.14. On 19 April 2015, the foundation excavation began, and "backfilling of the fill platform" with layers of GAP100[36] and compacted pumice fill was completed by 21 May 2015. This work was covered by inspections undertaken by engineer 1.

3.15. On 4 June 2015, the authority completed a siting inspection. The inspection report stated, "siting as per consented plans" and the floor level was in accordance with the plans. The inspection outcome was "pass". The same report confirmed that "no piles" were observed by the authority.

3.16. On 23 June 2015, the floor slab was poured. Engineer 2 undertook a pre-pour inspection to confirm the quantity and position of the steel reinforcing was in accordance with the plans.[37]

3.17. On 26 June 2015, engineer 2 issued to the owner a Producer Statement – Construction Review (PS4) in respect of "truck storage shed foundations" and building consent 73400.[38] It confirmed the inspection and verification of foundation steel work, titled "Fell Hotels, 2 – 6 Bidois Road, Proposed Truck Storage Shed, sheets 1 [to] 3)".[39]

3.17.1. The stated means of compliance of the building work was with Clause B1 Structure.

3.17.2. The PS4 did not indicate any amendments to the building consent 73400 and stated "no" in respect of any authorised instructions or variations.

[36] General all passing aggregate.

[37] Although engineer 2 stated in a letter to the Ministry (dated 3 October 2022), that it had undertaken a pre-pour inspection, it did not confirm the date of the inspection.

[38] The PS4 did not identify that any of the building work was subject to any amendment to, or variation from, the approved building consent plans and specifications.

[39] The PS4 did not state which revision of the plan sheets it related to.

3.18. On 30 June 2015, engineer 2 produced "as-built" plan sheets 1, 2 and 3, revision E.[40] Plan sheet 1 confirms the H5 treated timber piles were an average 300mm in diameter and estimated to be 14m to 16m long. Plan sheets 2 and 3 confirm the perimeter edge beam was 600mm wide x 525mm deep.

3.18.1. Plan sheets 2 and 3 state the 150mm thick reinforced concrete floor slab was supported on 500mm deep proprietary expanded polystyrene units, which in turn, is supported on 200mm layers of compacted "pumice sand backfill" with proprietary reinforcement.[41]

3.19. Several settlement monitoring surveys were carried out by engineer 2 between 3 July 2015 (the initial survey) and 17 November 2015.[42] The survey measured four points on the top of the perimeter edge beam at the corners of the truck shed, and 13 reference points spaced at different locations across the floor slab. Refer to figure 4.

A summary of the survey data is reproduced in table 1.

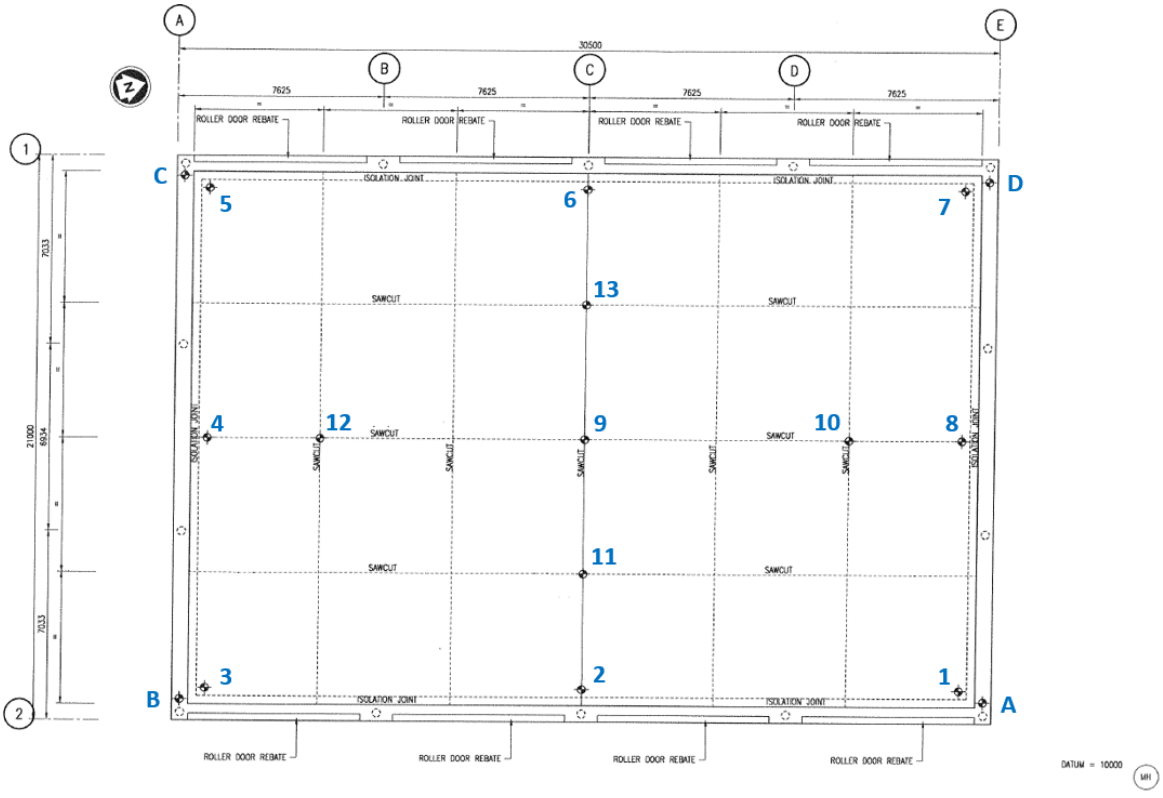

Figure 4: Location of survey points (not to scale).

(Notes: Plan reproduced from "Slab level monitoring plan", dated July 2015, reference number 19915A, sheet number 1A, by engineer 2. The survey points are indicated by small black and white circles with the relevant reference numbers or letters located

[40] The authority's "code compliance certificate assessment checklist" indicates that the authority did not receive any as-built plans; item number 13 of the checklist states "none [received]".

[41] The as-built plans do not indicate that some GAP100 backfill material was used, as noted in the site inspection reports from engineer 1.

[42] After the initial survey on 3 July 2015 to establish the base heights, six subsequent surveys were undertaken up to and including the 18 August 2015 prior to the issue of the code compliance certificate on 18 September 2015. One set of data was taken on 17 November 2015 after the issue of the code compliance certificate.

adjacent to them. The survey datum point is the manhole shown outside the northeast corner of the truck shed to the bottom right of figure 4).

Table 1: Settlement monitoring survey (engineer 2).

Survey point	Initial survey datum height[3] (m) (A)	Survey data for 18 August 2015 (m)[8] (B)	Difference in height[6] (A)– (B) =	Survey data for 17 November 2015 (m) (C)	Difference in height[6] (A) – (C) =
1	9765	9763	-2mm	9749	- 16mm
2	9765	9760	-5mm	9738	-27mm
3	9770	9771	+1mm	9768	-2mm
4	9770	9770	0mm	9757	-13mm
5	9765	9760	-5mm	9742	-23mm
6	9755	9741	-14mm	9705	-50mm
7	9755	9741	-14mm	9715	-40mm
8	9755	9743	-12mm	9709	-46mm
9	9770	9755	-15mm	9712	-58mm
10	9770	9758	-12mm	9721	-49mm
11	9765	9759	-6mm	9726	-39mm
12	9765	9762	-3mm	9737	-28mm
13	9765	9751	-14mm	9705	-50mm
A	9785	9783	-2mm	9786	+1mm
B	9780	9779	-1mm	9780	0mm
C	9780	9781	+1mm	9785	+5mm
D	9775	9772	-3mm	9774	-1mm

Notes:

1. The survey data is reproduced from engineer 2 plan sheet 1A dated July 2015, titled "Slab level monitoring plan" (despite some of the survey data having been recorded after the date on the plan sheet).

2. The survey base datum height of 10.000m was taken from a manhole adjacent to the northeast corner of the truck shed. All surveyed heights shown in columns (A), (B) and (C) are taken relative to the base datum height.

3. Initial survey heights for points 1 to 13 and points A to D inclusive were established on 3 July 2015.

4. The survey recordings for 10 and 17 July 2015 (for points 1 to 13) and 7, 12 and 13 August 2015 have not been included.

5. In a submission to the application for determination, the owner stated "a further eleven settlement surveys were undertaken between 18 August 2015 and 29 August 2016". These settlement readings are not included in table 1.

6. A difference in height shown as a "minus" figure (in the fourth and sixth columns) is a measure of the extent of settlement (downwards) compared against the initial survey height. A "plus" figure indicates the extent to which the top surface of the perimeter edge beam or floor slab has raised (upwards).

7. The difference in height is calculated from the initial survey data from 3 July 2015 and 17 July 2015 and not from any assumed slab level when the concrete was first poured on 23 June 2015.

8. The date of 18 August 2015 is referenced in column 3 as this is the last recorded survey data produced before the code compliance certificate was issued on 18 September 2015.

3.20. On 17 August 2015, engineer 1 issued a Producer Statement – Construction Review ("PS4") in respect of "Truck storage shed: Pile bearing capacity, foundation undercut and fill compaction" for building consent 73400. The stated means of compliance of the building work was with Clauses B1 Structure and B2 Durability. The PS4 confirmed there were no building consents amendments issued, and "nil" authorised instructions or variations made by engineer 1.

3.21. On 18 August 2015, engineer 1 issued to the designer a copy of its PS4 and supporting documentation in respect of the "Pile installation and granular base under [the] floor slab". The supporting documentation included:

3.21.1. compaction control test results dated 18 May 2015

3.21.2. impact soil test reports dated 19 and 21 May 2015

3.21.3. penetration resistance of a soil test report dated 21 May 2015

3.21.4. site inspection records by engineer 1, dated 21 and 24 April 2015, and a further seven in May 2015, in respect of filling (backfill of layers of pumice material and proprietary geotextile reinforcing product)

3.21.5. site inspection record by engineer 1, dated 8 April 2015, in respect of piling. The report stated the pile diameter was greater than 400mm and the depth was 14m to 16m, the piles were treated to H5. The report also stated, "piles were driven to [the] required depths as per investigations" and "a lot of water present on site, with a high groundwater table. The pile driving began to have stiff resistance around 12m [below ground level], they drove through this in most cases to the required level"

3.21.6. amended plan sheet 1 of 3 from engineer 2, titled "Foundation and Slab Plan", revision D, dated 31 March 2015. This stated the "average pile diameter of approximately 300mm, estimated length 14 to 16m"

3.21.7. producer statement – construction (PS3) for the pile driving works dated 15 July 2015 provided by the contractor. The penetration of the fourteen 300mm diameter specific engineering design piles installed below the underside of the footing was between 14m to 16.2m in depth.

3.22. On 26 August 2015, the authority completed a final inspection. The inspection report confirmed the authority had received an application for the code compliance certificate, a Producer Statement – Construction Review (PS4) from engineer 1 "for fill platform to workshop shed", and a separate PS4 from engineer 2 "for all foundation steelwork". The inspection report did not record any information about the as-built construction the inspector may have observed at that point in time. The inspection outcome was "pass".

3.23. On 26 August 2015, an agent[43] for the owners applied for a code compliance certificate.[44] The application confirmed "all building work to be carried out under the…building consent was completed on 27 August 2015".[45]

3.24. In early September 2015, the tenant occupied the truck shed.

3.25. On 11 September 2015, the authority completed a "code compliance certificate assessment checklist," which confirmed:

3.25.1. Work complies with the approved building consent (section 94(1) of the Act).

3.25.2. All the required inspections have been completed in accordance with the building consent "conditions".

3.25.3. The building consent conditions have been complied with.

3.25.4. "Pile driving" was observed by the engineer.[46]

[43] The designer (see paragraph 1.2.1).
[44] Section 92 of the Act.
[45] I note, this post-dates when the application form was signed and dated.
[46] I note the checklist did not record which engineer observed the pile driving.

3.25.5. "Foundation observation" by engineer 2, and associated Producer Statement – Construction Review (PS4) received.

3.25.6. "Ground conditions including compaction" observed by engineer 1, and an associated PS4 received.

3.25.7. No amendments or as-builts have been received.

3.26. On 18 September 2015, the authority issued the code compliance certificate as it was "satisfied, on reasonable grounds, that the building work complies with the building consent".

3.27. Between 23 March 2016 and 29 August 2016, engineer 1 conducted several surveys of the floor slab and perimeter edge beam. The results are summarised in table 2. The cumulative difference in levels is based on the initial survey heights being measured on 3 July 2015 (the same data as noted in table 1).

Table 2: Settlement monitoring survey (engineer 1)

Survey point[5]	Initial survey datum height[3] (m) (A)	Survey data for 29 August 2016 (m) (B)	Difference in height[4] (A) – (B)[2] =
1	9.765	9.724	- 41mm
2	9.765	9.720	-45mm
3	9.770	9.765	-5mm
4	9.770	9.744	-26mm
5	9.765	9.720	-45mm
6	9.755	9.661	-94mm
7	9.755	9.670	-85mm
8	9.755	9.658	-97mm
9	9.770	9.671	-99mm
10	9.770	9.679	-91mm
11	9.765	9.699	-66mm
12	9.765	9.711	-54mm
13	9.765	9.656	-109mm

A	9.785	9.796	+11mm
B	9.780	9.792	+12mm
C	9.780	9.794	+14mm
D	9.775	9.785	+10mm

Notes:

1. The survey recordings for 22 April 2016 through to 29 June 2016 have not been included.

2. A difference in height shown as a "minus" figure (in the fourth column) is a measure of the extent of settlement (downwards) compared against the initial survey height. A "plus" figure indicates the extent to which the top surface of the perimeter edge beam has raised (upwards).

3. Initial survey heights for points 1 to 13 inclusive were established by engineer 2 on 3 July 2015. Initial survey heights for points A to D inclusive were established by engineer 2 on 17 July 2015. See table 1.

4. The difference in height is calculated from the initial survey data from 3 July 2015 and 17 July 2015 and not from any assumed slab level when the concrete was first poured on 23 June 2015.

5. The survey points 1 to 13 and A to D inclusive are the same as shown in figure 4 and table 1.

3.28. On 17 November 2016, engineer 1 provided a further settlement report showing "the total settlement to date and settlement from January 2016" up to 9 November 2016. The results were represented on several "settlement plots" for the purposes of re-assessing "the rate of settlement and predicted settlement".[47] Engineer 1 stated:

> The slowing in the rate of settlement over the winter period appears to be continuing, and as stated previously is more than we consider would be predicted by a strict logarithmic decline of the type normally expected for consolidation settlement.
>
> [Engineer 1 considers] that ongoing settlement may now be mainly due to secondary creep in the organic soils only.

3.29. Incident reports from the company leasing the truck shed, dated 21 November 2019 and 2 June 2020, indicate damage being caused to vehicles accessing or exiting the truck shed because of the settlement of the floor slab. Photographs attached to the report from 2 June 2020 show that steel plates have been fixed in place to allow for the movement of vehicles over the perimeter edge beam due to the lower-level floor slab and external concrete hardstanding. Refer to figure 5.

[47] The settlement plots have not been reproduced in this determination.

(a) View from inside the truck shed

(b) View from outside the truck shed

Figure 5: The truck shed as of 2 June 2020.

(Note: Photograph 5(b) indicates damage to the exposed top corners of the perimeter edge beam).

3.30. On 24 July 2019, the Ministry received an application for a determination.

3.31. On 14 September 2020, engineer 1 issued a memorandum report with calculations and conclusions about the as-built foundation system ("the memorandum"). Refer to paragraph 4.14.

3.32. On 6 May 2021, the owner provided a further set of survey results from a registered surveyor. The survey was conducted on 7 April 2021. The survey used the same "survey points" and "initial survey datum heights" as shown in tables 1 and 2 above.

3.32.1. The greatest settlement recorded for the floor slab was -139mm at point number 13 and the least was 0mm at point 3.

3.32.2. The perimeter edge beam had raised upwards between 47mm at point B, and 50mm at point D.

3.32.3. The survey noted an approximate 10mm difference between the surveyed levels of the perimeter edge beam by engineer 1 and engineer 2.

3.33. On 22 August 2022, a draft determination was sent to the parties and persons with an interest. Responses to the draft determination are summarised in section 4 below ("Submissions") under the relevant sub-headings.

4. Submissions

The owner

4.1. The owner submitted:

4.1.1. In respect of the code compliance certificate issued by the authority, the owner queried whether it "should be cancelled" because "the truck shed perimeter foundation piling system as constructed differs significantly" from

the design approved in the building consent, and "the truck shed floating floor slab" is exhibiting "significant differential settlement". Consequently, it has failed to meet the requirements of Clauses B1 Structure and B2 Durability.

4.1.2. There was no reason given by engineer 1 for the change away from the fully piled design to the compensated floating slab design (refer to 4.3.5).

4.1.3. The amended design associated with the Producer Statement – Design (PS1) dated 31 March 2015 from engineer 1 was not submitted to the authority and was not consented.

4.1.4. The layer of GAP100 compacted to the bottom of the undercut to provide a working surface and the 1.5mm thick HDPE liner installed as shown in the site inspection records by engineer 1 were not shown on the original design and calculations and building consent, the amended design and calculations, or the as-built drawings and documentation. Compacting the hardfill may have disturbed the soil layers below and contributed to the average density of the backfill being as heavy as the material it replaced, thereby losing the compensatory effect on which the design depended.

4.1.5. The floor slab, and concrete hardstanding adjoining the truck shed, suffered from differential settlement immediately after the pouring of the concrete.

4.1.6. They had conducted their own settlement surveys on 11 December 2017 and 1 August 2018. The survey of 11 December 2017 indicated "the floor slab had settled up to 20mm since the final" survey by engineer 1 on 29 August 2016. The survey on 1 August 2018 "indicated that no further…settlement had occurred since" 11 December 2017.

4.1.7. The Producer Statement – Construction Review (PS4) dated 17 August 2015 was provided by engineer 1 to the authority on 18 August 2015.[48] However, the list of other documents noted as appendices to the PS4 were not included.[49] The PS4 indicates no instructions or variations were issued. However, engineer 1 issued the amended design "by way of instructions" to the designer, engineer 2, and the building and piling contractors. This meant the authority assumed the PS4 was in respect of the approved original foundation design.

4.1.8. They first became "aware of the unconsented design changes made to the perimeter foundation piling system" on 20 April 2018. Up until then, "the matter for concern had been the settlement of the floating floor slab and adjacent concrete hardstanding".

4.1.9. The "primary concern is the unconsented changes may have left the truck shed at risk in an earthquake" because "the unconsented design changes completely abrogate the critical load case assumed in the original design

[48] The PS4 indicates it was issued to the designer on 18 August 2015, and the authority received a copy on or before it conducted its final inspection on 26 August 2015.

[49] The other documents listed were the laboratory test certificates, site inspection records and photographs in respect of the backfilling and piling. The as-built plans were not included with the PS4.

calculations". The sand layer cannot be relied upon for bearing capacity in an earthquake, particularly if the upper soils layers are subject to liquefaction.

4.1.10. The floor slab has failed the durability requirements of the Building Code because differential settlement occurred immediately after the slab was poured. The hybrid design of a rigid perimeter foundation beam and floating floor slab meant the perimeter foundation stayed in place, while the floor slab and adjoining external concrete handstand settled differentially.

4.1.11. There was a "loss of amenity"[50] due to the "flawed engineering design that resulted in the floor slab and surrounding concrete hardstanding" settling.

4.1.12. Photographs which showed "timber chocks…placed on both sides of the [vehicle access] doors as a temporary measure so…trucks could climb over the door sills". Refer to figure 6. The owner stated the timber chocks have now been replaced with "steel plates to reduce the steepness of the climb into and out of the [truck] shed". Refer to figure 5(a).

(a) Timber chock inside the shed (b) Timber chock outside the shed

Figure 6: Vehicle access door to the southeast corner of the truck shed.

(Note: The date the photographs were taken is unknown).

4.1.13. The construction of the "floor slab system":

> has failed the durability requirements of Clause B2 Durability of the Building Code for functionality because the floor system requires reconstruction or major renovation (B2.2); and for performance because it has failed to meet the 50 year intended life of the building (B2.3.1(a)).
>
> It is also clear that the floor slab system failed the Clause B1 - structural functionality requirement because has failed to withstand the combination of loads it would experience during its life (B1.2); failed in terms of performance due to becoming unstable and losing equilibrium during construction and

[50] Clause A2 – Interpretation: *amenity* means an attribute of a *building* which contributes to the health, physical independence, and well being of the *building's* users but which is not associated with disease or a specific illness.

when in use (B1.3.1); and suffered loss of amenity through undue deformation[51] during construction and when in use (B1.3.2).

4.1.14. On 20 April 2020:

> The last survey the consultants conducted in late August 2016 showed the maximum settlement to be circa 130mm. Our most recent survey in early August 2018 showed the maximum settlement to be circa 160mm, averaging 120mm or more over approximately a third of the building, with a differential settlement across the floor slab of circa 130mm.

4.1.15. On 11 February 2021, a further limited survey was undertaken on or about 9 February 2021 "as a result of the recent earthquakes in the Rotorua area".[52] The survey indicated:

(1) the floor slab has settled a further 20mm in the northwest corner

(2) the floor slab has settled approximately 15mm further at the midpoint of the west wall

(3) elsewhere, the floor slab appears to be relatively unchanged

(4) the most recent survey results may have been caused by the earthquake

(5) the greatest difference in height between the top of the perimeter edge beam and floor slab is approximately 220mm on the north side of the truck shed

(6) the top of the perimeter edge beam is between 30 to 40mm higher than previous surveys.[53]

4.2. In response to experts' first report dated 21 June 2021 (refer to paragraph 5.1), the owner submitted:

4.2.1. The performance of the perimeter foundation's pile system is a critical factor, and the experts should have considered the causes of this, including the apparent uplift of the perimeter foundation pile system as a result of the earthquakes on 25 January 2021.[54] This caused the perimeter foundation beam and pile system to lift by 40mm to 50mm. Had the floor slab been structurally integral with the perimeter foundation system, there would have been considerably greater resistance to uplift.

[51] Deformation – limits specified in (for example, AS/NZS 1170.0:2002, table C1) are for control of deformation under applied load, including those from elapsed time effects (for example, creep strains), such as clause B1.3.4 (d) and (e).

[52] Two earthquake events on 25 January 2021 based on information from the GeoNet Strong Motion Database in the region of Tongariro and Bay of Plenty. Available at https://www.geonet.org.nz/earthquake.

[53] The owner also provided possible reasons for the top of the edge beam being at a higher level, including, errors with the original survey, a further lowering of the floor level and external concrete hardstanding, of the edge beam has lifted.

[54] The owner's submission referred to earthquakes on 20 January 2021 and 25 January 2021. The date of 25 January 2021 has been used here based on the information obtained from GeoNet Strong Motion Database in the region of Tongariro and Bay of Plenty for that date.

4.2.2. The amended design and calculations were unconsented by the authority and do not comply with Clause B1 Structure. The amended design and calculations are the original design and calculations with the pile calculations removed and a list of comments added, which in the owner's opinion is not a proper basis of design.

4.2.3. The as-built plans correctly illustrate the constructed work, but they fail to include the hardfill placed at the base of the undercut excavation.

4.2.4. The specific engineering design timber piles are 300mm in diameter. The pile set numbers were provided to the contractor by engineer 1. The Producer Statement – Construction (PS3) for the pile driving works dated 15 July 2015 provided by the specialist piling contractor was annotated by engineer 1 to state the piles were 400mm in diameter.

4.2.5. As a result of the unconsented amended design and calculations, the piles were founded on a thin sand layer at approximately 15m depth. The potential for punch through[55] of the thin sand layer should have been considered. Good engineering practice would have been to drive the piles to appropriate sets in the competent ground below the sand layer.

4.2.6. The Producer Statement – Design (PS1) dated 31 March 2015 did not allow for an assessment of the end bearing or the skin friction capacity of the piles.

4.2.7. It is assumed the reduced pile embedment depth and reduced diameter of the piles places the building at serious risk in a more severe earthquake than the relatively moderate earthquakes that occurred on 25 January 2021.

4.2.8. Settlement of the floor slab was observed shortly after the floor slab was poured on 23 June 2015, and the first recorded survey was 3 July 2015, and by the time the survey on 17 November 2015 was conducted there was a significant increase in the rate of differential settlement.

4.2.9. It is likely the earthquake from 25 January 2021 triggered between 40mm to 50mm of primary settlement of the floor slab along with the equivalent settlement of the exterior concrete hardstanding.

4.2.10. The tenant advises, when they first occupied the truck shed during the first week in September 2015, they could immediately see the floor slab weaving under the truck movements.

4.2.11. The majority of the primary settlement had occurred by approximately 2016 to 2017.

4.2.12. The settlement survey results do not explain the additional settlement of 15mm to 20mm between the 29 August 2018 and 9 February 2021 surveys, which is believed to be settlement mobilised by the 25 January 2021 earthquakes.

[55] The structural load on the pile foundation system is such that it causes the pile(s) to be forced through the bearing or supporting ground layer and penetrates into the softer or weaker soils below.

4.2.13. The statement from engineer 1 that the services should be designed to accommodate 100mm settlement is a standard disclaimer without any analytical basis and has no value as a prediction of future potential settlement. Further, there are no services under the floor slab, and the only underground services connections (power supply and stormwater) terminate outside the footprint of the truck shed.

4.2.14. The compensated foundation system or assembly, comprising the reinforced concrete floor slab, proprietary expanded polystyrene units, pumice sand and geotextile layers, does not comply with Clause B2 Durability, and the reinforced concrete slab component may fail within the 50-year intended life due to the effects of settlement.

4.2.15. Damage has occurred to the door sill parts of the perimeter edge beam from vehicle movements due to the settlement of the floor slab generating a non-trafficable surface at the floor slab to perimeter edge beam junction through the truck shed doorway entrance.

4.3. On 3 October 2022, the owner accepted the draft determination but stated:

4.3.1. It was not correct the uplift of the perimeter foundation beam was a reason the owner was of the view the authority was incorrect to issue the code compliance certificate.[56]

4.3.2. The perimeter foundation beam uplift did not occur until years after the authority issued the code compliance certificate.[57]

4.3.3. No appreciable settlement had occurred between the surveys conducted on 11 December 2017 and 1 August 2018. This is evidence that both primary and secondary settlement had ceased.

4.3.4. Attachments to the Producer Statement – Construction Review (PS4) were emailed to the authority on 22 August 2018 by the designer.[58]

4.3.5. The revised design by engineer 1 from 31 March 2015 intended to eliminate primary and secondary settlements.[59] Primary settlement was the issue, and the survey data shows the extent of secondary settlement to be relatively minor.

[56] I note this is contrary to other evidence provided to the Ministry during the course of the determination.

[57] I note the survey data from July 2015 in Table 1 (prior to the issue of the code compliance certificate on 18 September 2015) indicates minor variations in the elevation of the perimeter edge beam (between -3mm and +1mm), and further increases in November 2015 (up to +5mm), and in August 2016 of up to 14mm in total (refer to Table 2). Taken together, this data indicates the perimeter edge beam was already experiencing a measure of upwards movement soon after the issue of the code compliance certificate.

[58] The owner did not clarify whether he was referring to the PS4 issued by engineer 1 or engineer 2.

[59] The owner referred to the original letter from engineer 1 dated 12 February 2015.

4.3.6. The perimeter foundation beam and associated pile system failed the serviceability limit state (SLS) requirements of the Building Code as a result of the 25 January 2021 earthquakes.[60]

4.3.7. The uplift of the perimeter foundation beam as a result of the 25 January 2021 earthquakes invalidates the statement made by engineer 1 outlined in paragraph 4.14.3.

4.3.8. There was a visibly increased displacement between the perimeter foundation beam and the floor slab following the 25 January 2021 earthquakes.

4.3.9. The surveys through to 1 August 2018 show the settlement rate slowing, and settlement had essentially ceased between 11 December 2017 and 1 August 2018. However, settlement was mobilised again by the earthquakes on 25 January 2021.

4.3.10. They disagreed with the conclusion reached by the expert in paragraph 5.10.9 due to the earthquakes on 25 January 2021.

4.3.11. The building work does not comply with Clause B2 Durability. While the building materials probably met durability requirements on an individual basis the manner in which they were constructed meant they failed to meet the Building Code ie the functional requirement clause B2.2 that refers to "components and construction methods". Specific reference was made to the inclusion of the additional GAP 100 hardfill layer being a "construction method" aiming to overcome wet working ground conditions.

4.4. On 13 October 2022, in response to comments received from engineer 2 about the survey datum used (refer to paragraphs 4.17.6 to 4.17.8), the owner stated:

4.4.1. The apparent uplift of the perimeter edge beam was deduced between surveys conducted by the owner using the same benchmark.[61]

4.4.2. Settlement of the manhole was less likely than uplift of the perimeter edge beam "given there doesn't appear to be any visible evidence that would support the manhole and/or the surrounding hardstand slab having settled".

4.4.3. There were concerns that using a single benchmark for settlement surveys "is poor surveying practice". The owner referred to an alternative benchmark "on the corner of Bidois and Fairy Spring Roads", and another datum apparently used by the builder for the construction of the truck shed from a floor slab of a "red shed at the rear of the property".

4.4.4. "It's plausible that the manhole height has changed due to ground movements since the settlement surveys commenced. However, the settlement survey measurements up to [1 August] 2018 do not suggest there had been any

[60] The owner referred to *New Zealand Standard NZS 1170.5:2004 "Structural design actions – Part 5: Earthquake actions – New Zealand"*, section 2.5 "Deformation control", item 2.5.2 "Serviceability limit state", sub-item (a).

[61] On 10 October 2022 and 12 October 2022 respectively both engineer 2 and engineer 1 provided information that indicates they used the same benchmark as the survey datum point (a manhole lid to the northeast of the truck shed).

appreciable change in the height of the manhole up to that time. The next observation of a visible increase in the displacement between the floor slab and the perimeter foundation beam was post the [25 January] 2021 earthquakes suggesting that the earthquakes had caused the increased displacement".

4.4.5. "Finally, while we cannot definitively prove that uplift of perimeter foundation beam occurred as a result of the [25 January] 2021 earthquakes the available evidence points to this being the most likely case".

4.5. On 7 November 2022, the owner provided another set of survey data of the truck shed floor slab and perimeter edge beam. The survey was conducted by a registered surveyor on 28 October 2022. The owner stated:

4.5.1. There appears to have been no appreciable movement of the floor slab or the perimeter foundation beam since the two surveys following the 25 January 2021 earthquakes.

4.5.2. Primary and secondary settlement of the floor slab had essentially ceased in 2018.

4.5.3. Further settlement of the floor slab was activated by the earthquakes on 25 January 2021.

4.5.4. The extra surveying done to see if more light could be thrown on whether the perimeter foundation beam uplifted during the earthquakes was inconclusive.

4.5.5. Heights on the perimeter foundation beam were measured at the four corners points (A, B, C & D). The heights were essentially unchanged from the survey conducted on 7 April 2021. The survey results show a nominal increase in height of between 1mm to 3mm.

4.5.6. The survey results indicate a change in the cumulative height of the floor slab across survey points 1 to 13 of between plus 2mm to minus 4mm.

4.6. On 5 April 2023, the owner provided some additional information:

4.6.1. An extract of an email from engineer 2 to engineer 1 dated 12 August 2015. This referred to "the latest levels taken on the truck shed slab"[62] and a video that was shot on 11 August 2015 "showing the elastic movement of the slab under live loading".[63] The email stated "it can be reasonably assumed the slab movement was significant for it to be able to be captured on video. The owners noted this was 10 weeks after the pumice sand backfilling had been completed, and 5 weeks after the slab had been poured.

4.6.2. An extract of an email from engineer 1 to the designer and engineer 2 dated 6 August 2015. This refers to modelling of the settlement for the shed and theories being worked on regarding the expected maximum settlement.

[62] Refer to table 1, note number 4.

[63] I have not been provided with a copy of the video. The owner refers to the live loading being associated with "construction" activities ahead of the depot opening on 22 September 2015.

4.6.3. An extract from an internal email between persons at engineer 1 dated 17 August 2015. It considered if further settlement would occur "if another 10-25mm of concrete is added onto the floor".[64] Engineer 1 estimated an additional 5mm of immediate settlement, and a further 5mm longer term settlement. Engineer 1 estimated there was the potential for up to 60mm total settlement under the slab with 25mm to 30mm of that happening over several decades, "with the extra loading from the fill and additional concrete the risk of this occurring has increased".

4.6.4. An extract from an email from engineer 1 to the designer dated 18 August 2015. It referred to engineer 1's email dated 17 August 2015 and stated, "we have reviewed all the calculations and the survey results, and modelled the site soils and responses of the floor slab to determine what has happened at the site".

4.6.5. An extract from an email from engineer 2 to engineer 1 dated 20 August 2015. It referred to considerations being given to "adding a topping slab" and the possible effects of that, or a "ramping option between the settled slab and the ring beam to overcome the lip that has developed".

4.6.6. An extract from an email from engineer 1 to engineer 2 dated 21 August 2015. Engineer 1 appeared to prefer the option of installing a ramp and noted the alternative of an additional topping slab "will increase the amount and risk of long term settlement" due to its weight.

4.6.7. An extract of a letter from engineer 1 to engineer 2 dated 25 August 2015 (in response to engineer 2's email dated 20 August 2015). The letter stated:

(1) the settlement of the floor slab was observed very soon after the 150mm thick floor slab was poured and has continued at a slower rate since

(2) at the time of pouring the concrete floor slab between approximately 10mm to 30mm of settlement was observed[65]

(3) since then, between approximately 2mm to 15mm further settlement may have occurred at various points on the slab

(4) although the absolute levelling (survey) values may vary there is clearly settlement occurring

(5) the slab and undercut was designed to act as a compensated foundation whereby the net load imposed on the soils below was less than the original soils' weight thereby eliminating or reducing the risk of settlement occurring. The pumice fill and proprietary expanded polystyrene units were the key element in achieving this

[64] I have assumed the concept of placing an additional depth of concrete onto the existing floor slab was considered as an option to compensate for the settlement of the floor slab that was already evident.

[65] I note the owner was of the view the extent of the settlement observed was between the concrete floor slab being poured on 23 June 2015 and the first settlement survey on 3 July 2015.

(6) during construction additional layers of heavier aggregate were used than in the design due to the very soft soil conditions. This reduced the difference between the fill weight and the weight of the soil removed

(7) the settlement observed is part secondary settlement of the organic soils beneath

(8) based on what has occurred to date and the known soil properties for very similar conditions in Rotorua, engineer 1 estimated the range and rate of further settlement that may occur.[66]

(9) a recommendation not to add any further concrete surfacing to the existing slab which would otherwise increase the risk of long-term creep

(10) the degree of settlement is likely to be dependent on the number and weight of trucks using the site and duration of the loads being applied

(11) in conclusion, the slab may exhibit further settlement of between approximately 60mm to 100mm over the next 20 to 30 years.

4.6.8. A copy of an email from engineer 2 to engineer 1 dated 18 November 2015 following a meeting they had earlier that same day. Engineer 2 requested updated settlement predictions from engineer 1 based on the settlement data recorded on 18 November 2015.[67] The email noted that tenants (occupying the building) state that the usability of the truck shed is being compromised due to the large difference in level between the floor slab and the perimeter edge beam.

4.6.9. An extract from a letter from engineer 1 to the owner and engineer 2 dated 23 November 2015. Engineer 1 noted that between 3mm and 46mm further settlement of the floor slab had occurred in the 13 weeks since the previous survey data with an average of 27mm. Engineer 1 stated that between 12mm to 80mm total settlement has now been observed with an average of 54mm, and this is less than the 100mm predicted at the time of the design in its letter dated 20 January 2015 (refer paragraph 4.2.13). Engineer 1 was of the view the exact cause of the settlement is uncertain, but it is most likely to be due to the placing of the concrete and immediate compression of both the pumice fill and soft underlying soils.

4.6.10. The owner was of the view that the communications above demonstrate a high level of uncertainty pertaining to settlement of the floor slab before and after the issue of the Producer Statement – Construction Review (PS4) by engineer 1.

4.6.11. An extract of an email from engineer 1 to the builder dated 6 August 2015. Engineer 1 requested information about the proprietary expanded polystyrene

[66] The owner summarised four possible settlement cases described in engineer 1's letter for net load increases of 10kPa and 3kPa, and the extent of possible further settlement (ranging between 25mm to 115mm) and long-term creep of approximately 1mm to 3mm per year.

[67] Refer to table 1. However, I note the survey data summarised in table 1 refers to a date of 17 November 2015, whereas the email from engineer 2 implies it was surveyed on 18 November 2015.

units used, and whether any further fill or blinding layer was used on top of the other fill material.

4.6.12. An extract from an email from the designer to engineer 1 dated 10 August 2015. The designer confirmed the grade and type of proprietary expanded polystyrene units used were as specified on the plans. Regarding any possible additional blinding layers laid, the designer confirmed the builder had stated it was as per the plan and what engineer 1 had inspected.

4.6.13. The owner referred to the expert's report, specifically, the information about the test results of the pumice sand backfill, the weight of the GAP100 hardfill, and the bulk weight of the naturally occurring soils. The owner was of the view "it is highly probable that settlement of the backfill occurred during the five weeks prior to the concrete works commencing leading to the possibility that the floor slab may have been constructed lower than the design finished floor level shown on the building consent plans" this being consistent with the survey results from 28 October 2022.

The authority

4.7. The authority stated the issue of the building consent was conditional "to the affect…the owner was to retain professional services to verify…the geotechnical report was adhered to and to issue a PS4".

4.8. The authority stated it received a Producer Statement – Construction Review (PS4) from engineer 1 for "Pile installation and granular base under floor slab", and a separate PS4 from engineer 2 for "Truck storage shed foundations". Both PS4s were received "at the final inspection" and "no supporting documents were received at this time".[68]

4.9. The authority stated it "relied on the [third] party producer statements" when the code compliance certificate was issued on 18 September 2015.

4.10. The authority submitted:

> [it] was unaware of the changes in the design implemented during construction that utilised shorter piles than those in the approved building consent. It wasn't until approached by the owner post code compliance certificate that [the authority] became aware of the changes. No amendment to the building consent was applied for or approved.

4.11. In an email to the owners dated 8 July 2019, the authority stated:

4.11.1. the piles and edge beam foundation "were changed during construction without" its knowledge

[68] Copies of the information listed in the appendices of the letter from engineer 1 dated 18 August 2015, which included the PS4, namely, the laboratory test certificates and site inspection records, are contained in the authority's building consent file (file reference RDC-854986). It is not clear when the authority received this information.

4.11.2. the "change was significant and would have required an amendment" to the approved building consent and "this was never applied for"

4.11.3. the PS4 from engineer 1 "was silent on any amended design"

4.11.4. it had "assumed that the building work complied with the building consent based on the information provided"

4.11.5. the "extent of the settlement of the floating floor…means the building work has failed to meet the durability requirements" of the Building Code.

4.12. On 5 October 2022, the authority accepted the draft determination subject to the following comments:

4.12.1. The authority "believes it was reasonable to rely on the producer statements issued by the supervising engineers when issuing the code compliance certificates".

4.12.2. The authority "was not aware of the changes made to the design and construction……until after the code compliance certificate was issued".

Engineer 1

4.13. On 21 August 2021, engineer 1 provided background information and a sequence of events in respect of the geotechnical investigations at the site that they conducted, as well as recommendations on a foundation solution. Engineer 1 stated:

4.13.1. They had advised engineer 2 "of the significant risk of long term creep settlement to the floor slab", but "the estimated amount of potential settlement was not quantified".

4.13.2. They had advised engineer 2 on 26 March 2015 that "an error in the negative skin friction calculations for the foundation design" had been identified. As a result, the 23m long x 400mm diameter piles "could be reduced in length and diameter".

4.13.3. The revised Producer Statement – Design (PS1) dated 31 March 2015, which confirmed the piles were to be reduced in length to 16m, was issued to engineer 2 for presentation to the authority.[69] This included a letter from engineer 1 dated 12 February 2015 which explained "the risk of significant long-term creep settlement of the organic silts/clay materials".

4.13.4. Using "the revised uplift calculations in the final submitted design (revised PS1) the [edge] beam is sufficient to overcome the uplift forces".

[69] In response to the draft determination, engineer 2 disputes the statement made by engineer 1. Engineer 2 states it was not their responsibility to notify the authority of the amended design, but instead referred to the role of the designer (refer to paragraph 3.9).

4.13.5. The design and construction of the floor slab was undertaken by engineer 2 and the owner's various contractors.[70] Engineer 1 provided "a geotechnical design for the concrete [floor] slab and associated improvement works".

4.13.6. The floor slab was designed to take the live and static loads of the vehicles but also remain independent from the pile foundation system.

4.13.7. The only way to eliminate a risk of differential settlement between the two independent systems "was by preloading the site".

4.13.8. The Producer Statement – Construction Review (PS4) dated 18 August 2015 was issued to certify "that the foundation design was constructed in accordance with the revised PS1" (dated 31 March 2015).[71] Accordingly, there were no authorised instructions or variations to the design.

4.13.9. Engineer 1 does not agree that the code compliance certificate should be cancelled.

4.13.10. There is no evidence that the foundation design as detailed in the PS1 from 31 March 2015, upon which the code compliance certificate was granted,[72] differs significantly from what was constructed, was erroneous or otherwise failed to comply with the Building Code.

4.14. On 14 September 2020, engineer 1 provided a memorandum ("the memorandum") in respect "of the pile foundation capacity for the truck…shed". It considered information from the cone penetration tests, the as-built plan sheets (revision D) from engineer 2 (which confirmed the piles were between 14m to 16m long, and 300mm in diameter), the schedule from the contractor who installed the piles, and column loads from a memorandum prepared by another engineer dated September 2014.[73] The memorandum concluded:

4.14.1. The design pile vertical strength is sufficient for the maximum design loading.

4.14.2. If soil liquefaction occurs, the reduced design pile strength is greater than the highest design loading for an earthquake.

4.14.3. There are no load cases that impose an uplift force on the piles as the weight of the perimeter foundation edge beam is sufficient to resist design uplift forces.

4.14.4. "Downdrag on the piles", due to soil liquefaction or static settlement, is expected to cause the piles to settle about 0.5mm to 2.9mm. This is well within the tolerance of most similar structures. It does not affect the geotechnical capacity of the pile.

[70] In response to the draft determination on 3 October 2022, the owner was of the view the statement made by engineer 1 suggests there were other parties involved in the floor slab design (other than engineer 1 and engineer 2), which does not appear to be the case.

[71] The PS4 dated 18 August 2015, or the associated schedule attached to it, does not refer to the PS1 dated 31 March 2015; it states compliance of the building work with building consent 73400.

[72] Authority records confirm that the decision to issue the code compliance certificate was based (in part) on the PS4 issued by engineer 1, and not the PS1 dated 31 March 2015.

[73] HFC Group, Civil and Structural engineers.

4.14.5. The existing pile foundations are adequate to support the design building loads.

4.15. On 22 October 2020, engineer 1 confirmed it was not able to locate "the calculations that were prepared in 2015 in support of the amended design" but it was "comfortable that such calculations would have been produced". Engineer 1 then referred to its memorandum dated 14 September 2020.

4.16. On 29 September 2022, engineer 1 responded to the draft determination stating it had "no comments".

Engineer 2

4.17. On 3 October 2022, engineer 2 responded to the draft determination. Engineer 2 stated:

4.17.1. The designer and engineer 2 were notified by email of the proposed changes to the foundation system by engineer 1 on 1 April 2015. This included a new Producer Statement – Design (PS1) dated 31 March 2015 along with supporting calculations and other documentation.

4.17.2. On 24 April 2015, engineer 1 wrote to the designer to further advise on the changes to the design.

4.17.3. The Producer Statement – Construction Review (PS4) issued by engineer 2 dated 26 June 2015 "is limited to the structural steel layout for the perimeter beam and the mesh in the floor slab".

4.17.4. The design of the perimeter beam was undertaken by engineer 1. However, engineer 2 "agreed to observe the steel lay out".

4.17.5. The as-built plans were issued by engineer 2 on 30 June 2015 and were emailed to the designer (along with the PS4) "for lodgement with the authority once an application for [the] code compliance certificate was made". However, the as-built plans are not "acknowledged as having been received by the authority" (only the PS4 and covering letter).

4.17.6. The surveys conducted by the engineer 2 from 3 July 2015 to 17 November 2015 "used an existing benchmark to the northeast of the truck shed as the benchmark". Engineer 2 queried whether the same benchmark was used for "surveys conducted by others".

4.17.7. The manhole used as the "benchmark is subject to the following factors":

(1) Organic soils swelling and shrinking.

(2) Changes in groundwater volumes.

(3) Damage to the reticulation.

(4) Settlement due to the influence of the floor slab fill loads from within the building and slab / filling external to the building.

(5) Truck and plant loads (surcharge from equipment stored to the north of the manhole).

4.17.8. "If the manhole has been used as the benchmark and it has settled then the perimeter beam will give the appearance of having risen".

5. Experts' report

5.1. The Ministry engaged the services of a firm of chartered professional engineers with geotechnical and structural engineering expertise ("the experts") to assist with a review of the floor slab and foundation system for the truck shed. The experts were asked to consider the compliance of the building work with the building consent and the Building Code.

5.2. The experts did not conduct a site visit. In preparing their reports, the experts reviewed and relied upon the information received from the parties and persons with an interest in support of the application for determination.

5.3. The experts provided reports dated 21 June 2021 and 28 October 2021.[74] The reports were provided to the parties on 22 June 2021 and 1 November 2021, respectively.

Geotechnical investigations and ground conditions

5.4. The experts described the geotechnical information for the site, noting:

5.4.1. The surrounding area is covered in pyroclastic flow deposits and the predominant soils in Rotorua are soft diatomaceous silts and pumiceous sands.

5.4.2. The published geotechnical map[75] shows the site is underlain by a Holocene aged Tauranga Group Alluvium and given the proximity to Lake Rotorua will likely be underlain by a mixture of alluvial, volcanic airfall and lacustrine deposits, including gravel, sand, clay, silt and peat beds.

5.4.3. Property file records held by the authority for a previous proposed development indicate a geotechnical investigation found silt, peat and pumice soils in borings that extended up to 2.5m in depth.

5.4.4. Research shows cone penetration tests in diatomaceous silts and pumiceous sands give low values of cone resistance and sleeve friction, which lead to potential inaccuracies of the test field data obtained at the lower end of the measurement capabilities and is likely to result in errors.

[74] The second (addendum) report of 28 October 2021 (reference 281320-REP-02_Final_Addendum) was instigated in response to comments received from the owner (dated 15 September 2021) to the experts first report dated 21 June 2021.

[75] GNS Science (registered company name: Institute of Geological and Nuclear Sciences Ltd) QMAP 5 Rotorua 1:250,000 available at https://www.gns.cri.nz.

5.4.5. A GNS Science investigation mapped Bidois Street as being with an area of soft ground (Zone D).[76]

5.5. With respect to the first geotechnical report dated 23 May 2014, based on five cone penetration tests and seven hand augers, the experts noted the report indicated the ground conditions are significantly different between the east and west sides of the site. The strata profile for the west side of the side exhibited a greater thickness of weaker ground to approximately 15m below ground surface.

5.6. The experts were of the view the soil conditions do not meet the definition of good ground[77] because they do not provide ground capable of permanently withstanding an ultimate bearing pressure of 300kPa. The site is underlain by potentially compressible ground such as soft soils, and the site could foreseeably experience movement of 25mm or greater because of settlement due to compressible ground or liquefaction induced settlement.

5.7. Testing of the compacted pumice fill does not result in the site meeting the definition of good ground.

Settlement monitoring results

5.8. The expert produced several tables and graphs to show the extent of the settlement of the floor slab and upwards displacement of the perimeter edge beam. A summary of the expert's assessment of the settlement monitoring results is shown in table 3. The expert's assessment is based on the survey data provided by engineer 1 (see paragraph 3.27), engineer 2 (see paragraph 3.19), the owner (see paragraph 4.1.6), and the registered surveyor (see paragraph 3.32).

5.9. The expert's calculations are based on data related back the "assumed slab level when poured" (the concrete was poured on 23 June 2015).[78] The relevant "assumed" survey levels are listed in the owner's spreadsheet[79] titled "4-6 Bidois [Road] - All levels 5 [May] 2021".[80]

[76] GNS Science Consultancy Report 2010/81, dated October 2010, titled: "Rotorua District Council Hazard Studies: Distribution and Identification of Soft Soils", Figure 1, pages 5 to 8. Available at https://www.rotorualakescouncil.nz/repository/libraries/ accessed on 24 May 2022.

[77] "Good ground" is defined in Ministry of Business, Innovation and Employment Acceptable Solution and Verification Method for Building Code Clause B1 – Structure, First edition, Amendment 12, effective from 14 February 2014; this was the current version at the time the building consent was granted and issued.

[78] This is different to the calculations produced by engineer 1, engineer 2, the owner, and registered surveyor, which were based on initial survey heights established on 3 July 2015.

[79] The spreadsheet was attached to an email from the owner to the Ministry, dated 6 May 2021.

[80] In response to the draft determination, the owner confirmed they had assumed the original slab levels based on the assumption that the floor slab had been poured level with the soffit of the perimeter edge beam and there had had been no appreciable movement of the beam recorded in the surveys conducted by engineer 1 and engineer 2.

Table 3: The expert's settlement assessment

Survey point[1]	Assumed slab level when poured (A)	Survey data for 7 April 2021[2] (B)	Difference in height (B) – (A) =
1	9.795	9.711	-84mm
2	9.793	9.723	-70mm
3	9.791	9.770	-21mm
4	9.792	9.741	-51mm
5	9.793	9.694	-99mm
6	9.789	9.619	-170mm
7	9.785	9.626	-159mm
8	9.791	9.617	-174mm
9	9.791	9.657	-134mm
10	9.791	9.652	-139mm
11	9.791	9.696	-95mm
12	9.791	9.700	-91mm
13	9.791	9.626	-165mm
A	9.785	9.833	+48mm
B	9.780	9.827	+47mm
C	9.780	9.828	+48mm
D	9.775	9.820	+45mm

Notes:

1. The survey points are the same as those shown in figure 4, and tables 1 and 2.

2. The survey data from the 7 April 2021 is copied from the registered surveyor's onsite measurements (see paragraph 3.32).

3. A difference in height shown as a "minus" figure (in the fourth column) is a measure of the extent of settlement (downwards) compared against the assumed slab level when the concrete was first poured. A "plus" figure indicates the extent to which the top surface of the perimeter edge beam has raised (upwards).

5.10. The expert noted settlement monitoring results indicate:

5.10.1. The first settlement survey was carried out 58 days following initial backfilling.

5.10.2. The north-western portion of the truck shed floor slab has experienced settlement in the range of 134mm to 174mm, and this is clearly greater than the remainder of the slab.

5.10.3. The eastern and southern portions of the truck shed floor slab have experienced settlement in the range of 20mm to 100mm.

5.10.4. The vertical difference between points is a measure of differential settlement. The monitoring results indicates the truck shed floor slab has experienced significant differential settlement.

5.10.5. It is apparent that an increased rate of differential settlement followed the occupation of the truck shed by the tenant in early September 2015.

5.10.6. The perimeter edge beam supported on piles has displaced upward between 45 and 48mm. The cause of this movement is unknown.[81]

5.10.7. Settlement monitoring results for the period between 3 July 2015 and 7 April 2021 indicate the rate of settlement has slowed over this period. However, it does not appear to have ceased.

5.10.8. The settlement monitoring results from the 9 February 2021 survey indicate further settlement has occurred since 29 August 2016, with the north-western portion of the floor slab (survey points 6 to 10 inclusive and point 13) experiencing the most settlement. Survey point 8 has settled a total of approximately 174mm since the floor was constructed.

5.10.9. There is insufficient information to establish whether the additional settlement apparent between the second and third survey was earthquake induced.

5.10.10. It appears that settlement prior to mid-2016 occurred as a result of primary settlement (added load) and after mid-2016 as a result of secondary settlement (creep).

(1) The expert described primary settlement as:

> expulsion of water from the soil resulting in a reduction in volume, termed consolidation. Primary settlement occurs due to an increase in effective vertical stress which results in excess porewater pressures

[81] The owner suggested the cause was possibly earthquake activity in January 2021, but there is not enough information to ascertain if this is correct (either as the only, or as a contributory, factor to the upwards displacement of the perimeter edge beam).

> (increased pressure within the soil bound water) occurring within the soil. In simple terms, an increase in effective vertical stress is caused by additional load being applied at the ground surface (example, weight of concrete slab).
>
> Excess porewater pressures occur in response to the increase in effective vertical stress. Excess porewater pressures reduce over time as water is expelled, resulting in the soil particles themselves supporting the increase in effective vertical stress. Primary settlement is time-dependent and finishes when excess porewater pressures reach zero. The rate at which water is expelled is dependent on a soils' permeability, with clay and silt (fine grained) soils having relatively low permeability. Primary settlement is usually dominant in fine grained saturated clays.

(2) The expert described secondary settlement as:

> time dependent settlement that occurs under a constant effective stress (constant vertical load). While the mechanisms of secondary settlement are not fully understood, they describe the slow adjustment of the soil particles to a more stable arrangement under the action of constant load….In practice, it is identified by a straight line (linear) relationship between settlement and…time following primary (consolidation) settlement.
>
> Secondary settlement can occur in all soils but is particularly significant with inorganic clays and silts, organic clays and silts, and peats…

5.10.11. The expert estimated the time required for 90 percent primary (consolidation) settlement to occur is calculated to be 234 days. Based on this calculation and a review of the settlement monitoring results (prior to 21 February 2016), most of the settlement that occurred at the site was as a result of primary settlement.

Construction tolerances and deformations occurring over time

5.11. With respect to settlement tolerances, the expert noted:

5.11.1. Appendix B (Informative) of Acceptable Solutions and Verification Methods, B1 Structure,[82] B1/VM4, B1.0 Serviceability Limit State Deformations (Settlement),[83] states:

> B1.0.2 Foundation design should limit the probable maximum differential settlement over a horizontal distance of 6 m to no more than 25 mm under serviceability limit state load combinations of AS/NZS 1170 Part 0, unless the structure is specifically designed to prevent damage under a greater settlement.

[82] First edition, Amendment 12, effective from 14 February 2014; this was current at the time the building consent was granted and issued.

[83] The documentation for building consent 73400 does not specifically reference compliance with B1/VM4 for the truck shed. However, it does refer to compliance with clause B1 (eg in the PS1 from engineer 1), and by extension and not limited to, clause B1.3.3(m) "differential movement".

B1.0.3 The basis for analysing settlement should be stated in the design…

5.11.2. The rationale for adopting the compensated foundation[84] for the truck shed was understood by the expert to be to eliminate the risk of primary settlement. Design calculations appear to be based on the weight of the removed soil being equal to the applied weight (ie weight of the compacted pumice backfill, concrete floor slab, and vehicle loading). Refer to paragraph 3.10.

5.11.3. Results from the on-site testing indicate the density of the compacted pumice fill ranges between 14.2kN/m³ to 14.8kN/m³. This is greater than the assumed compensated foundation design of 12kN/m³.

5.11.4. The amended design and calculations from engineer 1, dated 31 March 2015, states that the compensated foundation design would reduce much of the potential long-term differential settlement risk. However, the site is at risk of potentially significant long-term creep settlement of the underlying organic silt and clay material, and that all service connections were to be designed to withstand 100mm of vertical movement.

5.11.5. However, settlement monitoring results from 7 April 2021 show the maximum measured differential settlement was between survey point 1 (84mm) and survey point 8 (174mm); this equates to 90mm over an approximate distance of 9.3m (a ratio of approximately 1:103). This is significantly greater than the suggested limit of 25mm over 6m (a ratio of 1:240[85]) in Appendix B of Verification Method B1/VM4.

5.11.6. The reinforced concrete perimeter edge beam is supported on driven timber piles, and long-term settlement of the beam would not be expected given the presence of relatively rigid supports.

5.11.7. The design does not state that the truck shed has been designed to prevent damage should the floor slab settle a specified amount. In the absence of any maximum allowable floor slab settlement or differential settlement being specified in the design, the expert considered the following:

(1) The guidance in Appendix B of Verification Method B1/VM4. Applied to the 29.3m length of the floor slab, and an allowable differential settlement of 25mm over a horizontal distance of 6m (represented as a ratio of 1:240), this equates to a design tolerance of 122mm.

(2) The design and construction of the reinforced concrete elements of the truck shed were required to comply with New Zealand Standards NZS 3101:2006 and NZS 3109:1997 (see paragraph 2.10).

NZS 3109:1997 specifies construction tolerances for structures designed in accordance with NZS 3101:2006. Table 5.2 “Tolerances for in situ

[84] Excavation of existing soil material and backfill, or replace with, lightweight compacted pumice fill and proprietary expanded polystyrene units.

[85] The expert expressed this as 1V:240H where V is “vertical” and H is “horizontal”. The ratio of 1:240 is calculated by 6000mm (or 6m) divided by 25mm = 240mm.

construction" in NZS 3109:1997 allows for an acceptable deviation of the top of a foundation (slab) element of plus or minus 12mm.

For an acceptable deviation in the flatness of the slab profile, NZS 3109:1997 refers to New Zealand Standard NZS 3114.[86] Table 3 "Tolerances for abrupt deviations or offsets and gradual deviations" in NZS 3114:1987 allows for an abrupt deviation[87] of 3mm over a level straight edge of 200mm, and a gradual deviation (difference in level over 3m straight edge or curved template)[88] of 5mm for exposed concrete.

As a construction tolerance does not account for any vertical movement built into the structure over its design life, it does not represent a reasonable design tolerance for slab settlement on its own.

(3) NZS 3101:2006 sets out the minimum requirements for the design of reinforced concrete structures. Section 2.4.2 "Deflection of beams and slabs", sub-section 2.4.2.1 in NZS 3101:2006 states, "The deflections computed in accordance with 6.8 shall,[89] where required, meet the limits given by AS/NZS 1170…".

As per AS/NZS 1170.0:2002,[90] assuming any vertical movement built into the design complies with suggested criteria in Appendix C, Table C1[91], the mid-span deflection of a normal floor system to satisfy serviceability limit state criteria is "span" divided by 400 (ie span ÷ 400). Based on a floor slab length of 29.3m, this equates to 74mm vertical deflection (ie 29300mm ÷ 400).[92]

Adding the construction tolerances noted in (2) above, this equates to 74mm + 12mm + 3mm + 5mm = 94mm of allowable slab settlement assuming any vertical movement built into the design complies with the suggested criteria in AS/NZS 1170.0:2002, Table C1. This is considered the strictest design tolerance for slab settlement that could be reasonably specified.

(4) A further means of assessing a design tolerance for slab settlement is consideration of the guidance for the assessment and repair of earthquake affected industrial buildings in Canterbury following the Canterbury earthquake sequence.[93] Table 3.2 "Usage dependent floor

[86] NZS 3114:1987 "Specification for concrete surface finishes".
[87] NZS 3109:1997, clause 304.1.2 and Figure 3 "Abrupt variations or offsets".
[88] NZS 3109:1997, clause 304.1.3 and Figure 4 "Gradual variations".
[89] NZS 3101:2006, section 6.8 "Calculation of deflection of beams and slabs for serviceability limit state".
[90] *Australian/New Zealand Standard AS/NZS 1170.0:2002 Structural design actions – Part 0: General principles*.
[91] AS/NZS 1170.0:2002, Appendix C "Guidelines for serviceability limit states (informative)", Table C1 "Suggested serviceability limit state criteria".
[92] A corresponding calculation based on the width of the floor slab at 20m equates to 20000mm divided by 400 = 50mm.
[93] Ministry of Business, Innovation and Employment *Assessment, repair and rebuild of earthquake-affected industrial buildings in Canterbury,* First edition, Published 1 December 2014. Available at https://www.building.govt.nz/assets/Uploads/building-code-compliance/canterbury-rebuild/industrial-rebuild-guidance/industrial-rebuild-guidance.pdf (accessed on 25 May 2022).

level indicator criteria" in the guidance document states that for vehicle storage buildings the following are deemed acceptable:

(a) Maximum level difference less than 150mm.

(b) Maximum floor gradient due to differential settlement less than 1 in 100.

5.11.8. Settlement monitoring results from 7 April 2021 indicate a maximum level difference of 174mm – 21mm = 153mm and a maximum floor gradient due to differential settlement of 1 in 103.[94] This exceeds reasonable design tolerances.

5.11.9. In addition, as the settlement of the reinforced concrete perimeter edge beam supported on driven timber piles is not apparent, an abrupt difference in height between the perimeter edge beam and floor slab has occurred (ie 48mm upwards movement of the perimeter edge beam, and 170mm downward of the floor slab). This caused a loss of amenity and required the installation of steel ramps so that vehicles can enter and exit the truck shed.

5.12. With respect to whether the settlement was primary or secondary settlement, the experts noted that the majority of settlement that has occurred at the site is likely a result of primary settlement, while more recent and future settlement of the slab is likely due to secondary settlement. The proportion of primary and secondary settlement cannot be determined without consolidation testing of soil samples recovered from the site.

Future settlement

5.13. With respect to whether further settlement was expected, the expert noted:

5.13.1. The rationale behind the compensated foundation design was to replace the full weight (including water) of soil removed with fill materials and floor slab of approximately equal or less weight. This would result in no increase in the effective stresses in the original ground beneath, such that no primary settlement would be expected.

5.13.2. The settlement monitoring results for the period between 3 July 2015 and 7 April 2021 do not appear to have plateaued. Based on the estimate of time required for 90 percent of primary consolidation to occur, the majority of primary settlement has occurred, and any continued movement may be due to secondary settlement. This could foreseeably continue for years.

5.13.3. The geotechnical report dated 23 May 2014 from engineer 1 recommended that further investigations be carried out prior to detailed design for the purpose of establishing the extent of soft soils present beneath the western portion of the site. Further investigations were to also include oedometer testing.[95] No testing of soil samples from the site was undertaken to evaluate

[94] Calculated by 9.3m/(174mm – 84mm).

[95] Measures a soil's consolidation properties by applying different loads to a soil sample and measuring the deformation response.

the physical and engineering characteristics of any settlement behaviour under loading.

5.13.4. It is not possible to quantify the amount of future settlement. In situ sampling using machine drilled boreholes, soil testing and detailed assessment would be required to assess the degree of further settlement at the site.

5.13.5. Alternatively, further settlement monitoring may be used to predict future settlement over the intended life of the building.

Effects of possible liquefaction

5.14. With respect to the effects of possible liquefaction, the expert noted:

5.14.1. In an ultimate limit state (ULS)[96] earthquake event (peak ground acceleration of 0.27g), the floor slab and pavements may experience significant vertical and differential settlements resulting in the loss of serviceability,[97] loss of access to the truck shed due to the difference in height between the reinforced concrete perimeter edge beam, the liquefaction of sand layers above the founding piles may result in partial loss of pile shaft friction and possibility of down-drag due to settlement of surrounding soils. While the piled edge beam foundation is likely to remain in place, seismic shaking may result in damage to the superstructure.

5.14.2. The likelihood of liquefaction occurring at the site as a result of the two earthquake events on 25 January 2021 was sufficiently low to be ignored for design purposes.

The original design and calculations

5.15. With respect to the original design and calculations, the experts considered:

5.15.1. The Producer Statement – Design (PS1), dated 17 February 2015, from engineer 1 does not provide a numerical estimate of long-term total or differential settlement beneath the truck shed.

5.15.2. The requirement in the design for the proposed backfill to be approved by the engineer should have identified the difference between the assumed density of the compacted pumice fill and the as-built backfill material.

[96] *New Zealand Standard AS/NZS 1170.5:2004 "Structural design actions Part 5" Earthquake actions – New Zealand*, Appendix A "Definitions", Ultimate limit state in its application to earthquake-resistant design, the ultimate limit state is defined as being when the capacity of an element and/or structure is reached, based on the design strength, strain, ductility and deformation limits that are specified for the ultimate limit state in this and appropriate material standards. The structure as a whole may have sustained significant structural damage, but shall have reserve capacity to avoid structural collapse.

[97] *Australian/New Zealand Standard AS/NZS 1170.0:2002 "Structural design actions Part 0: General principles"*, section 1.4 – Definitions, item 1.4.16 – Serviceability: Ability of a structure or structural element to perform adequately for normal use under all expected actions.

5.15.3. The design does not cover the potential for an abrupt difference in elevation between the perimeter edge beam and the floor slab to occur, and no design values have been provided.

Compensated floor slab design

5.16. With respect to the design and calculations for the compensated floor slab, the experts noted:

5.16.1. The assumed unit weight of the excavated soil was 18.0 kN/m³. The assumed unit weight of the compacted pumice fill was 12.0 kN/m³. Backfilling of the excavation was only to comprise of pumice fill. There was no allowance for GAP100 to be placed over the base of the excavation.

5.16.2. The bulk unit weight of the soils beneath much of central Rotorua was reported to be in the range of 12.4 to 12.8 kN/m³.[98]

5.16.3. The compensated floor slab, which should eliminate the possibility of primary settlement of underlying soils, does not represent the achievement of ultimate bearing pressure of 300kPa. The basis for carrying out compaction testing of the compacted pumice fill was only to confirm sufficient compaction has taken place, and that minor further settlement within the pumice fill layer would take place following construction of the truck shed slab. Compaction testing of the compacted fill does not result in the site meeting the definition of good ground. No testing of soil samples was undertaken to evaluate the characteristics of settlement behaviour under loading.

5.16.4. The unit weight of excavated soil was not verified as part of the compensated floor slab design, and the assumed weight is potentially higher. Test results indicate the in-situ unit weight range of the compacted pumice fill ranges between 14.2 to 14.8 kN/m³. The increase in weight of the compacted pumice compared with the original soils would result in additional loading of the underlying subsoil.

5.16.5. The compensated floor slab design was intended not to increase the effective stress in the original ground. The expert considered two cases[99] against a baseline assessment and concluded the design applies additional loading to the compressible soils beneath the building footprint and therefore increases effective stress in the original ground.

5.16.6. The compensated floor slab as constructed does not meet the requirements of clauses B1.3.1, B1.3.2, and B1.3.4 of the Building Code. This is based on the increase in unit weight of the compacted GAP100 and pumice fill compared with the assumed values used in the design, as well as the likely decrease in unit weight of the excavated material (soft soil).

[98] The expert referred to *Pearse-Danker, E. (2013). "Liquefaction potential of Rotorua soils" 19th New Zealand Geotechnical Society Geotechnical Symposium, C. Y. Chin, ed., Queenstown, NZ, 7.*

[99] Case 1 – Increased unit weight of the pumice fill. Case 2 – Increased unit weight of pumice fill and reduced weight of the in-situ soil.

5.16.7. The compensated floor slab design complies with Clause B2 Durability given that the concrete cover to the reinforcing has been selected in accordance with *New Zealand Standard NZS 3101.Part 1:2006 "Concrete structures standard",*[100] section 3 "Design for durability".

The amended design and calculations

5.17. With respect to the amended design and calculations for the piles that accompanied the revised Producer Statement – Design (PS1), dated 31 March 2015, the experts noted:

5.17.1. The results of the calculations using the Hiley formula[101] indicate the estimated pile sets of 170mm for the west side (resulted in an ultimate pile capacity of 130kN) and 150mm for the east side (resulted in an ultimate pile capacity of 147kN) would not achieve the safe load of approximately 100kN sought once the Geotechnical Strength Reduction Factor of 0.45 was applied. Plan sheet 1 of 3, revision D, dated 31 March 2015, "appear to be for an ultimate load of 110kN".[102] No calculations to support the end of drive pile installation sets were attached to the PS1.

5.17.2. The basis of the axial capacity calculations is limited to field notes provided by engineer 1 with no further explanation provided. No calculations have been provided detailing the design load cases and resulting vertical pile demand. No calculations have been provided to support the statement that uplift forces will be overcome by the dead weight of the edge beam. The safe end bearing and skin friction calculations are limited to depths below 15.36m; however, the sand layer is above 15.36m depths at two of the test sites,[103] meaning the calculated end bearing capacity of driven piles at the locations has not been provided.

5.17.3. There is insufficient information to establish whether the pile design meets the requirements of Clauses B1 Structure and B2 Durability of the Building Code for earthquake loading (namely, the potential weakening of the ground during earthquake shaking impacting the performance of the foundations). Otherwise, the pile design does meet the performance requirements of clauses B1 and B2. However, the calculations supporting the design are limited and do not clearly explain the design rationale.

5.17.4. No explanation is provided for the increase in the size of the edge beam between the original design and calculations and the amended design and calculations.

[100] Part 1: The design of concrete structures.

[101] Refer to Ministry of Business, Innovation and Employment Acceptable Solution and Verification Method for Building Code Clause B1 – Structure, First edition, Amendment 12, effective from 14 February 2014, B1/VM4, section 4.0 "Pile Foundations", comment to sub-section 4.0.1.

[102] The calculations by the experts referred to here were presented in their report dated 21 June 2021.

[103] Cone penetrometer test locations (CPT) 01 and 02.

Site records

5.18. With respect to the site records prepared by engineer 1 for the backfilling of the site, the expert noted:

5.18.1. There is no record of the acceptance of placing compacted GAP100 during backfilling or consideration of the impact of this, in lieu of the compacted pumice fill specified in the design. As such, there is no documented consideration given to the impact this change would have on the compensated foundation system.

5.18.2. Site inspection records do not specify the elevation of compacted fill at the time inspections were carried out, so it is not possible to accurately determine the as-built thickness of the compacted GAP100 and compacted pumice fill. However, based on the inspection records dated 11 May 2015 and 13 May 2015, the expert estimated the thickness of GAP100 fill material "to be in excess of 200[mm] to 300mm".

5.18.3. Site photos do not include captions detailing location and orientation as would generally be expected.

5.18.4. The site inspection record dated 21 April 2015 indicate over-excavation occurred to the eastern side of the building by approximately 600mm, but it does not detail the backfill material used.

5.19. With respect to the site records for piling, the expert noted based on the site inspection records for piling and end of drive sets provided by the piling contractor, the as-built driven timber piles meet the amended design parameters and the Building Code performance requirements for Clauses B1 Structure and B2 Durability with the exception of earthquake loading (namely, the potential weakening of the ground during earthquake shaking impacting the performance of the foundations).

5.20. The expert considered that the back-calculated factored pile strength in compression exceeds the ultimate load of 110kN, based on an assessment of the axial capacity of the as-built 300mm diameter, 16m long, specific engineering design (SED) piles with an end of drive set (penetration of pile per hammer blow) of 50mm, using the Hiley formula.[104]

The as-built plans and documentation

5.21. The experts considered the as-built foundation and floor slab based on the as-built drawings and documentation, did not comply with clauses B1.3.1, B1.3.2, and B1.3.4 because:

[104] The calculations by the experts referred to here were presented in their addendum report dated 28 October 2021. These calculations are distinct from the ones referred to in paragraph 5.17.1 based on an end of drive set of 50mm as noted in the attachments to engineer 1's letter to the designer dated 18 August 2015.

5.21.1. It was foreseeable that the concrete floor slab would rupture and lose equilibrium as a result of loading the highly compressible soils present beneath the building footprint.[105]

5.21.2. In the absence of any maximum allowable slab settlement or differential slab settlement being specified in the design, the results of the most recent survey (dated 7 April 2021) indicate floor slab movements have exceeded that assessed to be reasonable, resulting in a loss of amenity.[106] This includes the abrupt difference between the perimeter edge beam and the internal floor slab surface.

5.21.3. Due allowance was not made for the intended use of the building,[107] as there is an impedance of vehicles accessing the truck shed as a result of the difference in elevation between the perimeter edge beam and floor slab.

5.21.4. Due allowance was not made for the variability in unit weight of in-situ soil that was excavated and compacted pumice fill used as backfill material affecting the compensated foundation performance, as well as the variability of ground conditions across the building footprint.[108]

5.21.5. Due allowance was not made for the accuracy limitations in the methods used to predict the stability of the truck shed.[109] The design did not account for the foreseeable scenario in which loading of the highly compressible soils beneath the building footprint occurred.

5.22. The experts confirmed, on the basis of the Producer Statement – Construction Review (PS4) issued by engineer 2, the reinforced concrete perimeter edge beam complies with the performance requirements of Clauses B1 Structure and B2 Durability.

5.23. The experts considered that the as-built foundation and floor slab, at the time the decision was made to issue the code compliance certificate, based on the as-built drawings and documentation, complied with the Clause B2 Durability because the as-built plans specify reinforced concrete material and cover complying with NZS 3101 and NZS 3109 and piling inspection records indicate timber piles were treated in accordance with Acceptable Solution B2/AS1.[110] The experts noted that the assembly has a whole has not failed the durability requirements, rather the compensated foundation design was flawed, resulting in loss of amenity due to undue deformation.

5.24. With respect to the as-built foundation system and floor slab, the experts considered that now there is a difference in height between the reinforced concrete slab and perimeter edge beam, vehicle movements and impacts have caused damage to the door sill part of the edge beam as a by-product of the differential settlement. Should damage to the door sills continue as a result of vehicle movements and impacts, the

[105] Clause B1.3.1.
[106] Clause B1.3.2.
[107] Clause B1.3.4 (b).
[108] Clause B1.3.4 (d).
[109] Clause B1.3.4 (e).
[110] *Ministry of Business, Innovation and Employment Acceptable Solutions and Verification Methods for New Zealand Building Code Clause B2 Durability*, second edition, amendment 8, effective from 14 August 2014.

long-term durability of the perimeter foundation beam reinforcement may be adversely affected.

The memorandum

5.25. With respect to the memorandum from engineer 1 dated 14 September 2020 for the foundation piles (see paragraph 4.14), the experts noted:

5.25.1. The memorandum was provided to support the previously issued Producer Statement – Construction Review (PS4) by engineer 1. It was an independent check, without reference to the original design, changes made during construction, or concerns raised about the pile foundations.

5.25.2. The basis of design linking the original design and calculations, amended design and calculations, and as-built calculations and documentation is not clear.[111]

5.25.3. In general, except for the pile diameter, the calculations and conclusions appear to be correct and appropriate based on the provided information.

5.25.4. The adopted strength reduction factor of 0.45 does not differentiate between end bearing and shaft resistance. The LCPC[112] factors of safety for end bearing and shaft resistance should have been considered in the calculation of the design pile vertical strength.

5.25.5. The design factored pile strength should have been provided based on a calculated geotechnical strength reduction factor or factor of safety.

5.25.6. No explanation has been provided for the increase in the size of the perimeter edge beam from that which was detailed by engineer 1 on 17 February 2015 (500mm wide x 525mm deep) to the amended design on 31 March 2015 (600mm wide x 525mm deep).

5.26. With respect to the vertical pile capacities for the 300mm diameter specific engineering design H5 treated timber piles using the LCPC method in the memorandum, the experts noted:

5.26.1. The LCPC method is deemed appropriate for estimating the axial capacity of the driven timber piles based on cone penetrometer test data.

5.26.2. Calculations for design vertical strength based on the results presented in the memorandum show the geotechnical strength reduction factor of 0.45 is within the range of values (0.45 to 0.65) for design based on static analysis

[111] The memorandum refers to a review of revision D of the plan sheets 1 to 3 dated 31 March 2015, and not the as-built set (revision E) dated 30 June 2015.

[112] LCPC method (*Laboratoire Central des Ponts et Chaussées*) by Bustamante and Gianeselli, 1982, an analysis of pile load tests with a range of pile and soil types. The basis of the LCPC method is to estimate the axial capacity (end bearing and side friction) of various pile types using the results of CPT (Cone Penetration Test) data.

using cone penetrometer test data as detailed in Table 4 of Verification Method B1/VM4.[113]

5.26.3. The design pile vertical strength is greater than the applied factored loads required by Verification Method B1/VM4.

5.27. With respect to the calculations for the 300mm diameter specific engineering design H5 treated timber piles using the Modified Engineering News Record (ENR) method referred to in the memorandum, the experts noted:

5.27.1. The recommended factor of safety is 6.0; however, this may be overly conservative.

5.27.2. The hammer efficiency factor of 1.0 is considered unconservative as it assumes no energy losses.

5.27.3. No end of drive pile installation set cards were included in the appendix to the Producer Statement – Construction Review (PS4) from engineer 1. It is industry practice for end of drive pile installation set cards to be provided to the design engineer as a means of verifying the target set was achieved.

5.27.4. The design pile vertical strengths based on the Modified ENR method are unreliable, and therefore it cannot be confirmed if the applied factored loads required by Verification Method B1/VM4 have been met.

6. Discussion

6.1. The matter for determination is the authority's decision to issue a code compliance certificate for building work to construct a specific engineering design foundation system and floor slab for a new truck shed associated with building consent 73400.

6.2. The floor slab of the truck shed has undergone settlement and the perimeter edge beam raised in level since the building work was first completed. The owner is of the view that the authority was incorrect to issue a code compliance certificate for the building work.

6.3. Previous determinations (see for example Determination 2008/030[114] and 2021/008[115]) have established that considering a decision by an authority to issue a code compliance certificate and whether that decision should be confirmed or reversed by determination is a two-step process. Consideration should be given to whether the building work was completed in accordance with the building consent.[116] If the building work does not comply with the building consent, in making a decision under section 188 of the Act to confirm, reverse or modify the authority's decision, I

[113] Ministry of Business, Innovation and Employment: Acceptable Solution and Verification Method for Building Code Clause B1 – Structure, First edition, Amendment 12, effective from 14 February 2014, B1/VM1 – *Foundations*, Table 4, "Strength Reduction Factors for Deep Foundation Design".

[114] Determination 2008/030 The issuing of a code compliance certificate for a multi-storey apartment building (issued 5 May 2008).

[115] Determination 2021/008 Regarding the authority's decision to issue a code compliance certificate for a new dwelling at 19A Te Atatu Road, Auckland (issued 4 May 2021).

[116] Section 94(1)(a) of the Act.

will consider whether the building work complies with the Building Code, taking into consideration all the information now available about the compliance of the building work.

The legislation

6.4. When exercising a decision to issue a code compliance certificate, an authority must consider section 94 of the Act which states:

> **Matters for consideration by building consent authority in deciding issue of code compliance certificate**
>
> (1) A building consent authority must issue a code compliance certificate if it is satisfied, on reasonable grounds,-
>
> (a) that the building work complies with the building consent…

Compliance of the building work with the building consent

6.5. Building consent 73400 was issued on 13 March 2015.

6.6. The building consent appears to have been issued by the authority on the grounds:

6.6.1. the compensated slab design was deemed sufficient to limit the effects of primary (consolidation) settlement, but not secondary (creep) settlement

6.6.2. the piled support to the perimeter edge beam was deemed sufficient to limit the settlement therein so it was able to be accommodated by the building superstructure

6.6.3. any secondary (creep) settlement occurring in the future would not be such as to the make the building floor system non-functional

meaning overall compliance with the performance requirements of Clauses B1 Structure and B2 Durability would be achieved.

6.7. However, engineer 1 initiated an amended design to alter the diameter and length of the driven timber piles, and increase the size of the reinforced concrete perimeter edge beam. The amended design was instigated because engineer 1 had advised engineer 2 on 26 March 2015 that "an error in the negative skin friction calculations for the foundation design" had been identified. As a result, the 23m long by 400mm diameter piles "could be reduced in length and diameter". The change in the design was confirmed in a new Producer Statement – Design (PS1) issued by engineer 1 dated 31 March 2015.

6.8. The building work commenced on or before 8 April 2015 and it was undertaken in accordance with the amended design.

6.9. However, the evidence in this case indicates the building consent was not amended in accordance with section 45(4) of the Act, to take account of the change in the design by engineer 1.

6.10. Section 14B of the Act states an owner is responsible for obtaining any necessary consents, approvals, and certificates, including ensuring that building work complies with the building consent. However, the owner has stated they first became "aware of the unconsented design changes made to the perimeter foundation piling system" on 20 April 2018. Up until then, "the matter for concern had been the settlement of the floating floor slab and adjacent concrete hardstanding".

6.11. Further, the authority stated it "was unaware of the changes in the design [made]… during construction that utilised shorter piles than those in the approved building consent…No amendment to the building consent was applied for or approved".

6.12. The design was dependant on several inspections and testing to be conducted as specified on the approved plan sheet 1 of 3 (see paragraph 2.12). The building consent was also issued on condition inspections were to be conducted by the relevant engineers (see paragraph 3.11) and Producer Statements – Construction Review (PS4s) were to be provided to the authority.

6.13. On 26 June 2015, engineer 2 issued to the owner a PS4 in respect of "truck storage shed foundations" and building consent 73400. The PS4 did not indicate any amendments to the building consent and stated "no" in respect of any authorised instructions or variations.

6.14. On 17 August 2015, engineer 1 issued a PS4 in respect of "Truck storage shed: Pile bearing capacity, foundation undercut and fill compaction" for building consent 73400. The PS4 confirmed there were no building consents amendments issued, and "nil" authorised instructions or variations made by engineer 1.

6.15. Since the authority was unaware the design had been altered, it is evident that its decision to issue the code compliance certificate on 18 September 2015 was based on the original approved building consent plans and specifications and following receipt of the PS4s from engineer 1 and engineer 2.

6.16. Although the authority had conducted a final inspection on 26 August 2015, it did not record anything about the as-built construction. Instead, the authority stated it had "relied on the [third] party producer statements".

6.17. Therefore, in the absence of any other evidence, the authority appears to have relied solely on receipt of the PS4s from engineer 1 and engineer 2 when deciding to issue the code compliance certificate.

6.18. Despite reference to as built plans included in the PS4 provided by engineer 2, these were apparently not provided to the authority (refer to paragraph 3.25.7). In my view, if the as-built plans (revision E) had been provided, a relatively straightforward review to compare them against the original approved building consent plans (revision A), would have identified the changes made in the construction (for example, the reduced size of the timber piles and larger perimeter edge beam).

6.19. This situation is compounded by the fact the PS4s provided by both engineer 1 and engineer 2 indicated there were no building consent amendments issued, and "nil" or "no" authorised instructions or variations made (refer to paragraphs 3.20 and 3.17.2).

6.20. A comparison between the approved building consent documentation and the as-built construction is summarised in table 4.

Table 4: Approved building consent versus as-built construction

Approved building consent	As-built construction
Driven timber piles, 23m long, 400mm in diameter.	Driven timber piles, between 14m to 16.2m long, 300mm in diameter.
Reinforced concrete perimeter edge beam 500mm wide by 525mm deep.	Reinforced concrete perimeter edge beam 600mm wide 525mm deep.
The floor slab is supported on a 500m deep layer of proprietary expanded polystyrene units covered in a minimum 1mm thick flexible high density polyethylene membrane. Under these units is a variable depth of "pumice sand backfill compacted to 95% of maximum dry density at [an] optimum moisture content and less than 10% air voids in 200mm [maximum] layers" reinforced with two layers of a proprietary geotextile product used to strengthen soil.	As specified in the design except that some of the pumice sand backfill was substituted with approximately 200-300mm thickness of GAP100 fill material.
There was a requirement (via calculation) for the compacted density of the backfill to be less than 12kN/m³ (as stated in the design by engineer 1).	On-site test results indicate the density of the compacted pumice fill ranges between 14.2kN/m³ to 14.8kN/m³. Refer to paragraph 5.11.3.
The building work was to be completed in accordance with New Zealand Standards *NZS 3101:2006 Concrete structures standard* and *NZS 3109:2006 Concrete construction*. See paragraph 2.10. NZS 3109:1997 specifies construction tolerances for structures designed in accordance with NZS 3101:2006. NZS 3101:2006 sets out the minimum requirements for the design of reinforced concrete structures. See paragraph 5.11.7(3). The specification did not state any project specific construction tolerances to be achieved for the construction of	The expert stated the design does not cover the potential for an abrupt difference in elevation between the perimeter edge beam and the floor slab to occur, and no design values have been provided. As a construction tolerance does not account for any vertical movement built into the structure over its design life, I agree with the expert's assessment that it does not represent a reasonable design tolerance for slab settlement on its own. The as-built construction has not been completed in accordance with the approved plans in as much as the floor

the floor slab and perimeter edge beam. Therefore, reference is made to NZS 3109:1997, section 5.3 "Tolerances", table 5.2 "Tolerances for in situ construction". This allows for an acceptable deviation top of a foundation (slab) element is plus or minus 12mm. See paragraph 5.11.7(2). For an acceptable deviation in the flatness of the slab profile, NZS 3109:1997 refers to New Zealand Standard *NZS 3114:1987 Specification for concrete surface finishes*. Table 3 Tolerances for abrupt deviations or offsets and gradual deviations in NZS 3114:1987 allows for an abrupt deviation of 3mm over a level straight edge of 200mm, and a gradual deviation (difference in level over 3m straight edge or curved template) of 5mm for exposed concrete. The approved plans (sheets numbers 2 and 3) show the top surface of the perimeter ring beam was to be level with the top surface of the floor slab (see figure 3).	slab has settled (lowered in level) and the perimeter edge beam has displaced upward between 45 and 48 mm causing an abrupt change in level between the adjacent surfaces. See figures 5 and 6. The north-western portion of the truck shed floor slab has experienced settlement in the range of 134mm to 174mm, and this is clearly greater than the remainder of the slab. The eastern and southern portions of the truck shed floor slab have experienced settlement in the range of 20mm to 100mm. The expert concluded the monitoring results indicates the truck shed floor slab has experienced significant differential settlement and this increased following the occupation of the truck shed by the tenant in early September 2015. The expert stated settlement monitoring results from 7 April 2021 indicate a maximum level difference of 153mm and a maximum floor gradient due to differential settlement of 1 in 103. This exceeds reasonable serviceability deformation limits for construction of this type (94mm in this case, as outlined in paragraphs 5.11.7 (2) and (3)).

6.21. Based on the information now available, I am of the view the building work has not been completed in accordance with the building consent granted and issued on 13 March 2015.

Amendments to the building consent

6.22. There are some situations, known as minor variations, where changes to a consented design will not require a formal consent amendment. Sections 45 and 45A of the Act apply to amendments to building consents.

6.22.1. Section 45 allows for applications to amend a building consent. For minor variations the application must be in accordance with section 45A. In all other cases, the application for an amendment must be made as if it were an application for a building consent.

6.22.2. Section 45A specifies that an application for a minor variation does not need to be on a prescribed form and does not require the authority to issue an amended building consent. However, the authority must record the minor variation in writing.

6.23. A minor variation is defined in the Building (Minor Variations) Regulations 2009 ("the Regulations").[117] Regulation 3(1) states:

> A minor variation is a minor modification, addition, or variation to a building consent that does not deviate significantly from the plans and specifications to which the building consent relates.

6.24. The purpose of the Regulations is to set out when changes to building work do not require an amendment to a building consent. A minor variation generally does not affect the level of Building Code compliance, it simply achieves a compliant outcome in a different way.

6.25. Decisions about whether a minor variation can be granted are the responsibility of the authority. In this case, I note the authority was not made aware of any changes to the design. The authority stated the "change was significant and would have required an amendment" to the approved building consent and "this was never applied for" (refer to paragraph 4.11). For completeness, I have considered whether the changes to the design in this case could be considered to fall within the scope of a minor variation.

6.26. Previous determinations[118] have considered minor variations and referred to similar guidance from the Ministry.[119] The determination outlines a three-step process for an authority to consider whether a variation from the consented building work is a minor variation or not:

6.26.1. *Step 1*: Does the proposed change involve building work that is required to comply with the Building Code? If not, the authority does not need to approve the work.

6.26.2. *Step 2*: Does the proposed change come "within the definition of 'minor variation' contained in the [Regulations]"?

6.26.3. *Step 3*: Does the proposed change, for example, affect compliance with the Building Code, reflect common appropriate industry practice or standards, and not significantly increase the likelihood of a building element's performance failure?

6.27. The Ministry's guidance on minor variations outlines factors to consider when deciding whether a change to work covered by a building consent falls within the definition of a minor variation. The guidance also provides examples of minor

[117] Available at https://www.legislation.govt.nz/regulation/public/2009/0408/latest/DLM2615667.html

[118] For example, Determination 2020/002 Regarding the consented alterations to the walls and roof of a house and its compliance with Building Code clause B1 at 25 Sturrocks Road, Redwood, Christchurch (issued 17 March 2020).

[119] Minor variations to building consents: Guidance on definition, assessment and granting (First edition, 1 January 2010) available at https://www.building.govt.nz/projects-and-consents/build-to-the-consent/making-changes-to-your-plans/minor-variations-guidance/

variations involving aspects of specific engineering design of a structural element, such as changing the design of a beam or lintel.

6.28. In this case, the changes relate to the size of the driven timber piles (changed from 400mm diameter piles 23m long, to 300mm diameter piles 14 to 16m long), the increased size of the reinforced concrete perimeter edge beam (changed from 500mm wide x 525mm deep, to 600mm wide x 525mm deep), and part of the backfill material used to support the floor slab (using GAP100 material).

6.29. I have outlined in table 5 an assessment of factors relevant to consider when assessing whether the changes fall within the scope of a minor variation.

Table 5: Assessment of minor variation

Factors to consider	Assessment of amendment to the building consent
Step 1	
Has a variation in the building work occurred?	**Yes**. A variation in the building work was confirmed in the amended design proposed by engineer 1 on 31 March 2015 (refer to paragraph 3.12). This is after the building consent was issued by the authority on 13 March 2015.
Does the proposed variation involve building work that is required to comply with the Building Code?	**Yes**. The building work to construct the foundation system and floor slab is required to comply with the Building Code,[120] specifically, Clauses B1 Structure and B2 Durability.
Step 2	
Does the proposed change come "within the definition of 'minor variation' contained in the [Regulations]"?	**No**. The variations do deviate significantly from the plans and specifications to which the building consent relates. Although the original design intent remains the same in terms of isolating the foundation system from the floor slab, the loading characteristics have changed, for example, the effective design to allow for earthquake loading (see paragraph 5.17.3) and possible effects of liquefaction (see paragraph 5.14).
Step 3	
Was substitution of comparable building	**Partly**. Although the size of the driven timber piles and reinforced concrete perimeter edge beam have

[120] Section 17 of the Act.

products and materials undertaken in the same or similar position and manner?	changed, they have been constructed in the same position as intended in the original design, using the same construction methodology. The design size of the piles stated in the building consent was 23m long and 400mm in diameter. The amended design from 31 March 2015 reduced the size of the piles to 14m to 16m long and 300mm in diameter. The safe end-bearing and skin friction calculations are limited to depths below 15.36m. However, the sand layer is above 15.36m in depth at two of the test sites, meaning the calculated end bearing capacity of driven piles at the locations has not been provided (refer to paragraph 5.17.2). This is relevant because the piles terminating in the sand layer, rather than below it, will impact the load able to be taken by the piles. The substitution of the GAP100 as part of the backfill material, in lieu of the specified pumice sand backfill is not comparable. This is particularly relevant to the comparability in this case as the weight and density of the backfill material was a key aspect of the design of the compensated floor slab.
Are there any alterations that change the footprint of the building, or location of internal loadbearing supports, or affect fire safety aspects?	**No**. The variations in the size of the driven timber piles, the size of the perimeter edge beam, and compacted fill material do not alter the footprint of the building, or the location of any internal load-bearing supports, and do not change any fire safety aspects.
Is there as different design concept or load path in the varied building work?	**Partly**. The design concept was not changed as a result of the variations made on 31 March 2015. The foundation system of reinforced concrete perimeter edge beam supported on driven timber piles remained the same. Similarly, the concept of a compensated floor slab isolated from the perimeter edge beam supported on backfill material is unaltered. Consequently, it is evident the load path for the foundation system and floor slab was intended to be the same. However, the loading characteristics have changed, for example, the effective design to allow for earthquake loading (refer to paragraph 5.17.3), the possible effects of liquefaction (refer to paragraph 5.14), the depth of the sand layer relative to the length of the shorter piles used (refer to paragraph 5.17.2), and the increase in the density of the

	backfill material used to replace the excavated soils below the floor slab.
Does the proposed change comply with the Building Code?	**No**. Refer paragraphs 6.32 to 6.52 for more information.
Is there a different (lesser) degree of compliance regarding structural performance than assumed in the approved building consent?	**Yes**. Refer paragraphs 6.32 to 6.52 for more information.
Does the proposed change reflect common appropriate industry practice or standards?	**Partly**. The expert noted no calculations have been provided detailing the design load cases and resulting vertical pile demand, and no calculations have been provided to support the statement that uplift forces will be overcome by dead weight of the perimeter edge beam. I am of the view the provision of such calculations would be common industry practice. The specific engineering design (SED) changes (namely the size of the timber driven piles and perimeter edge beam) were subject of a Producer Statement – Design (PS1) issued by a Chartered Professional Engineer. This is common industry practice for this type of specialist design. Construction monitoring of the SED elements was conducted by engineer 1 and engineer 2, and they both provided Producer Statement – Construction Reviews (PS4s). This is common industry practice for this type of specialist design. While they occurred after the design had been amended, I also note it is evident that the PS4s and as-built documentation do not accurately reflect the changes made which is contrary to common industry practice (eg incorporation of the increase in unit weight of GAP100 backfill material in lieu of specified compacted pumice sand).
Does the proposed change significantly increase the likelihood of a building element's performance failure or of damage to other property?	**Yes**. The proposed changes are such that they do significantly increase the likelihood of performance failure of the floor slab and driven timber piles. The floor slab has already experienced differential settlement that exceeds design or acceptable construction tolerances, and there is insufficient

	information to be satisfied the amended design of the piles and ring beam will comply with the requirements of the Building Code relating to earthquake loading.

6.30. Based on the evidence available in this case, I am of the view that the changes made to the design (and subsequently the as-built construction) of the foundation system and floor slab deviated significantly from the plans and specifications such that they did not meet the test of being a minor variation to the building consent. Therefore, they were required to be authorised by way of a formal amendment to the building consent in accordance with section 45(4)(b) of the Act.

Compliance of the building work with the Building Code

6.31. Section 17 states all building work must comply with the Building Code to the extent required by this Act, whether or not a building consent is required in respect of that building work.

Clause B1 Structure

6.32. The objective[121] of Clause B1 Structure is to safeguard people from injury caused by structural failure and loss of amenity caused by structural behaviour.

6.33. The functional requirement of clause B1.2 states buildings, building elements and sitework shall withstand the combination of loads that they are likely to experience during construction or alteration and throughout their lives.

6.34. The performance criteria for clause B1 includes (but is not limited to):

> B1.3.1 Buildings, building elements and sitework shall have a low probability of rupturing, becoming unstable, losing equilibrium, or collapsing during construction, or alteration and throughout their lives.
>
> B1.3.2 Buildings, building elements and sitework shall have a low probability of causing loss of amenity through undue deformation, vibratory response, degradation, or other physical characteristics throughout their lives, or during construction or alteration when the building is in use.
>
> B1.3.3 Account shall be taken of all physical conditions likely to affect the stability of buildings, building elements and sitework, including:
>
> (a) Self-weight,
>
> (b) Imposed gravity loads arising from use,
>
> …
>
> (d) Earth pressure,
>
> (e) Water and other liquids,

[121] Clause B1.1.

(f) Earthquake,

…

(m) Differential movement,

…

(q) Time dependent effects including creep and shrinkage, and

(r) Removal of support.

B1.3.4 Due allowance shall be made for:

(a) The consequences of failure,

(b) The intended use of the building,

(c) Effects of uncertainties resulting from construction activities, or the sequence in which construction activities occur,

(d) Variation in the properties of materials and the characteristics of the site, and

(e) Accuracy limitations inherent in the methods used to predict the stability of buildings.

B1.3.6 Sitework,[122] where necessary, shall be carried out to:

(a) Provide stability for construction on the site,

…

B1.3.7 Any sitework and associated supports shall take account of the effects of:

…

(c) Ground loss and slumping.

6.35. The owner has stated:

6.35.1. "the truck shed floating floor slab" is exhibiting "significant differential settlement", and consequently, it has failed to meet the requirements of Clauses B1 Structure

6.35.2. the sand layer cannot be relied upon for bearing capacity in an earthquake, particularly if the upper soils layers are subject to liquefaction

6.35.3. the earthquake actions on 25 January 2021 caused the perimeter edge beam and pile system to be displaced upward (ie raised in level) by 40mm to 50mm

6.35.4. the floor slab system failed to withstand the combination of loads it would experience during its life (clause B1.2); failed in terms of performance due to

[122] Section 7 of the Act – Interpretation: Sitework means work on a building site, including earthworks, preparatory to, or associated with, the construction, alteration, demolition, or removal of a building.

becoming unstable and losing equilibrium during construction and when in use (clause B1.3.1); and suffered loss of amenity through undue deformation during construction and when in use (clause B1.3.2).

6.36. Engineer 1 has stated:

6.36.1. the existing pile foundations are adequate to support the design building loads

6.36.2. the floor slab was designed to take the live and static loads of the vehicles but also remain independent from the pile foundation system

6.36.3. the design pile vertical strength is sufficient for the maximum design loading

6.36.4. if soil liquefaction occurs, the reduced design pile strength is greater than the highest design loading for an earthquake

6.36.5. there are no load cases that impose an uplift force on the piles as the weight of the perimeter foundation edge beam is sufficient to resist design uplift forces.

6.37. The expert stated:

6.37.1. the monitoring results indicates the truck shed floor slab has experienced significant differential settlement

6.37.2. the soil conditions do not meet the definition of good ground because they do not provide ground capable of permanently withstanding an ultimate bearing pressure of 300kPa

6.37.3. there is insufficient information to establish whether or not the additional settlement apparent between the second and third surveys was earthquake induced

6.37.4. the perimeter edge beam supported on piles has displaced upward between 45 and 48 mm; the cause of this movement is unknown

6.37.5. the majority of primary settlement has occurred, and any continued movement may be due to secondary settlement, and this could foreseeably continue for years

6.37.6. the compensated floor slab design does not meet the requirements of clauses B1.3.1, B1.3.2, and B1.3.4 of the Building Code. This is based on the increase in unit weight of the compacted GAP100 and pumice fill compared with the assumed values used in the design, as well as the likely decrease in unit weight of the excavated material (soft soil)

6.37.7. there is insufficient information to establish whether the pile design meets the requirements of Clauses B1 Structure and B2 Durability of the Building Code for earthquake loading (namely, the potential weakening of the ground during earthquake shaking impacting the performance of the foundations)

6.37.8. it was foreseeable that the concrete floor slab would rupture and lose equilibrium as a result of loading the highly compressible soils present beneath the building footprint

6.37.9. in the absence of any maximum allowable slab settlement or differential slab settlement having being specified in the design, the results of the most recent survey (dated 7 April 2021) indicate floor slab movements have exceeded that assessed to be reasonable, resulting in a loss of amenity

6.37.10. due allowance was not made for the intended use of the building, as there is an impedance of vehicles accessing the truck shed as a result of the abrupt difference in elevation between the perimeter edge beam and the floor slab and required the installation of steel ramps so vehicles can enter and exit the truck shed

6.37.11. due allowance was not made for the variability in unit weight of in-situ soil that was excavated and compacted pumice fill used as backfill material affecting the compensated foundation performance, as well as the variability of ground conditions across the building footprint

6.37.12. due allowance was not made for the accuracy limitations in the methods used to predict the stability of the truck shed.

Factors considered in this case

6.38. The evidence in this case points to several factors that inform a decision as to whether the building work complies with Clause B1 Structure, these include:

6.38.1. the soil conditions at the location of the truck shed do not meet the definition of good ground

6.38.2. the floor slab has experienced significant differential settlement

6.38.3. the perimeter edge beam has been displaced upwards[123].

6.39. There is a possibility the displacement of the perimeter edge beam may have been as a result of earthquake induced actions in 25 January 2021, albeit some upwards displacement was evident from the earlier survey results prior to that date.

6.40. There is a possibility the floor slab may experience further settlement. However, results from the most recent surveys would indicate this has been minimal to date.

6.41. Insufficient information has been provided to establish if the pile design meets the Building Code requirements for earthquake loading.

[123] I note the engineer 2 raised concerns about potential movement of the manhole used as a benchmark for surveying. I accept that manhole benchmarks may move upwards/downwards during successive surveys. However, I consider if this had occurred there would be evidence of the movement due to the hardstanding surrounding the manhole and the associated drainage connections. In addition, I do not consider this would be a source of difference between successive results in this case, since the benchmark is a relatively short distance from the building and all levels are 'relative to the benchmark' adopted on the day.

6.42. At the truck shed entrance doorways to the building, the floor slab must be trafficable. This means the beam-to-slab junction and the adjoining floor slab should not exhibit an abrupt change in the vertical surface profile exceeding 25mm. On top of that, it also should not show a gradual change in the vertical surface profile exceeding 1 in 240 in the direction of travel (refer to paragraph 2.4).

6.43. The settlement of the floor slab and displacement of the perimeter edge beam exceed the requirements of the relevant design standards specified and acceptable construction tolerances. Settlement monitoring results from 7 April 2021 indicate a maximum level difference of 153mm and a maximum floor gradient due to differential settlement of one in 103 (refer to paragraph 5.11.8). In addition, an abrupt difference in height between the perimeter edge beam and floor slab has occurred (ie 48mm upwards movement of the perimeter edge beam, and 170mm downward of the floor slab) (refer to paragraph 5.11.9). Consequently, the as-built construction exceeds the maximum tolerances stated above.

6.44. The plans for the building work indicate an intention to provide a trafficable level surface across the top of the perimeter edge beam and the floor to allow for vehicles to access and egress the building. For the reasons outlined in paragraphs 6.42 and 6.43, I conclude that settlement of the floor slab and displacement of the perimeter edge beam have resulted in a loss of amenity within the life of the building. Therefore, the building work does not comply with clause B1.3.2.

6.45. Due allowance was not made for the intended use of the building (clause B1.3.4 (b)), as there is an impedance of vehicles accessing the truck shed as a result of the abrupt difference in elevation between the perimeter edge beam and the floor slab.

6.46. In spite of the expert's conclusions, I consider there is insufficient evidence to conclude the building has ruptured, become unstable or lost equilibrium to date (clause B1.3.1). Notwithstanding this, and bearing in mind the current situation, and taking into account the likelihood of continuing secondary settlement, there may be a possibility of the floor slab rupturing throughout its life if it were to continue as it is. However, given that I have already concluded the work does not comply with Clause B1 for other reasons, it is not necessary for me to reach a conclusion on this point.

6.47. The floor slab has experienced differential settlement (clause B1.3.3 (m)) and removal of support (B1.3.3 (r)). This is due to the characteristics of compressible soils under the building and the variations in the properties of the heavier backfill material used to replace the lighter excavated soils. This state has been reached during the life of the building.

6.48. Due allowance has not been made of the consequence of failure (clause B1.3.4 (a)). Construction tolerances have already exceeded the design standards stated in the building consent, due to the differential settlement of the floor slab, and this has occurred during the life of the building (notwithstanding the corresponding upwards displacement of the perimeter edge beam). Given the building was designed to allow entry and exit of large vehicles, regard should have been given to the consequence of the differential settlement in terms of the entry to and exit from the building.

6.49. Due allowance has not been made for the effects of uncertainties resulting from the construction activities or the sequence in which construction activities occur (clause

B1.3.4 (c)). The variabilities in the compressible and liquefiable soils across the property were evident at the outset of the project (refer to paragraph 3.2) and there remained a potential long-term issue for this site (refer to paragraph 3.6.7). This was exacerbated (in part) by using the heavier GAP100 fill material during the construction phase (clause B1.3.4 (d)).

6.50. Due allowance has not been made for the accuracy limitations inherent in the methods used to predict the stability of the building (clause B1.3.4 (e)). For example:

6.50.1. the design change in the size of the timber piles and perimeter edge beam to overcome earthquake actions (refer to paragraph 5.17).

6.50.2. the exceedance of construction tolerances due to the differential settlement of the floor slab.

6.51. Siteworks have not been undertaken to the extent that provides stability for construction on site (clause B1.3.6(a)) or taken account of the effects of ground loss and slumping (clause B1.3.7(c)). This is evident due to the excavation of the natural occurring soils and subsequent loss of equilibrium and differential settlement caused by the loading imposed on the highly compressible soils using the heavier backfill materials.

6.52. Taking into consideration the factors listed above and the other evidence available to me in this case, I am of the view the amended design and the construction of the truck shed floor slab and foundation system do not comply with Clause B1 Structure.

Clause B2 Durability

6.53. The objective of clause B2, outlined in clause B2.1 is to ensure that a building will throughout its life continue to satisfy the other objectives of the Building Code.

6.54. The functional requirement of clause B2 requires:

> B2.2 Building materials, components and construction methods shall be sufficiently durable to ensure that the building, without reconstruction or major renovation, satisfies the other functional requirements of this code throughout the life of the building.

6.55. Accordingly, the building materials and construction method used for the truck shed floor slab and foundation system must be sufficiently durable to ensure they will continue to comply with the relevant clauses of the Building Code throughout its life.

6.56. While the term durable is not defined in the Act or the Building Code, the Ministry's Verification Method and Acceptable Solution B2/VM1 and AS1[124] define 'durable' as 'resistant to wear and decay'.

6.57. "Construction methods", as used in clause B2.2, is defined indirectly through the following interpretation, and "construction" has a corresponding meaning:

[124] Second edition, Amendment 8, dated 14 August 2014.

> *Construct*, in relation to a building, includes to design, build, erect, prefabricate, and relocate the building.[125]

6.58. In this case, the specified intended life of the importance level 2 (IL2)[126] truck shed floor slab and foundation system is not less than 50 years (refer to paragraph 2.2). This is confirmed in the building consent certificate issued by the authority on 13 March 2015.

6.59. In this case, clause B2.3.1(a) is applicable:

> B2.3.1 *Building elements* must, with only normal maintenance, continue to satisfy the performance requirements for this code for the lesser of the specified intended life of the building, if stated, or:
>
> (a) The life of the building, being not less than 50 years, if:
>
> (i) Those building elements (including floors, walls, and fixings) provide structural stability to the building, or
>
> (ii) Those building elements are difficult to access or replace, or
>
> (iii) Failure of those building elements to comply with the Building Code would go undetected during both normal use and maintenance of the building.

6.60. The term "building elements" is defined in Clause A2 'Interpretation' as:

> Any structural and non-structural component or assembly incorporated into or associated with a building. Included are fixtures, services, drains, permanent mechanical installations for access, glazing, partitions, ceilings and temporary supports.

6.61. The term 'normal maintenance' is not defined in the Act or the Regulations. However, paragraph 2.1 'Normal Maintenance' of Acceptable Solution B2/AS1 states:

> Normal maintenance is that work generally recognised as necessary to achieve the expected durability for a given building element. The extent and nature of that maintenance will depend on the material, or system, its geographical location and position within the building, and can involve the replacement of components subject to accelerated wear.

6.62. In essence, in order to continue to satisfy the performance requirements of the Building Code, building elements, with only normal maintenance, need to be sufficiently durable to withstand the environmental conditions they will experience, whether above or below ground, for the specified intended life of the building. For example, the performance characteristics of the building elements must not degrade below a certain standard due to possible effects such as corrosion, bacterial activity, presence of chemicals, ultraviolet light, and salt-laden air.

6.63. The owner stated:

[125] Sub-part 2, Section 7 – Interpretation, of the Act.

[126] In accordance with Australian/New Zealand Standard, *AS/NZS1170.0:2002, Structural design actions Part 0: General Principles*, incorporating Amendment number 5 (September 2011), Tables 3.1 and 3.2.

6.63.1. the truck shed floating floor slab is exhibiting "significant differential settlement" and this occurred immediately after the concrete was poured. Consequently, it has failed to meet the requirements of Clause B2 Durability.

6.63.2. the floor slab has failed the durability requirements of clause B2 for functionality because the floor system requires reconstruction or major renovation (clause B2.2); and for performance because it has failed to meet the 50-year intended life of the building (clause B2.3.1(a)).

6.64. The authority stated the "extent of the settlement of the floating floor…means the building work has failed to meet the durability requirements" of the Building Code.

6.65. The expert stated:

6.65.1. the compensated floor slab design complies with Clause B2 Durability given that the concrete cover to the reinforcing has been selected in accordance with *New Zealand Standard NZS 3101.Part 1:2006 "Concrete structures standard"*, section 3 "Design for durability"

6.65.2. based on the site inspection records for piling and end of drive sets provided by the piling contractor, the as-built driven timber piles meet the amended design parameters, and the Building Code performance requirements for Clauses B1 Structure and B2 Durability

6.65.3. on the basis of the Producer Statement – Construction Review (PS4) issued by engineer 2, the reinforced concrete perimeter edge beam complies with the performance requirements of Clauses B1 Structure and B2 Durability

6.65.4. the as-built plans specify reinforced concrete material and cover complying with NZS 3101 and NZS 3109

6.65.5. the piling inspection records indicate timber piles were treated in accordance with Acceptable Solution B2/AS1

6.65.6. the assembly has a whole has not failed the durability requirements; rather, the compensated foundation design was flawed, resulting in loss of amenity due to undue deformation

6.65.7. due to the difference in height between the reinforced concrete slab and perimeter foundation edge beam, vehicle movements and impacts have caused damage to the door sill part of the edge beam. Should damage to the door sills continue as a result of vehicle movements and impacts, the long-term durability of the perimeter foundation beam reinforcement may be adversely affected.

6.66. Engineer 1 issued two Producer Statements – Design ("PS1s") on 17 February 2015 and 31 March 2015. Both PS1s stated compliance with clause B2.

6.67. On 17 August 2015, engineer 1 issued a Producer Statement – Construction Review (PS4) in respect of "Truck storage shed: Pile bearing capacity, foundation undercut and fill compaction". The stated means of compliance of the building work was with Clauses B1 Structure and B2 Durability.

6.68. With the exception of the damage already sustained to the perimeter edge beam at the door sills, I have received no information that may bring into doubt compliance with the durability requirements of the building elements or materials used to construct the floor slab and foundation system (eg either the individual building element such as the timber treatment of the piles, concrete specification, and steel reinforcement, or the associated construction method used).

6.69. There is evidence to indicate some damage has occurred to the perimeter edge beam as a result of vehicle movements in and out of the truck shed. This has been caused by the abrupt difference in the finished internal floor and external ground levels either side of the door sills (refer to figure 5(b)).

6.70. However, there is insufficient information to confirm the extent of the damage sustained to date and how this may have affected the concrete cover to the reinforcement. Regardless, it is evident that if the current situation prevails, or worsens as a result of any future settlement of the slab or uplift of the perimeter edge beam, then it is likely the damage to the concrete will increase which could decrease the effective cover to the steel reinforcement. However, due to the exposed surface of the perimeter edge beam, any failure is likely to be easily detected, accessed, and repaired during normal maintenance.

6.71. However, in terms of the other building elements, I have considered the following factors based on the evidence provided in this case, whilst acknowledging no invasive investigations or testing has been conducted to this point:

6.71.1. The individual building elements or components that make up the foundation system or floor slab do not appear to have been subject of any of the environmental conditions that may cause them to degrade.

6.71.2. The assembly and construction method used to form the floor slab, which include the various materials used for backfill under the slab, do appear to be sufficiently durable.

6.71.3. It is the highly compressible, naturally occurring soils that have responded to the loads imposed by the weight of the material placed on them which has caused the settlement of the floor slab to occur. This failure occurred relatively quickly after the building was first constructed.

6.71.4. I am of the view the highly compressible, naturally occurring soils underlying the site are not building elements. Neither are they part of the building elements or components used in the building work.

6.71.5. The highly compressible, naturally occurring soils existed before the building work was undertaken and forms the natural ground on which the backfill material and floor slab is founded.

6.72. As discussed previously, it is the non-compliance of the building and building elements with clause B1, “throughout their lives”, that is relevant in this case. This is distinct from clause B2.3.1(a) whereby *building elements* must, with only normal maintenance, continue to satisfy the performance requirements of this code for no less than 50 years.

6.73. Based on the evidence in this case, I am of the view that the building work does comply with Clause B2 Durability. However, I note that if the current situation remains and the concrete cover to the steel reinforcement in the perimeter edge beam is compromised at the door sills due to the damage incurred by vehicle movements in and out of the building this may result in non-compliance with clause B2.

7. Summary and conclusion

Summary

7.1. Building consent 73400 is in respect of the specific engineering design of a foundation system (driven timber piles and reinforced concrete edge beam) and compensated floor slab for a new truck shed. The compensated floor slab design was not intended to increase the effective stress in the original ground in order to eliminate any primary settlement; this was based on the weight of the removed soil being equal to the applied weight (ie weight of the compacted pumice backfill, concrete floor slab, and vehicle loading).

7.2. The building was to function as a vehicle storage and maintenance area. The design plans indicate an intention to provide a trafficable level surface across the top of the perimeter edge beam and the floor to allow for vehicles to access and egress the building.

7.3. The design was changed by the chartered professional engineers involved with the project after the building consent was issued by the authority, and before the building work commenced. The design change initiated using smaller sized driven timber piles and a larger cross-sectional area of reinforced concrete edge beam. The authority was not notified of the changes made in the design

7.4. Survey data provided by the owner, engineer 1, and engineer 2, after the building work had commenced, indicates the as-built perimeter edge beam has been displaced upwards and the floor slab has been affected by differential settlement (downwards). The extent of the displacement and settlement exceeds construction tolerances. This has created an excess abrupt change in level at the vehicle entrance doors (notwithstanding the difference in level across the floor slab). Subsequently, damage has been sustained to several of the vehicles accessing or egressing the building, as well as damage to parts of the perimeter edge beam. Although further settlement of the floor slab has not been discounted, I am of the view the current as-built situation does not meet the intended functional requirements of the building.

7.5. It is not clear exactly what has caused the perimeter edge beam to have been displaced upwards, however, it is possible it was due in part to earthquake induced ground-motions experienced at the site around 25 January 2021. Regardless, the cause of the differential settlement of the floor slab appears to be associated with the over-loading of the compressible soils, that remained in place after the excavation of the ground, by the heavier backfill material used.

7.6. Although I have considered all available information from the building consent documentation, in addition to other information subsequently provided by the parties and persons with an interest, I have also relied on expert advice to inform my

decision. This is particularly relevant where, for example, appropriate design calculations have not been provided to support the changes made to the design after the building consent was issued.

Conclusion

7.7. The building work to construct the floor slab and foundation system for the new truck shed does not comply with the designer's plans and specifications (including supporting calculations) contained in building consent 73400.

7.8. The changes made to the specific engineering design, including the amended size and as-built penetration of the driven timber piles, the size of the perimeter edge beam, and use of the heavier backfill material to replace the lighter excavated soils, was sufficient to trigger the requirements of section 45(4)(b) of the Act such that this exceeded what might be considered as a minor variation under section 45A of the Act.

7.9. The building work to construct the floor slab and foundation system supporting the superstructure for the new truck shed does not comply with Clause B1 Structure.

7.10. The building elements used to construct the floor slab and foundation system for the new truck shed do comply with Clause B2 Durability. However, if the current situation remains and the concrete cover to the steel reinforcement in the perimeter edge beam is compromised at the door sills due to the damage incurred by vehicle movements in and out of the building this may result in non-compliance with clause B2.

8. Decision

8.1. In accordance with section 188 of the Building Act 2004, I determine the authority's decision to issue the code compliance certificate for building consent 73400 was incorrect. As I have also identified that the work does not comply with the Building Code, I reverse the authority's decision.

Signed for and on behalf of the Chief Executive of the Ministry of Business, Innovation and Employment on 9 June 2023.

Katie Gordon

National Manager, Building Resolution