FaultRock

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Report prepared for

Regarding

GARAGE FLOOR SETTLEMENT AT …

Contents

1 EXECUTIVE SUMMARY

The garage foundation of the _____ residence, at _____, has been damaged during the Canterbury Earthquake Sequence. Fletchers EQR provided conflicting assessments of the damage during on-site discussions and subsequent reporting. I undertook a total station survey of the garage floor slab to clarify the situation. I find that, although some of the floor levels are consistent with Fletcher EQR's report, some are not. The results show that the slab clearly exceeds the criteria for engineered repair work by 40% for total vertical differential settlement, and by 300% for maximum slope over 2 m. Re-opening of cracks between the house and garage during a moderate earthquake in December 2014 indicate that the garage has minimal capacity to resist deformation, and can be expected to further damage the house roof structure during future earthquakes.

2 BACKGROUND

Mr and Ms _____ (hereafter the _____s) requested an independent review of the floor levels in the garage attached to their dwelling at _____. The garage floor levels had been previously measured by a Fletchers EQR representative on 6th October 2014, using a Zip Level Pro or similar level. The level data provided to the _____s, on site, prior to departure of the surveyor, were inconsistent with those provided in the subsequent report. In particular, the level of the NW corner of the slab, relative to the central datum, had been altered from +40 to +36 between the site visit and final report. Since the time of this unreliable survey, the _____s have observed further evidence of foundation-instability, which is described below.

3 SCOPE

I was employed to resurvey the garage floor slab at _____ to clarify conflicting results arising from the Fletchers EQR survey. I also review the guidance for engineering repairs, and comment on the implications of surveyed floor levels for possible repair or further investigation options.

4 SITE DESCRIPTION

The _____ dwelling is located at _____, Parklands and surrounded by houses classified as rebuilds. Differential LiDAR maps available on the geotechnical database show that the area surrounding the dwelling subsided by <0.4 m at the eastern end and may have uplifted by <0.1 m at the western end of the property, during the earthquake series to June 2011 (Figure 1)

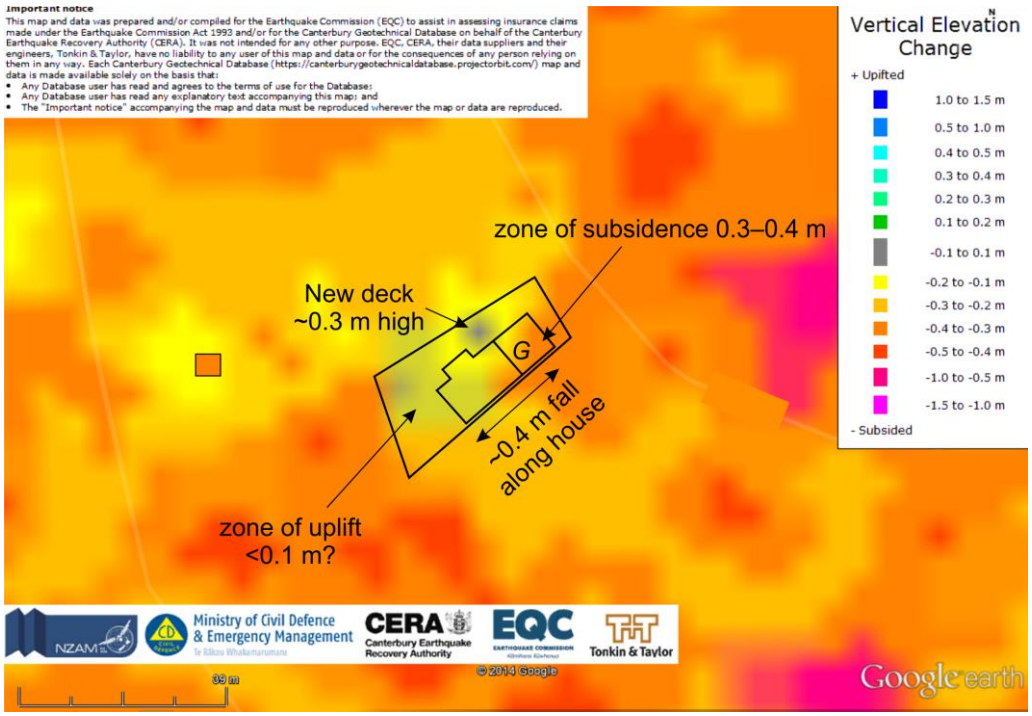

Figure 1. Differential Lidar map from the Canterbury Geotechnical Database. G – Garage. Note the general eastward increase in subsidence, and the sharp gradient passing below the eastern end of the house.

The dwelling itself consists of a Type-B2, timber-framed, brick veneered, piled house with a perimeter concrete foundation. The house is attached to an internal-access, Type-C2 garage, with timber frame and brick veneer over a concrete-slab-on-grade foundation. The garage slab abuts the northeastern end of the house perimeter ring foundation. A double concrete step links the house to the garage, and the entire dwelling is covered by a continuous roof constructed of concrete tiles on timber trusses. A pronounced sag in the roof is visible where the house passes into the garage. The garage ceiling is constructed at the same level as the ceilings within the house.

On the outside of the house, details of the brickwork at the connection of the garage and house veneer walls do not presently match, and indicate a downward displacement of the garage relative to the house. A crack opened on both inside and outside walls at these localities during the Canterbury earthquake sequence; it was especially obvious on the inside, next to the internal access door. This internal crack was 'repaired' by covering it with timber coving during EQC earthquake repairs in June 2014. The opening is now once-again visible (Figure 2a–c), having reopened during a M_w4.5 earthquake in early December 2014. External cracks at this location have also been reactivated.

The internal access door from the garage leads through the washroom into the kitchen. The washroom floor is clearly bulging, which the clients report developed during the Canterbury

earthquake sequence. Drainage on the kitchen floor indicates a fall to the east. The kitchen bench, which was installed level prior to the earthquakes is now warped down to the east, which has resulted in buckling of the stainless steel sink.

5 METHODS

Floor levels at the residence were previously taken by a Fletchers EQR representative using a ZIP LEVEL PRO 2000 or similar. Assuming that the Zip level was within 1.2 vertical metres of the base unit (the high precision range), the product specifications indicate a typical isothermal accuracy equivalent to the greater of 0.2 mm or 0.2% of the reading.

A comparative survey of the garage floor levels was carried out on 15th December 2014, using a Trimble 5600 semi-robotic total station (Figure 2d). The survey data was reduced using Trimble's Terramodel 10.41 survey software. The instrument was mounted over the sharp external corner of the property's water cut-off valve enclosure. A reference site was established and surveyed both prior to, and at the close of, the survey. Both sites are available for re-checking. The vertical error between repeated shots at the reference site was less than 1 mm. Levels were measured at 49 other individual points across the garage floor, and the localities were recorded on the slab in permanent marker. The reduced floor levels and contours are shown in Figure 3A, and the on-site and final-report versions of the EQR survey are shown for comparison in Figure 3B.

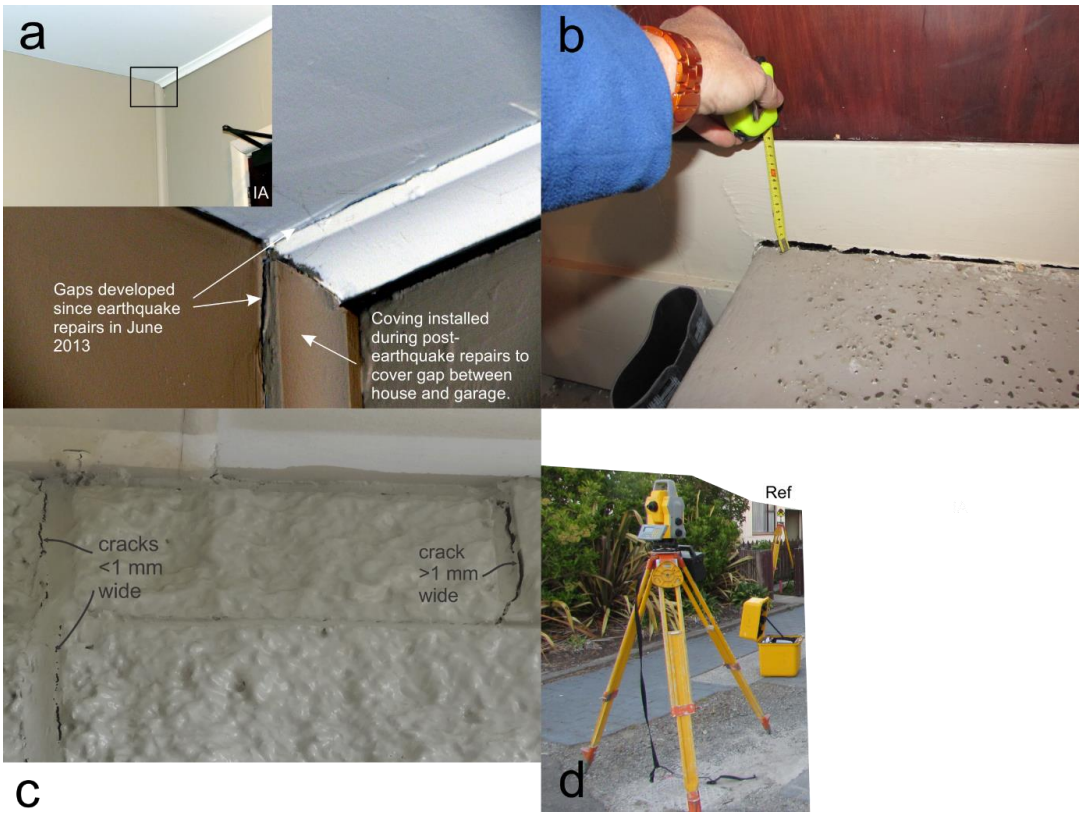

Figure 2. a) Reactivation of earthquake damage on internal walls, SW corner of garage. b) earthquake-related gap between concrete step and internal access door. c) new cracks in repaired external join of house and garage. Crack on right of picture is not reactivated, but a new crack formed in December 2014. d) survey set up. Note reference station to left of garage. Photo d altered to protect client privacy.

6 FLOOR LEVELS

The floor levels within the garage measured between 265 and 336 mm above the instrument position, a total range of 71mm. The entire slab slopes to the east, with a maximum full-width gradient of 0.95%. The western part of the slab dips more steeply, with a maximum slope over 2 m of 1.6%. This steep slope is located immediately abutting the house perimeter foundation.

Apart from the SW corner of the garage, where the EQR survey was ~25 mm too low (well in excess of Zip Level instrumental error), the results of this survey are consistent with the EQR data *provided on-site.* They are substantially less consistent with Fletcher EQR's final report data. The total station survey result of +40 mm in the SW corner of the garage is internally consistent with the slope defined by multiple other measurements in that quadrant, and so is more reliable than either single-point Fletcher EQR survey result.

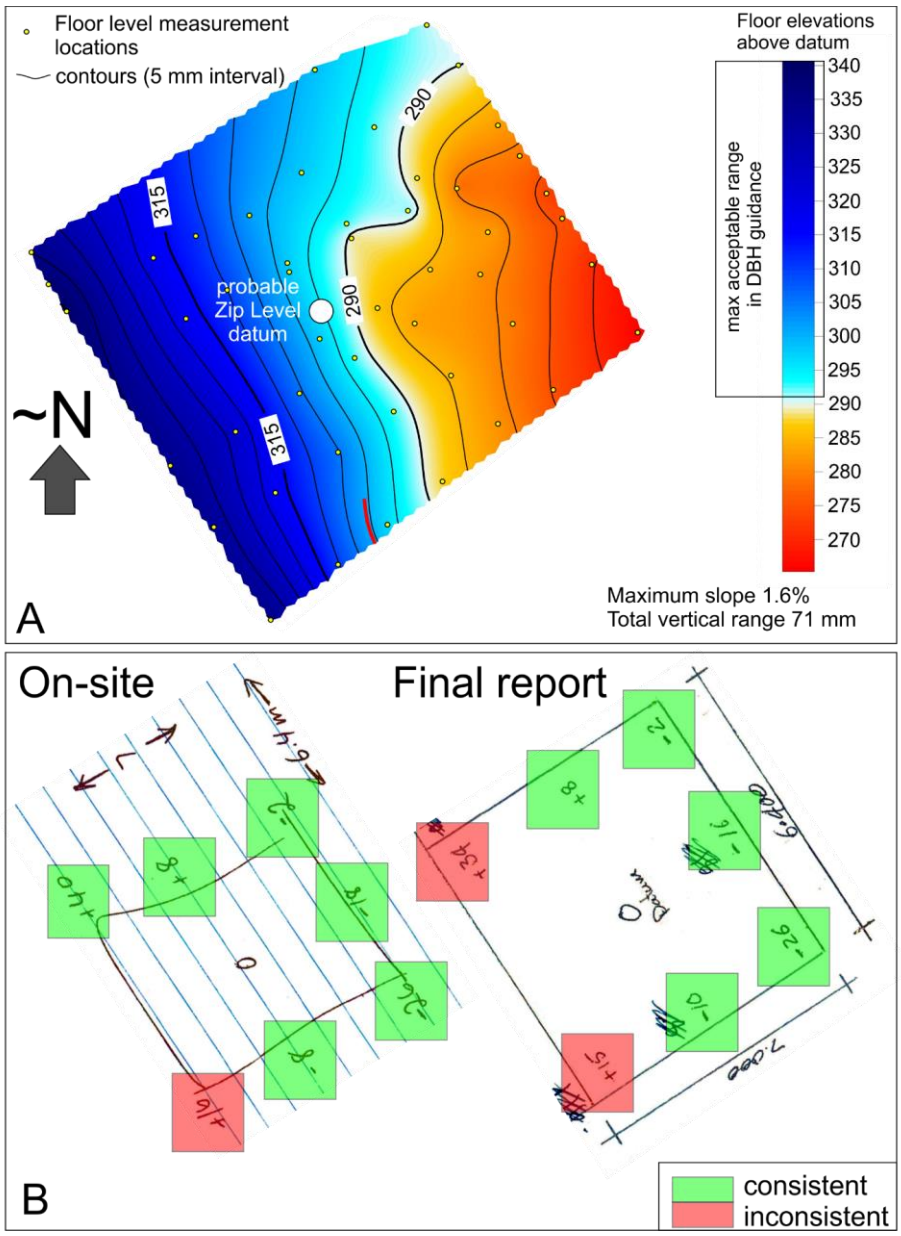

Figure 3. A) Map summarizing the results of re-surveying of garage floor levels at _____. Blue tones define the acceptable range. B) Relative floor levels for garage floor provided by previous surveyor on-site and in post-visit report. Note the variation between on-site and final records, particularly the 6 mm change in the NW corner. Note also the clear inconsistency of the measurement in the south corner, compared with some six measurements taken in the present survey.

7 COMMENTS RELATING TO THE DBH CRITERIA FOR STRUCTURAL REPAIR

The criteria for structural repair of foundations are given in Part A, section 2.2 of the Department of Building and Housing's document entitled "Guidance: repairing and rebuilding houses affected by the Canterbury earthquakes" (hereafter the DBH guidance), and reproduced in Table 1.

For a type-C building, such as the _____ garage, the DBH guidance does not require structural repair where the vertical differential settlement is less than 50 mm across the space, and the floor slope is less than 1:200 (0.5%) between any two points >2 m apart. The garage floor at the _____ residence is out of level by a maximum of 71 mm (40% over the minimum criterion for structural repair), and the maximum floor slope observed over 2 m in this survey is 1.6% (>300% over the minimum criterion for structural repair).

Table 1. Indicator criteria given in Table 2.2 of the Guidance for foundation damage not requiring structural repair. Buildings meeting all 3 of settlement status, lateral stretch status and crack width criteria do not require repair.

Dwelling Foundation Type	Settlement Status		Lateral stretch status		Crack widths[1]/Other
Type A	Vertical differential settlement <50 mm and floor slope less than 1 in 200 between any two points >2 m apart	and	<20 mm [2]	and	Pile tilt <15 mm per 1 m height and no floor framing damage
Type B					<5 mm cracks in perimeter foundation
Type C					<5 mm cracks in the floor slab

(1) Crack widths are those principally related to earthquake actions

(2) A maximum lateral stretch of 20 mm is based on a resulting potential out of plumb of house end walls of 10 mm.

Section 2.2 of the Guidance notes that, if significant differential and/or overall settlement has occurred, it may be necessary to rebuild foundations, even if there is only minor damage to the foundation or superstructure elements. No lateral stretch status is derived here, nor are major cracks present in the slab. Nevertheless, the results of this survey clearly exceed the criteria for foundation damage requiring specific engineering input as per section 14.2 of the guidance, and by a significant amount.

Notwithstanding the previous paragraph, the guidance requires that engineering judgement should be exercised when applying the criteria for foundation repair. The guidance specifically notes that not all foundations that meet repair criteria will necessarily be repaired, and that engineering judgement regarding repair decisions must be informed by considerations including the intended use of the space, its construction materials, the cost-benefit ratio of the repair, the capacity to resist deformation, and the effects of gradients on the amenity of the space (Section 14.2).

The following points are therefore emphasised:

1) The garage space is connected to the house through the roof and the maximum settlement abuts the house perimeter foundation. This suggests that either a) differential settlement of the (settled) garage and (unsettled) house will be exerting bending stresses on the roof, with implications for both the foundations and superstructure of the house, or b) The differential

settlement reflects an underlying ground-surface-displacement that projects into the washroom/kitchen area of the house. Either option merits a rigorous inspection of the roof and the house foundations, but bending/bulging of the washroom floor and kitchen bench, along with gradients recorded by differential LiDAR (Figure 1) suggest that option b is more likely.

2) The space is used as a home workshop as well as a garage. The development of a 71 mm fall toward the garage door, and particularly the steepness of the fall near the house foundation, has resulted in the car now having a tendency to roll out of the garage, and tools having a tendency to roll off the bench.
3) A wide crack opened between the house and the garage during the Canterbury earthquake sequence, and was 'repaired' by covering with timber coving during EQC earthquake repairs in June 2013. The opening is now once-again visible (Figure 2) due to further differential settlement after the repair. This settlement appears to have occurred during a Mw 4.5 earthquake (id 2014p933966) on Saturday, December 13th 2014. The nature of the damage is excessive for the light shaking intensities reported from Parklands, and suggests that the present foundation has a low capacity to resist deformation.

On the basis of this survey, and specifically points 1–3 above, I recommend a full engineering evaluation of both house and garage, to inform an appropriate decision of further action. Given the pattern of differential subsidence, it would be appropriate to have the garage floor checked for sub-floor cavities.