Structural damage arising from slope movements
Inspecting and assessing houses

September 2025

This guidance has been prepared for structural engineers undertaking the inspection and assessment of houses affected by slope movements, and for others involved in the assessment process.

It draws on recent experiences from severe weather events and previous earthquakes in New Zealand, highlighting the unique damage patterns and repair considerations associated with landslides and other slope instability. The focus is on practical approaches to assessment and the development of repair strategies, recognising the additional complexities slope movements present compared to earthquake damage.

This document follows on from, and should be read in conjunction with, Legacy Document 4 – *Guidance for Engineers on Residential Damage Assessment and Reinstatement*. This document arose from the forensic work of the Christchurch Expert Earthquake Engineering Panel and captures good practice for residential damage assessment and reinstatement following natural disasters. This guidance builds on that foundation, adding specific considerations for damage caused by slope movements, informed by field experience and a case study. It is expected that geotechnical engineering input is obtained where slope movement damage is involved.

This targeted guidance has been developed by Engineering New Zealand and members of the Engineering New Zealand Natural Disaster Recovery Panel (NDR Panel), with support from the New Zealand Claims Resolution Service (NZCRS) and the Natural Hazards Commission Toka Tū Ake. It is intended as an adjunct to the legacy guidance, providing specific advice on the additional elements associated with slope movements that are not covered in the earlier document.

Cover image courtesy of Auckland Council. This image is not related to any houses referenced in this document.

Introduction

Landslides affect a significant number of houses across New Zealand every year. The extreme rainfall that occurred in Auckland in January 2023 followed shortly afterwards by Cyclone Gabrielle caused extensive damage across a number of regions, as did the severe weather event that impacted Nelson and Marlborough in August 2022.

The Canterbury and Kaikōura earthquakes have also highlighted the vulnerability of slopes (both natural and developed) and the houses constructed on them to strong ground shaking.

The Natural Hazards Insurance Act 2023, which replaced the Earthquake Commission Act 1993, defines a 'landslide' as follows:

"... movement (whether by way of 1 or more of falling, sliding, or flowing) of ground-forming materials (being 1 or more of natural rock, soil or artificial fill) that before they moved, formed an integral part of the ground; "

Landslides and the damage they cause occur across a range of scales. While geotechnical engineering input is always expected, structural engineering input will be required where the damage to houses is minor to moderate, and repairs may be feasible.

This guide is primarily for structural engineers undertaking damage assessment and, where appropriate, repair specifications for houses affected by landslides. It may also be a helpful document for others involved in the assessment of damage to houses arising from slope movements.

Engineering New Zealand would like to acknowledge Steven Knowles as the primary author of this guidance, with significant contributions from Dave Brunsdon, Andrew Palmer and Greg Melvin.

Residential damage assessment and reinstatement

In 2023, Engineering New Zealand developed legacy documentation to capture lessons learnt from the work of the Engineering New Zealand Expert Panel in helping to resolve insurance claims related to the Canterbury Earthquake Sequence. These were developed with input from the Panel and the Engineering Advisory Group, and in consultation with stakeholder representatives from the Homeowners Advisory Group, private insurers, Toka Tū Ake EQC, NZCRS and lawyers.

Legacy Document 4 – Guidance For Engineers On Residential Damage Assessment and Reinstatement, provides practical advice and key considerations for engineers undertaking an engineering assessment of residential buildings damaged by natural disasters.

This guidance augments and should be read in conjunction with Legacy Document 4, noting that the guidance provided in that document is not reproduced in this document.

Understanding slope movements

The New Zealand Geotechnical Society has produced a Slope Stability Geotechnical Guidance Series. Part 2 of Unit 1, *General Guidance*, provides relevant information on slope movement types and processes. Part 3 provides information on recognition and identification of slope movement.

This document provides good background information and illustrations for structural engineers.

It is expected that slope movements that have caused damage to houses will be investigated by geotechnical engineers. Where no geotechnical reports are available, the structural engineer should recommend the involvement of a geotechnical engineer.

Matters that are likely to require geotechnical engineering input include:

- extent and scale of slope movement
- stability of the slope and its future viability for residential structures
- slope stabilisation recommendations.

Possible effects on structures

Slope movements are complex and have numerous elements that can have different effects on residential structures. Figure 1 shows typical features of a slope movement.

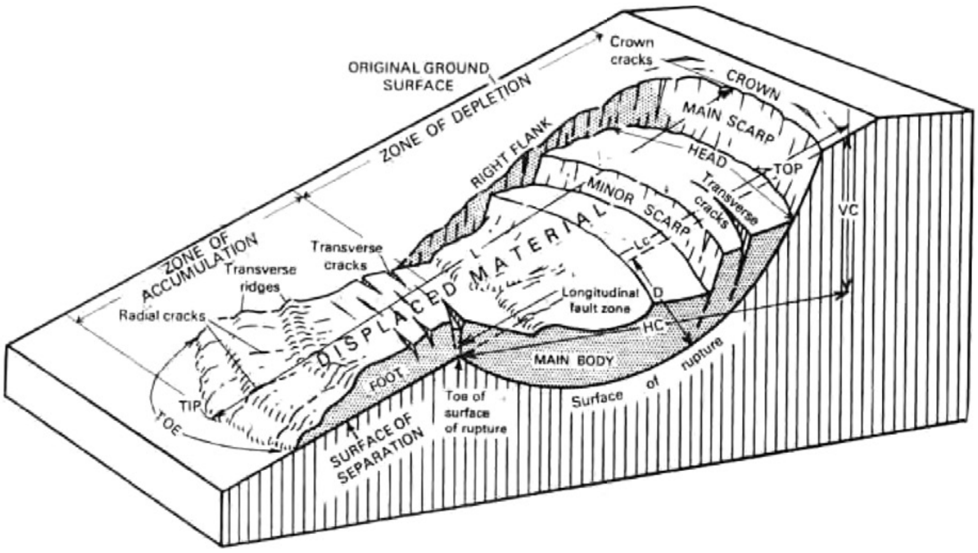

Figure 1: Idealised Landslide Components (Varnes, 1978)

Depending on the position of the structure relative to the slope movement, these effects can include:

- loss of support to foundations
- dislevelment of foundations – typically house foundations further down the slope have greater settlements. Note in some locations the opposite can be found (eg in a section of toe bulge at the bottom of the circular rupture surface) where the ground has lifted creating floor falls into the slope rather than down the slope.
- foundation stretch
- foundation compression
- plan twisting – where the slope movements are not consistent across the width of the structure
- structural collapse
- debris inundation
- boulder impact.

These potential effects need to be considered and evaluated as part of any structural assessment of a landslide-affected house.

Key differences between earthquake damage and slope movement damage can include:

- less structural rupture – slope movements are usually slower so there is more time for materials to absorb movement, causing less structural rupture
- less damage at the top of structures – the amplification of movement at higher levels from vigorous shaking during earthquakes does not occur, and as a result there is usually less damage at higher levels
- increased plan distortion at foundation level – slope movements are typically larger than earthquake movements, resulting in increased plan distortion including stretch, compression and twisting.

Case study: Plan distortion

Plan distortion can be a feature of slope movement, and it requires additional assessment beyond the assessments carried out for earthquake damaged houses. It is best understood through an example.

The following case study illustrates how plan distortion manifests in practice.

A single-storey house in Nelson was built in 1953 on a moderately steep slope above Tahunanui. A partial lower storey was subsequently built under the downhill side of the house, and a reinforced concrete masonry garage was added more recently in 2009. Refer to Figure 2 for a longitudinal section through the house and slope.

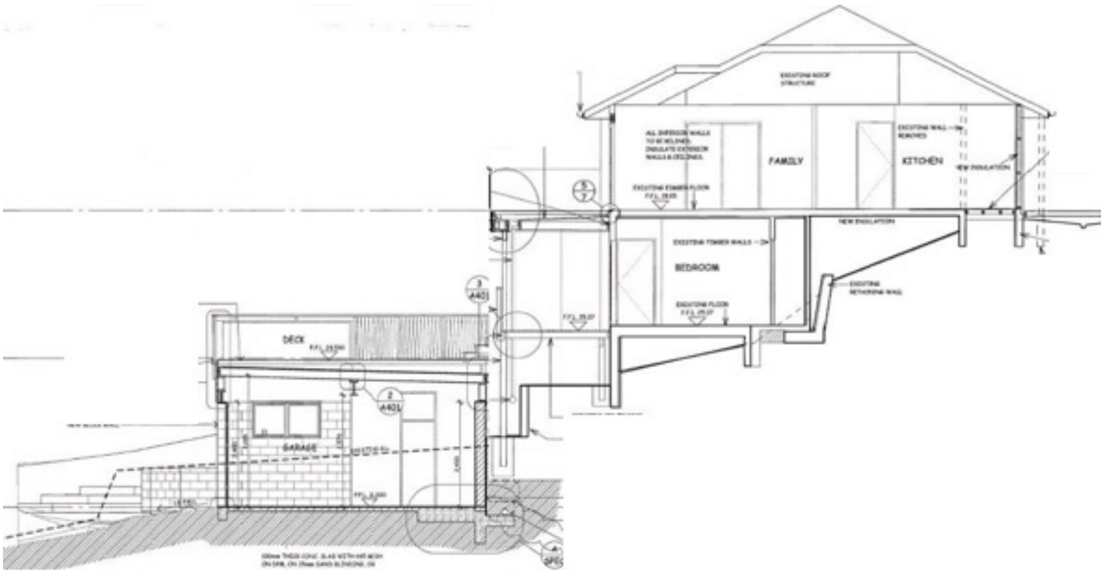

Figure 2: Longitudinal section of house and slope

The house was seriously affected by a slope movement in August 2022 associated with discrete localised movement within the Tahunanui Slump. The house presented with damage to most walls, both those perpendicular to the slope and those parallel to the slope. Figures 3 and 4 show the damage observed.

The significant damage included:

- rupture of the perimeter foundation and buckling of the internal linings at the northern end of the western wall that was perpendicular to the slope
- racking of the walls/doors on the northern wall that was parallel to the slope
- significant cracks and separations in the internal plasterboard linings up to 30mm wide
- cracks and separations in the timber flooring.

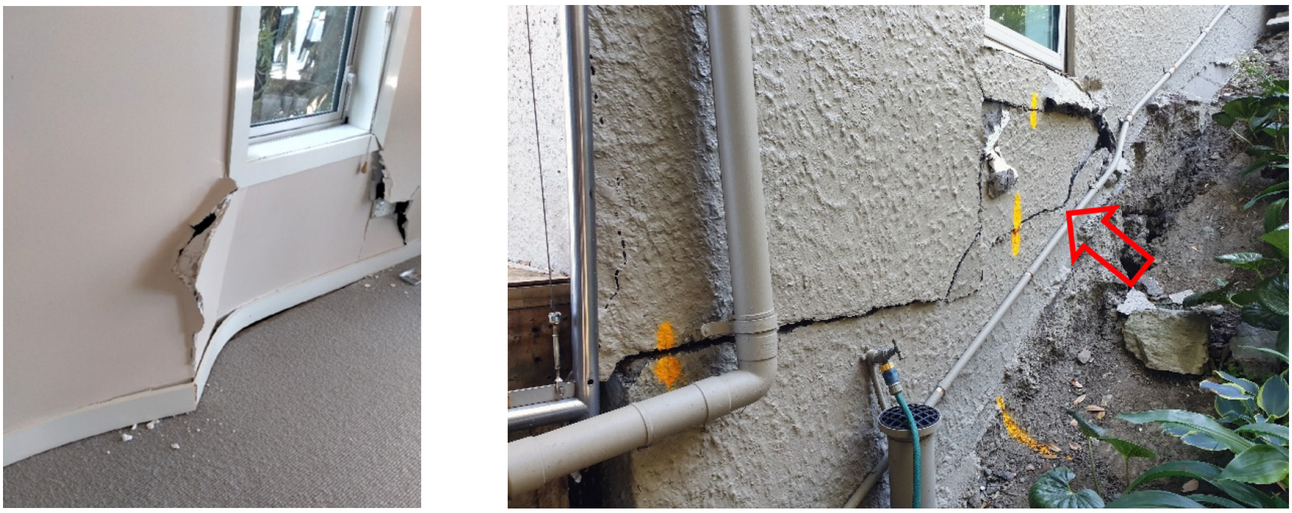

Figure 3: Photos from Mitchell Vranjes Structural Engineering Report illustrating the internal and external damage observed at northwestern corner.

Figure 4: Photos from Mitchell Vranjes Structural Engineering Report illustrating the damage observed along first floor of north wall.

As a result of engineering inspections, the insurer and owner made the decision to demolish the house.

Members of the NDR Panel inspected the dwelling before it was demolished and completed a floor level survey and a survey of the outside walls.

Some localised floor level variations that were likely caused by the slope movement were observed. This was discernible mostly in the northwest corner of the lounge. However, the damage mostly arose from the plan distortion of the house. The house foundation had been restrained from movement at the northwest corner but elsewhere had been freer to move downhill with the slope movement.

Figure 5 shows the recorded measurements of the plan position of the corners of the house on a distorted scale. The northwest corner of the house had a lean towards the north of 85mm and a lean to the east of 87mm. The blue arrow shows where the house foundation was restrained, and the red arrow shows the slope movement direction.

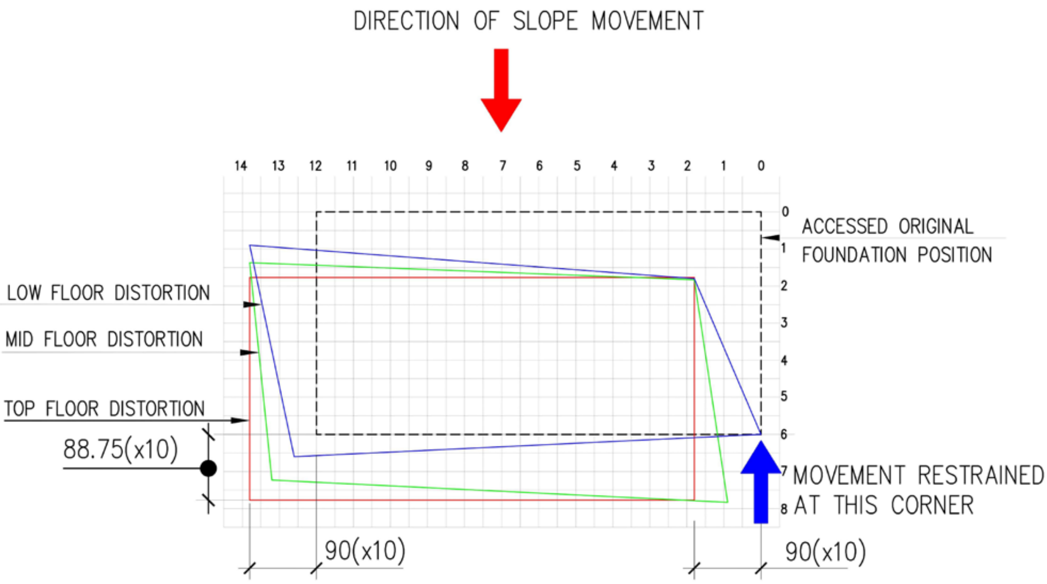

Figure 5: Measured positions of the corners of the house (10x distorted)

Figure 6 shows an isometric schematic of a representative two storey house illustrating the twist that occurred at the house. The ground floor (foundation) was twisted by the slope movement. Measurements highlighted the enormous capacity for a timber framed house to absorb these movements. The ceiling diaphragm (red) retained its original planar shape more or less and had simply translated down the slope. The first floor diaphragm was partly twisted but not as much as the ground floor.

In summary, the house had been twisted at the foundations, but the floor and ceiling diaphragms worked to remove the twist at ceiling level. This untwisting caused the racking of the northern wall. Leader lines are shown to indicate more clearly the racking of the northern wall. Rather than rack the ceiling diaphragm out of its planar shape, the house absorbed the foundation twist by racking the northern wall, which had a large number of joinery units.

Without the measurements of the external walls this effect and the scale of this effect was not easily understood from the presenting damage.

Other damage to the house could be readily determined from the normal assessment procedures for earthquake damaged houses.

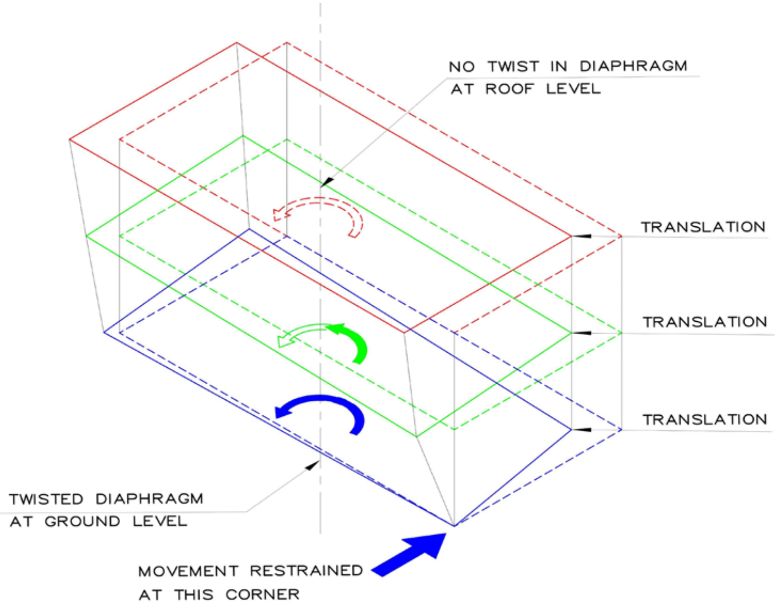

Figure 6: Isometric schematic of twist in a representative two-storey house

Inspection methodology

Inspections should be completed in line with the guidance provided in *Legacy Document 4 – Guidance for Engineers on Residential Damage Assessment and Reinstatement*.

For houses affected by slope movement, the structural engineer should also consider personal safety, land damage observations and plan shape.

Personal safety

Prior to entry the engineer should complete an assessment of the current risks by carrying out a thorough external inspection of the structure. Only enter the structure or parts of the structure that are considered to be safe. Identify the nearest exit routes before entering the building. If appropriate, station a colleague outside the structure to provide assistance or call for help should this be required. Take all other normal precautions for site inspections.

Land damage observations

Land damage observations may increase the understanding of the likely movement of land. These are typically completed by geotechnical engineers, but a general understanding of the direction and scale of the land movement will also help the structural engineer to develop an appreciation of how the structure was loaded. Land damage observations can include:

- ground cracks
- ground deformations
- separations between rigid or long elements and the ground
- relative movements between shallow founded items (eg paths and items with deeper foundations)
- retaining wall deformations
- fence lines
- inclination of tree trunks.

Plan shape

In addition to floor level surveys and measurement of wall inclinations, the plan shape of the structure can be measured at key levels up the structure.

One way to complete this is to create a series of vertical laser planes around the house that are square to each other as shown in Figure 7.

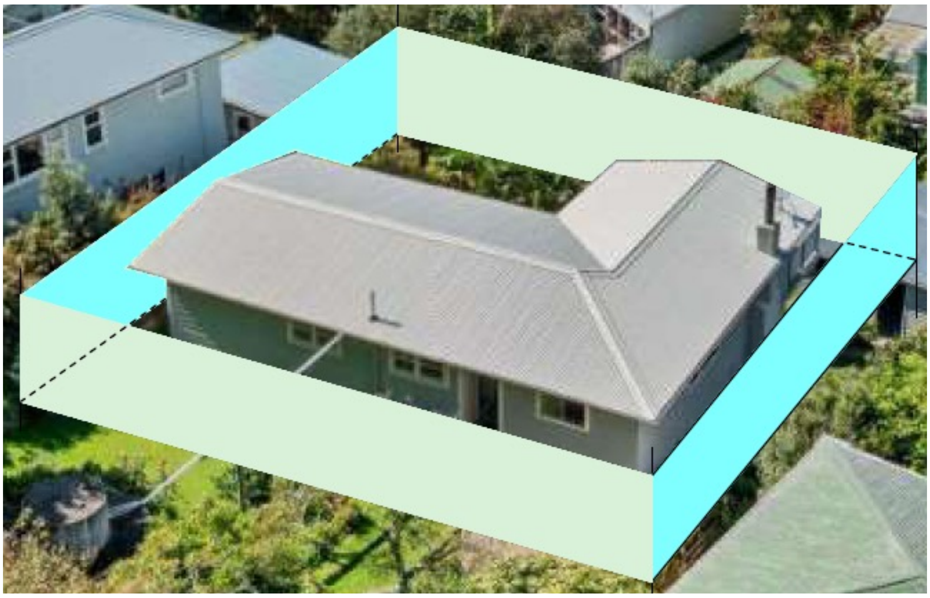

Figure 7: Possible method to measure plan shape at diaphragm levels

Horizontal measurements can be taken from the laser planes to the house at each diaphragm level (eg floors and ceilings) and the foundation level along each wall, possibly at the corners and mid length. The plan shape at each level can then be determined and compared with those at other levels.

Notes:

- This may be beyond the normal survey tools of a structural engineer, and a cloud survey from a surveyor may be a more suitable survey. In this circumstance it is important the structural engineer is involved in the selection of the points of comparison from the cloud survey to best allow for the variations in the exterior cladding thicknesses at the different levels.
- The survey could be tied to a reference point outside the zone of the slope movement to monitor any ongoing movements.
- Caution should be taken to confirm planar distortion, and the structural engineer should clearly identify damage to the house that supports that planar distortion has occurred.

Repair strategies

The structural engineer should develop repair strategies based on their measurements and observations, and in conjunction with the geotechnical assessment of the slope and any recommendations for stabilisation. Most repair strategies will be similar in nature to those for an earthquake damaged house, except as follows.

Foundations

Foundation repairs are likely to be specifically engineered. The Ministry of Business, Innovation and Employment (MBIE) publication *Repairing and rebuilding houses affected by the Canterbury earthquakes* (version 3 dated December 2012) and subsequent updates and clarifications (MBIE Residential Guidance) provide guidance on foundation repairs. These solutions were developed for flat sections to address liquefaction and do not directly apply to sloping sections with slope movement.

Planar distortion

The MBIE Residential Guidance also provides advice on the acceptability of foundation stretch. If the foundation stretch does not exceed 20mm, it may not be necessary to rebuild the foundation, based on the permitted construction tolerances for wall verticality.

This extent of stretch would equally apply to planar distortion of the foundations or diaphragms. If the discernible distortion is less than 20mm it may not be necessary to return the diaphragm to its assessed original planar shape. It would still be necessary to repair any lining, flooring or cladding damage and to realign joinery items.

Where the planar distortion exceeds 20mm repairs should be considered. Repairs may include removal of linings, cladding and flooring to allow the diaphragm to be returned to its original shape. This would be best completed as a single operation, as a wall-by-wall release is unlikely to restore the correct diaphragm shape.

Other considerations

The structural engineer should also consider other matters in determining their recommendations for repair:

- the Australian Geoguides for slope management and maintenance
- guidance on complying with Sections 71–74 of the Building Act which relate to Natural Hazards
- permitted construction tolerances and their relevance.

Reporting

Reporting should be completed in line with the guidance provided in *Legacy Document 4 Guidance for Engineers on Residential Damage Assessment and Reinstatement*.

Development of this guidance

It is intended that this guidance will evolve with additional information from inspections and new technologies becoming available.

There is a perceived need for improved guidance on repair strategies for slope movement damaged properties providing more specific strategies based on quantified damage akin to MBIE's Repairing and rebuilding houses affected by the Canterbury earthquakes. Such industry guidance would increase consistency of repair recommendations within the regulatory context.

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