BULLETIN

BRANZ
BUILDING ON KNOWLEDGE

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LESSONS FROM THE 1987 EDGECOMBE EARTHQUAKE

- Houses on simple piles are vulnerable to foundation failure unless adequate bracing of the sub-floor system is provided.
- Houses constructed in accordance with the requirements of NZS 3604 and also well-built older houses survived the earthquake without structural damage.
- Different types of shaking result when separate parts of a building are founded on different types of foundation. Often damage will occur at the junction of the differing parts.
- Chimneys are particularly vulnerable. It is essential that precast chimney units are properly reinforced, and that the chimney is adequately attached to the structure or is designed to stand independently.

This Bulletin replaces No 258 Lessons from the 1987 Edgecumbe Earthquake (1992).

1.0 INTRODUCTION

1.0.1 At 1.35pm on Monday March 2, 1987 the southern Bay of Plenty was shaken by a magnitude 5.2 earthquake (on the Richter scale). Seven minutes later a very shallow earthquake of 6.3 shook the same area causing significant damage to major industrial plants, houses, bridges, roads and services in the area. The most affected was the Rangitaiki Plains, and the townships of Edgecumbe, Te Teko and Kawerau. Areas of neighbouring Whakatane were also damaged during the two shocks.

1.0.2 Several surface traces of the fault movement have been located. The largest trace extends about 7 kilometres with movement of up to 2 metres vertically and 0.7m horizontally across the trace. The shallow depth of the epicentre of the earthquake (10km) and the very soft soil conditions on the plains resulted in intense shaking (intensity IX on the Modified Mercalli Scale). Ground slumping was common, particularly near rivers and waterways.

2.0 THE AFTERMATH

2.0.1 From its study of the effects of the earthquake on the area BRANZ noted that:

- Houses on simple piles are vulnerable to foundation failure unless adequate bracing of the sub-floor system is provided
- Houses constructed in accordance with the requirements of NZS 3604 performed well and generally survived the earthquake without structural damage

PILED FOUNDATIONS

Figure 1: Houses built before *NZS 3604* frequently used unbraced piles and jackstuds. Movement and partial collapse was common with about 30 houses moving on their foundations. The result was that many seriously damaged their superstructure and services.

- Different types of shaking result when separate parts of a building are founded on different types of foundation. Often damage will occur at the junction of the differing parts.
- Chimneys are particularly vulnerable. It is essential that precast chimney units are properly reinforced, and that the chimney is adequately attached to the structure, or is designed to stand independently
- The performance of buildings is dependent on local ground conditions, and the shape and regularity of the building in both plan and elevation
- Houses of a regular plan area and shape were less affected by the earthquakes
- Several free-standing stoves and fireboxes were dislodged by the earthquake, demonstrating the need for them to be adequately fixed to the floor
- Houses with intermittent corner foundation walls performed well and were not dislodged from their foundations
- Most concrete masonry structures were not damaged
- Few windows in domestic dwellings were damaged
- The soft ground had a marked effect on the behaviour of the buildings. In some cases the ground apparently moved beneath the building, compressing the soil around the foundations and damaging services into the building.

Figure 2: Many anomalies were seen and probably resulted from the effects of variable soil conditions giving rise to differing building movement in the earthquake. A near identical house next door to this one remained on its foundations and largely undamaged.

Figure 3: This subfloor consists of concrete piles with jackstuds. This detail would not comply with the bracing requirements of NZS 3604. The number of braces and the nature of their connections in this house were insufficient to withstand the imposed earthquake load from the house. (This is a close-up of the house shown in Figure 2)

Figure 4: Ordinary piles are not able to resist lateral loading. Anchor piles or braced piles are now required for this purpose. The Te Teko Returned Services Association Hall rolled over on its piles, while the chimney base and steps remained in place.

Figure 5: The floors of several structures which fell off their foundations, were punctured by interior piles that remained upright as the building fell.

Figure 6: Some houses were founded on driven timber piles to overcome soft foundation conditions. Movement of up to 50mm was observed between the bearers and the piles. NZS 3604 requires a 6kN connection in this situation, which clearly was not provided here. This connection is one that is still commonly not carried out correctly, even in houses built today.

Figure 7: This house, on the foothills at Awakeri, suffered substantial damage to its foundations and brick veneer. The floor system was independently supported on unbraced piles and was not tied to the perimeter walls. Lateral displacement of the house battered the veneer, dislodging it from its seating on the perimeter wall.

Figure 8: Provisions for lateral support of foundation walls are intended to prevent this happening. The joists should be connected to a plate bolted to the top of the foundation wall.

Figure 9: The damage to this wall of a block of three flats occurred when the flats moved as a unit and compressed the soft ground adjacent to the end of the walls. When the building stopped moving, the corners of the end wall (which were connected to the sidewalls) had returned to their original position, but the centre of the end wall (which was not connected to the floor) remained displaced.

Figure 10: NZS 3604 and NZS 4229 still permit floor slabs not to be connected to foundation walls for single-storey buildings providing they are 'contained' within the foundation walls. Here, the floor in the flats (refer to Figure 9) has separated from the end wall when the middle of the wall has not returned to its original position, leaving a significant gap.

Figure 11: Some houses and additions were built partly on piles and partly on slab-on-ground. Often there was damage at the junction between these types of construction because each type moved differently. This is a particularly vulnerable feature of alterations and additions if there is not adequate connection between the old and the new.

Figure 12: Soft ground in the area resulted in subterranean movement. The floor slab of this garage moved laterally, displacing the adjacent paving slabs.

Figure 13: In the same garage as shown in Figure 12, the movement of the stormwater sump relative to the down pipe was approximately 200mm.

Figure 14: Ground movement often caused surface cracking. A slab-on-ground 'L' shaped dwelling was crossed by a significant fissure and the slab has split by about 100 mm. Minor settlement also occurred around the property, resulting in reverse fall of gutters, etc. It is not practical to build domestic buildings to resist this sort of damage.

Figure 15: Reinforced concrete masonry structures generally performed well. Among those that did not, was this house built in the mid 1960s on the Rangitaiki Plains. Some cracking of the concrete masonry lintel beam and the brick veneer can be seen on this elevation.

Figure 16: The lower storey concrete block masonry was reinforced both horizontally and vertically with plain mild steel rods. Despite the reinforcing, cracking occurred in several places at the corners.

Figure 17: This type of wire tie, which was in common usage, is no longer permitted. As can be seen, they did not succeed in their role of tying the brick veneer to the timber-framed wall.

Figure 18: A view of the rear of the house reveals the extent of the brick veneer failure. Note that the windows have remained intact despite the severe shaking the building has suffered.

Figure 19: The minimum reinforcing requirements of NZS 4229 are intended to prevent the total disintegration of masonry structure as shown here.

Figure 20: Brick veneer panels between windows were particularly vulnerable, yet the windows nearly always remained intact.

Figure 21: This masonry firewall on a boundary did not have adequate fixing to the roof framing or a foundation from which it could cantilever and stand alone.

Figure 22: Many precast concrete chimneys collapsed. External chimneys that were not well connected to the buildings generally fell outwards. The Acceptable Solution B1/AS3 to the Building Code requires masonry chimneys to be reinforced and tied to the building at roof level. NZS 3604 provides for the extra bracing demand on the building structure. The introduction of these requirements mean that there should be much less failure than evidenced in the Edgecumbe earthquake.

Figure 23: Many chimneys that failed were found to have no reinforcing in them, and the individual elements separated as the chimney collapsed.

Figure 24: In some instances, reinforcing steel was present but the grout had not penetrated along the full length of the steel, as shown in this example.

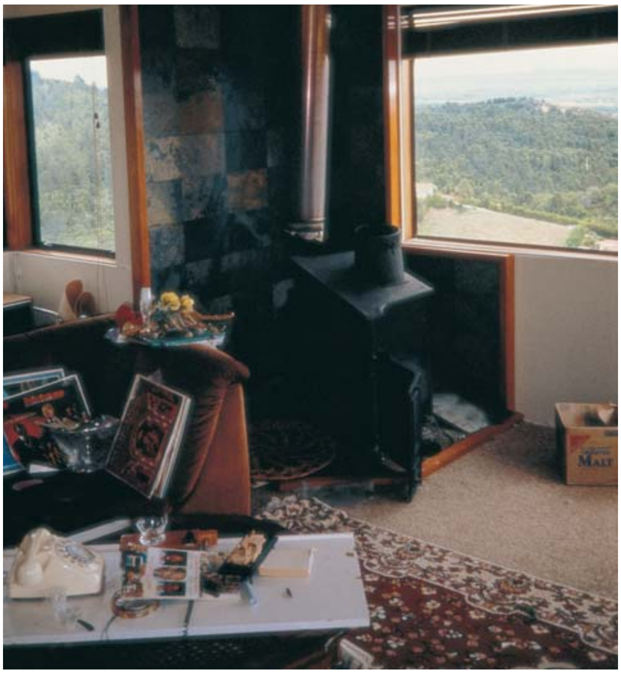

Figure 25: Wood-burning stoves, both free standing and in-built, were displaced by the earthquake. The need to adequately fix these appliances to the floor was clearly demonstrated as many stoves were standing on smooth hearths and when shaken they moved easily, tearing free from their flue and, in some instances, tipping over and spilling the contents of their fire boxes.

UNLINED HOUSES

Figure 26: Unlined houses are particularly vulnerable to lateral loading from either earthquake or wind actions. The contribution of the internal linings to the resistance to lateral load, and the need to ensure adequate nailing of the lining, is shown by the near collapse of this unlined house.

Figure 27: Inside the house the internal metal angle braces were insufficient to handle the earthquake loads from the relatively heavy upper-storey.

Figure 28: This split-level house, overlooking Whakatane, has been constructed on a pole platform, and from this view appears undamaged.

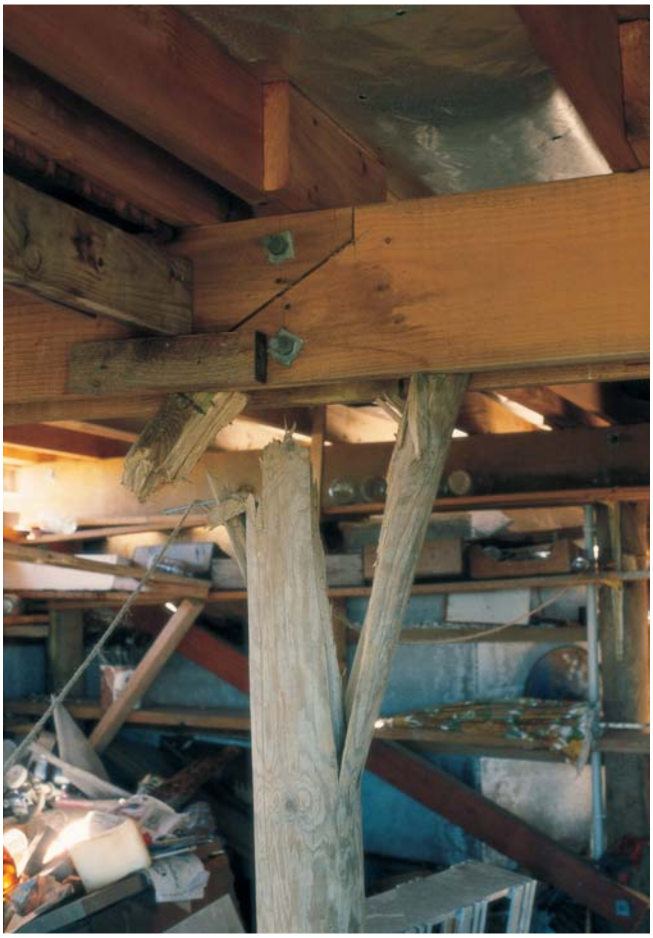

Figure 29: The pole supports acted as cantilevers and were unbraced. This internal pole, fractured below the beam. The split-level floor reduced the effectiveness of the floor diaphragm action. NZS 3604 now requires a bracing line at all discontinuities of the floor level.

Figure 30: Walls of different height moved differently, often resulting in cracked wall linings and fractured plaster joints.

WATER-CONTAINING STRUCTURES

Figure 31: Water-containing structures experienced substantial damage during the earthquake. Many pools were badly damaged in the area. Water was described as being 'thrown' from pools in Edgecumbe.

ROOF BRACING

Figure 32: In this gable-ended concrete tiled roof, the nailed connections between the diagonal roof braces and the ridge board failed. The end of the brace was fixed to the ridge board directly below a rafter. When the brace was loaded in compression, it raised the ridge board, pushing the rafter out of place.

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