**(a) Anchorage failure** **(b) Close-up of failed anchorage detail**

**Figure 3.9 Anchorage failure of awning brace due to parapet collapse**

### 3.1.7 Wall failures

Out-of-plane wall failures were the first images to appear on television directly after the earthquake. Inspection of this damage typically indicated poor or no anchorage of the wall to its supporting timber diaphragm. Several examples of wall failure are shown below. Figure 3.10(a) shows a corner building that had walls fail in the out-of-plane direction in both perpendicular directions, on both sides of the corner. Figure 3.10(b) shows a 3-storey building where walls in the upper two stories suffered out-of-plane failures and Figure 3.10(c) shows similar damage for a 2-storey building. In all three of these instances, it appears that the walls were not carrying significant vertical gravity loads, other than their self weight, due to the fact that the remaining roof structures appeared to be mostly undamaged. In contrast, Figure 3.10(d) shows an out-of-plane failure of a side wall which was supporting the roof trusses prior to failure.

(a) Corner Worcester and Manchester streets

(b) 118 Manchester Street


(c) 179 Victoria Street

(d) Failure of long wall

**Figure 3.10 Examples of out-of-plane failures in solid masonry walls**

As shown in Figure 3.11, several examples of face load wall failure closely resembled observed damage in dry stack masonry experiments (Restrepo-Velez and Magenes, 2009), providing further support to the supposition that many of the wall failures were partly attributable to poor mortar strength.

(a) Wall damage at 140 Linchfield Street

(b) High speed photograph of a dry-stacked masonry wall failing during a tilt test

**Figure 3.11 Failure mechanism comparisons – observed earthquake damage versus experimental simulation**

Cavity wall construction is generally believed to be much less common in New Zealand than is solid multi-leaf (or multi-wythe) construction. However, cavity wall construction can be extremely vulnerable to out-of-plane failure in earthquakes in situations where the cavity ties were poorly installed, or more commonly have corroded over time, as the wall is then comparatively slender and less stable than for solid construction. Figure 3.12(a) and (b) show examples of cavity wall buildings that suffered out-of-plane wall failures.

**(a) Cavity wall failure in a residential building**


**(b) 832 Columbo Street**

**(c) Butterfly wall ties still intact**

**(d) Metal wall ties badly deformed.**

**Figure 3.12 Examples of out-of-plane failures in cavity walls**

Figure 3.12(c) and (d) show that cavity ties were present but were insufficient to prevent the outer leaf from failing.

In some cases wall-diaphragm anchors remained visible in the diaphragm after the wall had failed, indicating that failure had occurred due to bed joint shear in the masonry (refer Figure 3.13(a)). Figure 3.13(b) shows a situation where a diaphragm anchor had been embedded within the wall. It can be seen that the anchor successfully prevented the restrained wall from failing, but was not able to prevent toppling of the parapet that was located above the anchor.

(a) Gable end wall failure despite anchor (see also Figure 13a).

(b) Wall anchor still intact (see also Figure 6a).

**Figure 3.13 Wall-to-diaphragm anchor details**

### 3.1.8 Successful wall anchorage

A significant feature of the earthquake was the number of occasions where anchored walls performed well during the earthquake. Photographs showing this are presented in Figure 3.14 and Figure 3.15. A typical wall-to-diaphragm (roof or floor) anchor typically consists of a long 20 mm bolt with a large circular disk of about 150-200 mm diameter between the wall exterior and nut that clamped the disk to the wall. This detail is shown quite clearly in Figure 3.13(a).

(a) Arts centre building

(b) Arts centre building

**Figure 3.14 Successful gable end wall and side wall anchorages**

### 3.1.9 In-plane wall failures

Where walls exhibited some damage to in-plane deformation the cracks were mostly seen to pass vertically through the lintels over door or window openings. Although this type of damage was not widely observed, examples are shown in Figure 3.16.