Section 2:

The Architectural Characteristics and the Number and Seismic Vulnerability of Unreinforced Masonry Buildings in New Zealand

New Zealand's unreinforced masonry (URM) construction heritage is comparatively young, spanning from 1833 until approximately 1935 and peaking during the first four decades of the twentieth century. Consequently, a study of New Zealand's masonry building stock has a narrow scope in comparison with international norms (see Binda & Saisi, 2005; Lourenço, 2006; Magenes, 2006). This comparatively narrow time period has the advantage of facilitating the documentation and reporting of New Zealand URM construction practice with a greater degree of accuracy than is often possible in countries with an older and more diverse history of masonry construction (Binda, 2006).

2.1 Early Masonry Construction in New Zealand

Captain James Cook anchored off the coast of New Zealand on 9 October 1769. This event was followed by a gradual haphazard increase in the population of Europeans in New Zealand over the next 70 years. Jacobs (1985) reports that the European population of New Zealand in 1830 was probably a little more than 300, by 1839 the number had risen to possibly 2000, and at the beginning of the 1850s there were 26,000 Europeans in New Zealand. William Hobson's arrival in Auckland in 1840 as the First

Governor General of New Zealand marked the beginning of New Zealand as a British colony.

(a) **1866 View of the lower end, west side, of Queen Street, Auckland [Alexander Turnbull Library]**

(b) **Queen Street and Queen Street Wharf, Auckland, 1882 [Alexander Turnbull Library]**

Figure 2.1 Early masonry construction in Auckland

Construction in Auckland in the period from 1840 to 1880 was primarily of timber for residential and small commercial buildings, but masonry buildings also began to appear close to the harbour (see Figure 2.1). Oliver (2006) reports that clay bricks were first manufactured in Auckland in 1852, with production of about 5,000 bricks per day. Timber was in plentiful supply and so it was only natural that outside the central city nearly all buildings were constructed of timber. Within Auckland central city the construction of timber buildings was not restricted until the City of Auckland Building Act of 1856. A fire in central Auckland in 1858 provided further impetus for the transition from timber to clay brick masonry construction.

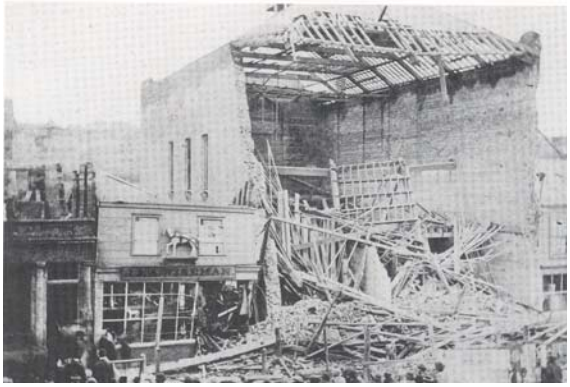
(a) **The 1833 Stone Store at Kerikeri was built by the Church Missionary Society [Alexander Turnbull Library]**

(b) **Two Chinese miners in front of a stone cottage in central Otago, ca. 1860 [Alexander Turnbull Library]**

Figure 2.2 Examples of early masonry construction in New Zealand

The lack of durable local building stone meant that the great majority of Auckland city's masonry buildings were constructed of clay brick with a stucco finish. In other parts of New Zealand there was a more plentiful supply of natural stone, with New Zealand's earliest masonry building having been constructed of stone in 1833 (see Figure 2.2(a)). Figure 2.2(b)[2] shows an example of early rural construction in parts of New Zealand were timber was scarce and natural stone was the primary construction material.

(a) **Looking down Shortland Crescent, Auckland, ca. 1865. Construction is a mix of timber, brick masonry and stone masonry [Alexander Turnbull Library].**



(b) **Collapse of a new masonry auction market building, Queen Street, 1865 [Alexander Turnbull Library]**

Figure 2.3 Transition from timber to masonry construction

Figure 2.3(a) shows Auckland at a time when the majority of buildings were constructed of timber, but a number of masonry buildings were becoming prominent. However Figure 2.3(b) shows that not all masonry buildings were well constructed. Hodgson (1992) reports that inferior materials and uncertain ground conditions were not uncommon in building projects of this period. Hodgson also reports that Auckland city went through a transformation during the 1870s when almost all timber buildings were replaced by masonry buildings. Figure 2.4 shows that by 1910 the central city was composed almost entirely of URM buildings.

[2] Note that the style of unreinforced masonry construction shown in Figure 2.2(b) is not representative of the New Zealand URM building stock remaining today, and is not further considered in this report. Elsewhere in the world where this style of construction remains prevalent, past large earthquakes have repeatedly led to widespread and catastrophic collapse of this type of construction.

(a) **Looking along a row of commercial buildings on Queen Street, Auckland, ca. 1910 [Alexander Turnbull Library]**

(b) **Lorne Street, Auckland, ca. 1910 [Price Collection, Alexander Turnbull Library]**

Figure 2.4 Masonry building stock in Auckland in 1910

2.1.1 The influence of the Wairarapa and Murchison Earthquakes

The Wairarapa Earthquake occurred on Tuesday 23 January 1855 and had an estimated magnitude of M8.2 (Grapes & Downes, 1997). This earthquake is the largest to have occurred in New Zealand since the time of European colonisation (see Dowrick & Rhoades (1998) for a catalogue of major New Zealand earthquakes from 1901-1993). The shock was felt across almost the entire country, was highly destructive in Wellington, and also caused severe damage in Whanganui and Kaikoura.

(a) **General store damaged by the 1929 Murchison earthquake [Alexander Turnbull Library]**

(b) **Damaged business premises after the earthquake of 17 June 1929 [Alexander Turnbull Library]**

Figure 2.5 Damage to masonry buildings in the 1929 Murchison earthquake

The M7.8 earthquake that struck Murchison on the 17th of June 1929 was felt throughout New Zealand (Dowrick, 1994). Fortunately, the most intense shaking occurred in a mountainous and densely wooded area that was sparsely populated. Casualties were therefore comparatively light and the damage was mostly confined to the surrounding landscape, where the shaking triggered extensive landslides over

thousands of square kilometres. Nonetheless, the shock impacted with damaging intensities as far away as Greymouth, Cape Farewell and Nelson (see Figure 2.5). Fifteen people were killed in the Murchison earthquake.

(a) **Overlooking Napier City, ca. 1900 [Alexander Turnbull Library]**

(b) **Overlooking Napier at the buildings ruined by the 1931 earthquake and the fires [Alexander Turnbull Library]**

(c) **Hastings Street, Napier, ca. 1914 [Alexander Turnbull Library]**

(d) **View down Hastings Street, Napier after the earthquake 1931 [Alexander Turnbull Library]**

Figure 2.6 Damage to masonry buildings in the 1931 Hawke's Bay earthquake

2.1.2 The 1931 Hawke's Bay Earthquake

As reported above, it was the combustibility of timber buildings that prompted the focus in Auckland towards building in clay brick unreinforced masonry, and occasionally in stone masonry. Early earthquakes in the Wellington region resulted in a slower adoption of masonry construction. This caution proved to be well justified. On the morning of 3 February 1931 the Hawke's Bay region of the eastern North Island was struck by a M7.8 earthquake that destroyed much of the city of Napier (see Figure 2.6). Fires swept through the wreckage, destroying much of what was left. Perhaps the largest brick masonry building to collapse was the Napier Anglican Cathedral (see

Figure 2.7). The shaking resulted in damage from Taupo to Wellington, and left 30,000 people homeless. The official death toll was 256, and the event currently remains the worst disaster of any type to occur on New Zealand soil (Dowrick, 1998; Dalley & McLean, 2005).

(a) **St John's Anglican Cathedral in Napier, ca. 1885 [Alexander Turnbull Library]**

(b) **Ruins of the Napier Anglican Cathedral after the 1931 Hawke's Bay earthquake [Alexander Turnbull Library]**

Figure 2.7 Napier Anglican Cathedral before and after the 1931 Hawke's Bay earthquake[3]

2.2 Architectural characterisation of New Zealand's URM building stock

In order to ascertain the structural seismic response of both individual URM buildings and the aggregated URM building stock, several key attributes of these building require characterisation. Within the characterisation of URM buildings, the broadest and most important classification is that of the overall building configuration. The seismic performance of an URM building depends on its general size and shape, as a small, low-rise, square building will behave differently when subjected to seismic forces than a long, row-type, multi-storey building. In addition to this, retrofit interventions which may be appropriate for one type of building may not be appropriate for another, different, type of building (Robinson & Bowman, 2000). Whilst a "one size fits all" approach is not viable for all URM buildings, for initial seismic assessments and vulnerability analyses, classification of buildings into typologies is a useful and necessary exercise. This exercise also enables a broad understanding of the financial and economic factors associated with seismic assessment and improvement of potentially earthquake-prone buildings.

The word typology is used as a classification according to a general type, and in the sphere of architectural characterisation different groupings of buildings can be classified

[3] Note the parallels to the damage observed to the Christchurch Cathedral as reported in section 5.1.1.

according to common features or elements. Tonks et al. (2007) began a preliminary identification of building typologies in New Zealand, based on those identified in Italy by Binda (2006). Three typologies were identified, differing from those identified in Italy because of age and materials:

- Stand alone isolated secular or religious buildings and chimneys;
- Row residential buildings;
- Row commercial and retail buildings.

It has since been identified (Russell, 2010) that the New Zealand building stock warrants seven typologies, which are outlined in Table 2.1, and photographic examples are given in Figure 2.8. Buildings are separated according to storey height, and whether they are isolated, stand-alone buildings or a row building made up of multiple residences joined together in the same overall structure. A suggestion for the expected importance level of the structure is also given, according to AS/NZS 1170.0:2002 (Standards New Zealand, 2002). All New Zealand URM buildings fall into importance level 2 or higher because of the number of people that can be expected to be in the building during or after an earthquake, with medium to high consequences for loss of human life. Within the identified typologies, further distinctions can be made. For example, Type A buildings can be divided into those which have a dividing wall down the centre (Type A1), and those which do not (Type A2). Type G buildings are generally monumental structures and those which do not fit easily into the other categories. Usually for such structures unique detailing is encountered, and unique analyses are necessary. Nevertheless there are useful sub-classifications which can also be made within this grouping. For example, Type G1 buildings are religious buildings and Type G2 are warehouses and factories with large tall sides and large open spaces inside. Further detail on each typology can be found in Russell & Ingham (2008).

Table 2.1 New Zealand URM typologies

Type	Description	Importance level (from NZS 1170.0)	Details
A	One storey, isolated	2, 4	One storey URM buildings. Examples include convenience stores in suburban areas, and small offices in a rural town.
B	One storey, row	2, 4	One storey URM buildings with multiple occupancies, joined with common walls in a row. Typical in main commercial districts, especially along the main street in a small town.
C	Two storey, isolated	2, 4	Two storey URM buildings, often with an open front. Examples include small cinemas, a professional office in a rural town and post offices.
D	Two storey, row	2, 4	Two storey URM buildings with multiple occupancies, joined with common walls in a row. Typical in commercial districts.
E	Three+ storey, isolated	2, 4	Three + storey URM buildings, for example office buildings in older parts of Auckland and Wellington.
F	Three+ storey, row	2, 4	Three + storey URM buildings with multiple occupancies, joined with common walls in a row. Typical in industrial districts, especially close to a port (or historic port).
G	Institutional, Religious, Industrial	2, 3, 4	Churches (with steeples, bell towers etc), water towers, chimneys, warehouses. Prevalent throughout New Zealand.