Review of transect of Christchurch CBD Following 22 February 2011 earthquake

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SUMMARY
Two days after the 22 February 2011 M6.3 earthquake in Christchurch, New Zealand, three of the authors conducted a transect of the central city, with the goal of deriving an estimate of building damage levels. Although smaller in magnitude than the M7.1 4 September 2010 Darfield earthquake, the ground accelerations, ground deformation and damage levels in Christchurch central city were more severe in February 2011, and the central city was closed down to the general public. Written and photographic notes of 295 buildings were taken, including construction type, damage level, and whether the building would likely need to be demolished. The results of the transect compared favourably to Civil Defence rapid assessments made over the following month. Now, more than one year and two major aftershocks after the February 2011 earthquake these initial estimates are compared to the current demolition status to provide an updated understanding of the state of central Christchurch.

Keywords: Christchurch, 2010-2012 earthquakes, rapid damage assessment

1. INTRODUCTION

For the first few days following the 22 February 2011 earthquake, engineering resources were primarily directed at assessing the damage to residences and local services in the Christchurch suburbs, such as supermarkets, and to the repairing of essential lifelines. Hence engineering activities in the central business district (CBD) at that time were principally focussed on urban search and rescue, with building damage assessments limited to an 'as needed' basis. Two of the authors were in Christchurch on 22 February 2011 and one arrived the following day. Ingham had experience in rapidly assessing and placarding buildings following the 4 September 2010 earthquake, Moon had also been involved in the assessment of URM buildings following the 4 September 2010 earthquake and fortuitously had undertaken a tour of the CBD on 20 February 2011, and Biggs has significant experience as a forensic engineer including working on the remains of the World Trade Center following the 2001 terrorist attacks. These three authors sought to establish the overall damage condition of buildings in the Christchurch CBD due to the February 2011 earthquake, and especially the condition of those buildings of URM construction. It was decided to undertake a transect as a suitable survey tool to generate an initial estimate of the level of building damage in the Christchurch CBD. The results from this transect compared favourably to publicly available Civil Defence data released the following month. However, after over 10,000 aftershocks, including two exceeding magnitude 6.0 over a year later, initial assessments and demolition estimates are compared with the current state of the Christchurch CBD.

2. THE TRANSECT

A transect is a sampling method widely used in the scientific community to assess the abundance of animals or plants, or to estimate the density of a population of a species in an area (Marques 2004).

Transects take a number of forms, including a *line transect* and *strip transect*. In a *line transect* an observer travels a pre-determined path along which the count of the phenomena of study is recorded, as is the distance from the line to each sighted phenomena. In a *strip transect* only the phenomena occurring between two parallel line segments are counted. An analogy of a *strip transect* was conducted in the Christchurch CBD on 24 February 2011 by three of the authors, to sample the level of building damage following the 22 February 2011 earthquake. The route chosen is shown in Figure 2.1, and buildings directly along the route (on both sides of the streets) were assessed, with the building type and damage level recorded and each building photographed. The findings and observations from the transect have been reported by Ingham et al. (2011) and Moon et al. (2012a, 2012b).

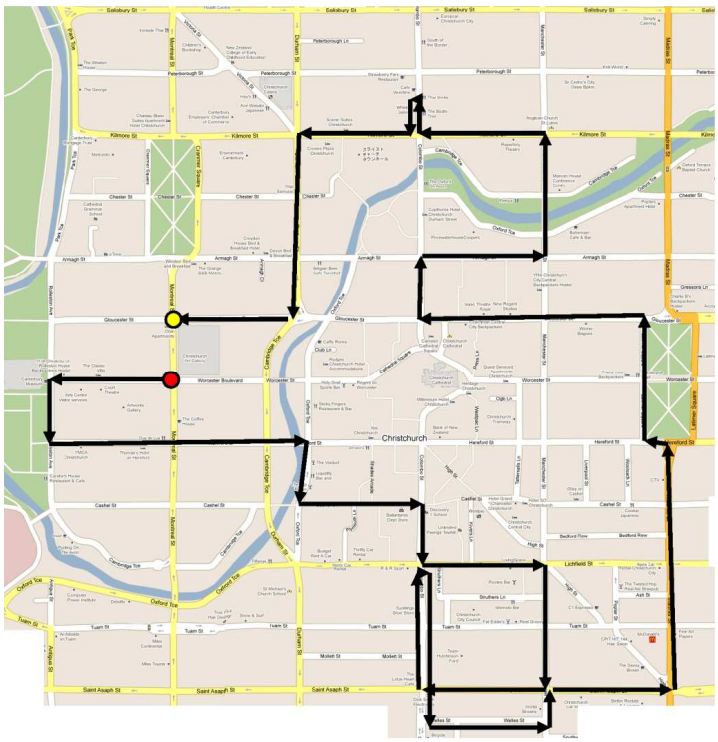


Figure 2.1. Route of CBD transect, 24 February 2011 [source: Ingham et al., 2011]

The transect route was chosen to encompass a large proportion of unreinforced masonry (URM) buildings with which some of the authors were familiar from their previous reconnaissance work following the September 2010 earthquake (reported by Dizhur et al. (2010) and Ingham & Griffith (2011)), and was similar to the route Moon had followed and photographed four days earlier. This photographic record in many cases enabled the damage sustained in the February 2011 earthquake to be distinguished from existing damage. The route was chosen to include one of the two multi-storey concrete buildings that fully collapsed in the 22 February 2011 earthquake. Although the building types recorded during this transect may not have specifically reflected the overall distribution of building types within the city, the transect route did contain a sample of all building types. However, given the homogeneity of building types and age of construction throughout the CBD any path may have been expected to provide similar results. Because of the significant number of aftershocks that were being experienced at the time when the transect was undertaken, and the associated falling hazards, no buildings along the route were entered and in general observations were limited to the front of buildings only.

The transect process consisted of an assessor describing the visible damage and the likely cause; one recorder documenting addresses, building types and damage levels; and the second recorder documenting all building damage via a photograph log. The assessments consisted of classifying each building as either ‘green’, ‘yellow’ or ‘red’, similar to how placards are assigned to buildings during

Level 1 rapid assessments where buildings are normally inspected from the outside only. Buildings with no or minor structural damage were classified green, those with major structural damage but not in imminent danger of collapse were classified yellow and those on the verge of collapse, or deemed unsafe for entry, were classified red. In contrast to the Rapid Assessment process where risk to the public is considered, buildings were not classified red if the only danger was from adjacent buildings as the focus of the transect was on the condition of individual buildings and whether they were repairable or would require demolition.

The transect was conducted in one afternoon and the results were collated, written up and published on the NZSEE Clearing House blog the same evening (Blog, 2011). The results were conveyed to city council representatives next morning (25 February 2011) and interviews were held with media that same morning to inform the general public of the condition of buildings within the CBD (TVNZ 2011), with the story then being circulated worldwide over the next 24 hours (BBC 2011). All buildings along the route observed to have a potentially catastrophic failure mechanism were reported to emergency management officials on the afternoon of 24 February 2011, while further details were provided over the following days.

In addition to its immediate use, the data collected during the transect has formed a solid basis for ongoing research on the performance of buildings in the CBD during the 22 February 2011 earthquake. The early timing of the transect, in relation to the earthquake, meant that observations were made before significant demolition and clean-up work was conducted.

3. RESULTS AND OUTCOMES OF THE TRANSECT

The results of the transect observations are shown in Figure 3.1. The graph shows the number of each building type surveyed, and the breakdown of each building type into the different placard colours. In total 295 buildings were surveyed, of which 145 were URM buildings.

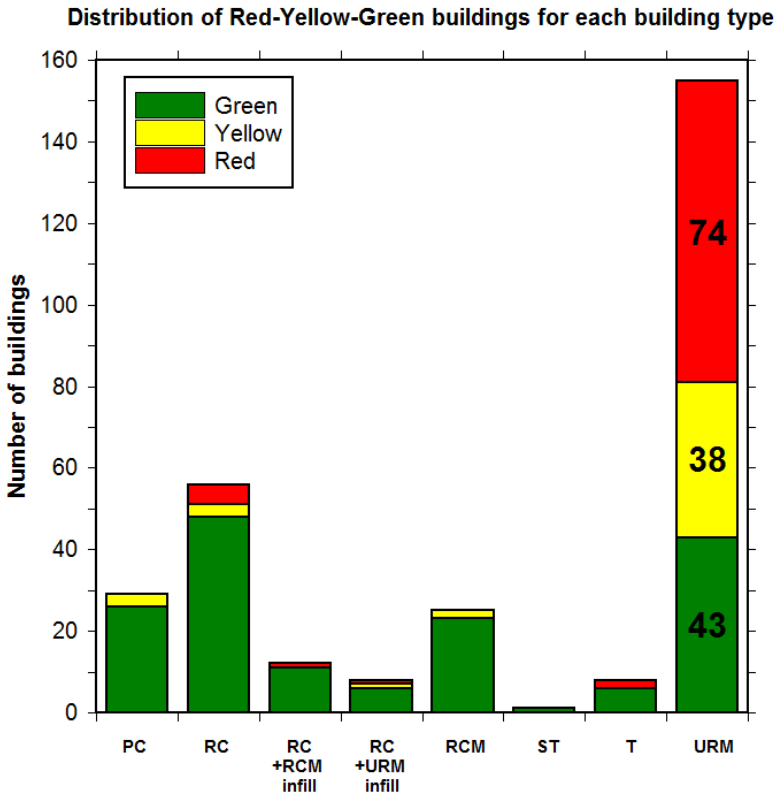
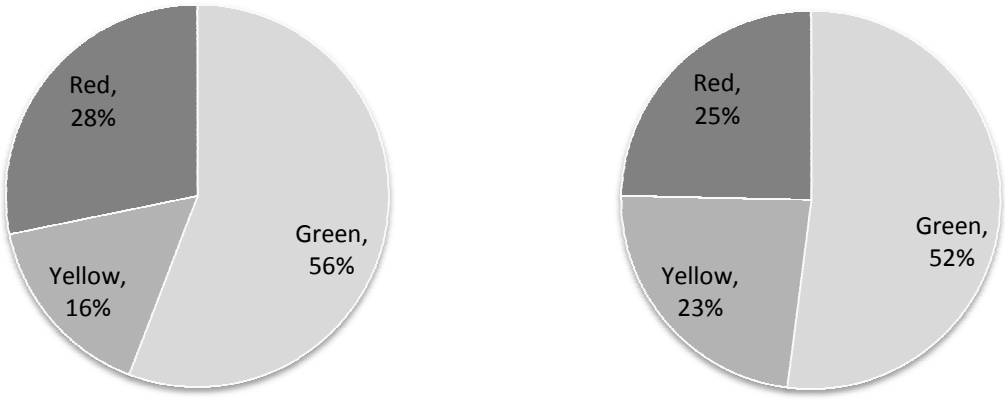


Figure 3.1. Damage breakdown of buildings observed on 24 February 2011 [source: Ingham et al., 2011]

The results of the transect clearly showed that URM buildings performed were the building class which performed the worst during the earthquake. Almost half of all URM buildings were assessed as being red, compared to less than 10% for all other building types. This finding is to be expected as URM buildings are known to behave poorly when subjected to large lateral loads, and the URM buildings tended to be older and therefore have a lower seismic capacity than newer buildings. From the transect data, it was estimated that approximately one-third of all buildings in the CBD would need to demolished. This determination was based on the assumption that all of the red tagged buildings and 50% of all the yellow tagged buildings would be uneconomic to repair or would need to be demolished urgently for safety reasons, and that the transect was a good representation of the distribution of and damage to building types throughout the CBD.

On Friday 25 February 2011, emergency management decided that some 'indicator' buildings were to be selected and asked Ingham and Biggs to assist in their selection. An example building typical of each construction type was to be chosen, and these 'indicator' buildings were monitored and reinspected after each major aftershock. In the event that an 'indicator' building sustained significant additional damage during an aftershock, or showed signs of movement, all buildings of that construction type were to be reinspected. Results from the transect allowed those in charge to be more confident that their selection of indicator buildings were representative of particular construction types and damage levels.

At the time when the transect was performed the focus by authorities was on search and rescue, and engineering assessments in the CBD were limited to an 'as-needed for emergency assessment' basis with most other engineering resources assigned to assessing suburban residences. Rapid building assessments in the CBD had not begun, and therefore the estimates from the transect were the first overall study of the damage levels of buildings within the CBD. Figure 3.2 shows the overall distribution of damage classifications assigned during the transect (Figure 3.2(a)) and those assigned by the Civil Defence volunteers in the following month (Figure 3.2(b)). The Civil Defence data, published by the Christchurch City Council (2011), covers over 4000 buildings within the CBD, and shows an overall damage distribution that is strikingly similar to that obtained from the transect.



a) CBD damage assessment data from transect – 24 February 2011

b) CBD placard data from Civil Defence – 24 March 2011

Figure 3.2. Assessment data from Christchurch CBD, February and March 2011

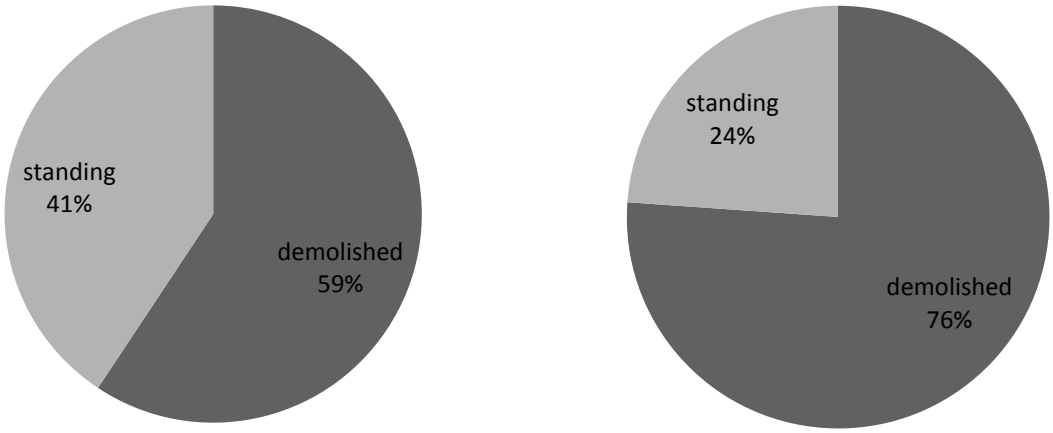
The similarity in overall damage levels between the estimate based on the transect and the official data published the following month occurs despite the fact that the surveying conducted as part of the transect was limited to rapid external visual inspections, usually of the front face of the building only. This survey type can be compared to Level 1 type external inspections, and was not intended to be

used to determine the suitability of use of any particular building. Instead the survey was successful in providing a quick and accurate understanding of the overall damage in the CBD. Where it was not possible to accurately determine the construction materials of the buildings, best engineering judgement was used.

The transect provided a useful survey method for acquiring data on building damage in the CBD. Given the size of the city it was not practical to assess all buildings in such a short time, so a sample was needed. The familiarity of the authors with the route allowed them to better distinguish the new damage from existing, giving a clearer picture of the damage specifically attributable to the 22 February 2011 earthquake. Although the number of URM buildings along the chosen route far exceeded that of other buildings, this distribution was not solely due to the choice of route. URM buildings abounded in the central, historic heart of Christchurch, and are often small in footprint size compared to more modern steel and concrete buildings. Therefore, it was not surprising that there were a greater number of smaller, older, URM buildings in the study than large, modern, multi-storey buildings.

4. TRANSECT ONE YEAR LATER

In the 12 months following the 22 February 2011 earthquake, Christchurch was subjected to over 5000 aftershocks (Nicholls, 2012), including two events on 13 June 2011 and 23 December 2011each having a magnitude greater than 6.0. The epicentre of both later earthquakes was within 10 km of the CBD (GNS, 2011), and both resulted in the evacuation of suburban malls and many public buildings (Stuff.co.nz, 2011a; 2011b). Many buildings that appeared to have sustained only minor structural damage or were considered repairable following the 22 February 2011 earthquake were required to be demolished following the additional aftershocks. Figure 4.1 shows the status, where known, of all the buildings, as well as just the URM buildings, along the original transect route in April 2012. The status of buildings was obtained from the demolition list published by CERA (Canterbury Earthquake Recovery Authority) (2012) and from personal observation. The CERA demolition list is updated about once a month. Buildings which are currently on the demolition list but which have not yet been demolished are included in the chart as demolished. As can be seen in Figure 4.1(a) and Figure 4.1(b) respectively, in April 2012 less than half of all the buildings and 24% of URM buildings from the transect remain or are likely to remain. From previous results this estimate is likely to be indicative of the entire CBD.



a) Status of all buildings

b) Status of URM buildings

Figure 4.1. Fate of buildings along transect current at April 2012

Figure 4.2 shows the status of the transect buildings based on their original assessment level. The percentage of demolished buildings is greatest for buildings originally assessed as red, and smallest for buildings previously assessed as green. The greatest percentage of buildings still standing occurs for buildings initially assessed as green, and only 5% of buildings initially assessed are standing. In the initial estimate of demolitions it was assumed that 50% of buildings assessed as yellow would need to be demolished, whereas this figure now stands at around 70%. In addition nearly 40% of buildings that were assessed at the time of the transect as green are to be demolished. Despite this it appears that the initial assessments are consistent with the current status of buildings.

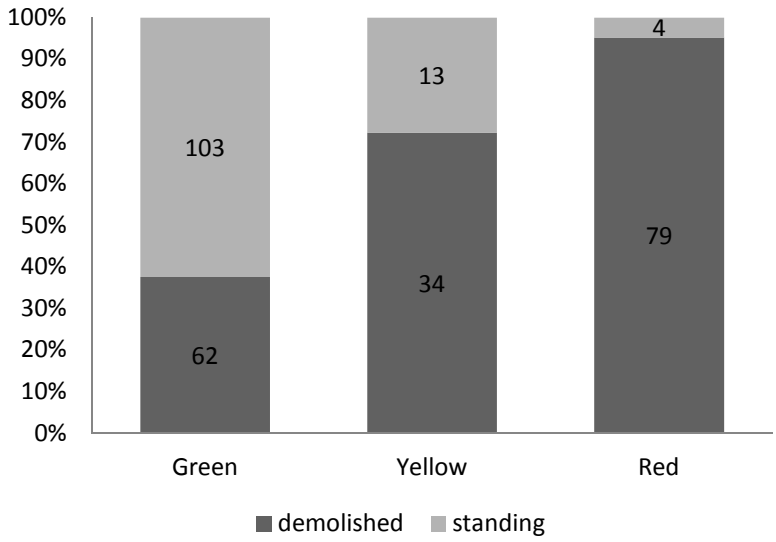
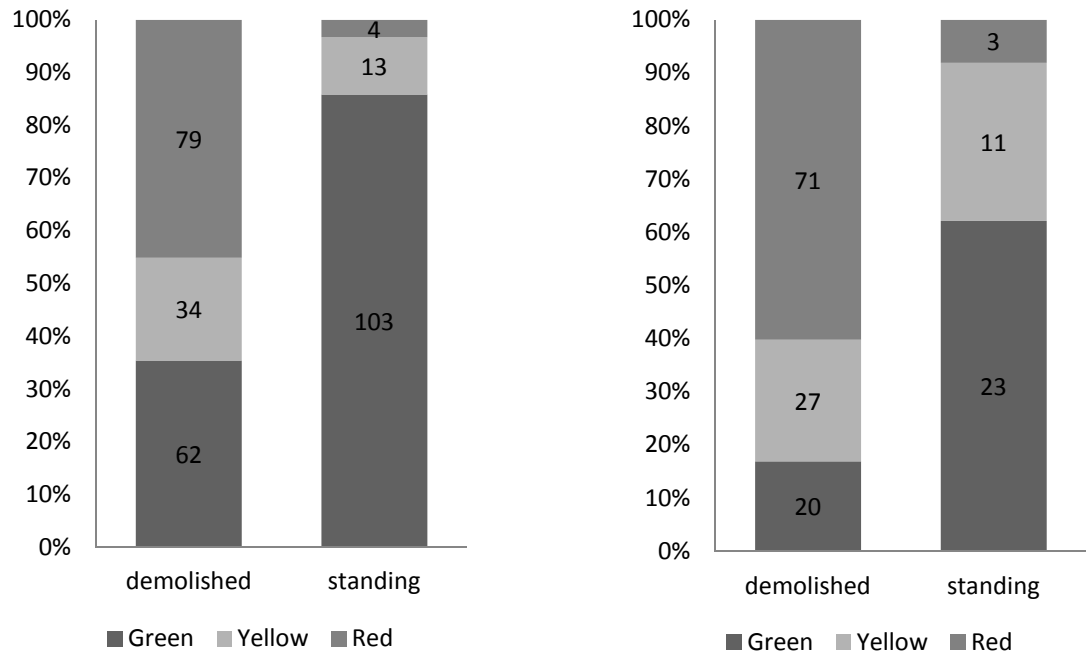


Figure 4.2. Status of buildings compared to the original assessments, current April 2012

Figure 4.3 shows the breakdown of the current demolition status by initial assessments for all the buildings along the transect (Figure 4.3(a)) and for URM buildings along the transect (Figure 4.3(b)). Both graphs show that most of the buildings now demolished, or to be demolished, were originally assessed as red or yellow, and that less than 5% of buildings assessed as red are known to remain standing. The graphs also indicate that URM buildings initially assessed as green are more likely to remain than all buildings assessed as green. In part this may be due to the fact that the authors collectively had greater familiarity with the URM buildings, however it is also possible that damage to URM buildings is more likely to be visible from initial external inspections.



a) Demolition status of all transect buildings

b) Demolition status of transect URM buildings

Figure 4.3. Initial assessments of buildings disaggregated into demolition status, current April 2012.

The current demolition status in April 2012 of buildings initially assessed during the 24 February 2011 transect consistently indicates that buildings initially assessed as red are mostly, if not all, demolished, and that buildings initially assessed as green are the most likely to still be standing. Of the buildings originally assessed as yellow over 70% have since been or are to be demolished. Although the initial estimate of 33% demolition of CBD buildings appears to now be closer to 60% it must be remembered that since the transect the buildings have been subjected to continuing fatigue and damage from thousands of aftershocks, including two further events having a magnitude greater than 6.0.

5. CONCLUSIONS

Christchurch CBD is changing dramatically as a result of the 2010-2012 earthquake sequence. Since the initial estimate of 33% of buildings needing to be demolished following the 22 February 2011 magnitude 6.3 earthquake, it now appears that only approximately 40% of original buildings will remain. The dramatic change in the percentage of demolitions is primarily due to damage caused by additional large aftershocks and fatigue from the many aftershocks, but may also be due to the preference of building owners and insurance companies to demolish and rebuild where feasible structural strengthening may be possible. The threat of additional large aftershocks hangs over the city.

The first overall assessment of building damage in the Christchurch CBD was conducted by undertaking a transect roughly 48 hours after the 22 February 2011 Christchurch earthquake. The transect provided the opportunity to quickly collect valuable data about the state of many different buildings in the CBD by briefly assessing all buildings along a pre-determined route, enabling a quick estimate of overall building damage levels. From the transect it was estimated that approximately one-third of all buildings in the CBD would need to be demolished.

The surveying conducted as part of the transect was limited to external inspections of all building, and often of just the front façade. This procedure can be compared to Level 1 type rapid assessment external inspections, and while not suitable for the assessment of individual buildings it did generate a useful estimate of the overall damage levels in the CBD at a time when most resources were still focused on search and rescue. The results from the transect were found to be similar to those published

by Christchurch City Council on 24 March 2011 following completion of the rapid damage assessment of the whole CBD.

Transects could be used in the future for similar applications in other cities as a quick overall damage assessment tool. Ideally, transect routes could be pre-planned and devised such that they cover a sufficient range and distribution of all building types.

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