Wellington International Airport – Prepared for rapid self-assessment

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ABSTRACT: Many airports are open nearly 24/7. When an earthquake is felt, the operations management team at any busy airport has to decide very quickly whether to order an aircraft on final approach to abort its landing, and whether an evacuation of the terminal is warranted. At any one time, a large proportion of the occupants of the terminal will be members of the public who may be in transit some distance from their homes. Both Christchurch and Wellington airport companies now have a seismometer installed which sends within seconds the peak ground acceleration to their operations centres. In Wellington, the duty manager is provided with criteria for initiating appropriate responses that range from "do nothing" to "close the airport". In addition, the airport's consultant has prepared rapid assessment instructions for both the runway and the terminal building that highlight indicators of potentially serious damage. This paper describes the derivation of these indicators and the recommended responses.

1 INTRODUCTION

The earthquakes that have shaken more densely populated areas in the last few years have highlighted the difficulties for the operations managers of public transport systems. Unlike the occupiers of office buildings, they cannot simply take the most conservative option and evacuate the building until the appropriate structural engineer has been summoned to check out whether the building has suffered significant damage. The operations management team at any busy airport has to decide very quickly whether to order an aircraft on final approach to abort its landing because of potential damage the runway, and whether an evacuation of the terminal is warranted. At any one time, a large proportion of the occupants of the terminal will be members of the public who may be in transit some distance from their homes with no obvious alternative interim accommodation to which they can retreat. Also, the airport becomes a critical part of the emergency management infrastructure following a quake to bring in emergency teams and equipment and export injured survivors.

There are now seismometers installed at both Christchurch and Wellington airports which send within seconds the peak ground acceleration of the last shake to their respective operations centres. Of course, peak ground acceleration on its own is a crude indicator of the shaking's damage potential. Nevertheless, it is easily measured, available very quickly, and has relevance for the stability/resilience of both soil structures (e.g., runways and embankments) and structures.

Opening the Christchurch airport so soon after the 22nd Feb 2011 quake has been directly attributed to a number of lives saved. The system described here for Wellington Airport has been applied at Christchurch Airport during several earthquakes, and proven to be very dependable for sound decision-making.

Beca has provided professional services for the runway maintenance to Wellington Airport for many years, and undertook the structural and building services design for the newest parts of the terminal. They were therefore well placed to assist Wellington International Airport Limited (WIAL) in a refresh of their emergency planning for earthquakes.

2 AIRPORT INFRASTRUCTURE

2.1 Runway

Wellington Airport's runway was opened in 1959 and has had minor extensions at each end. Massive earthworks were required to create it, and the precipitous nature of the ends is well known to regular users. There is a pedestrian tunnel crossing beneath it towards the northern end, and there is a road tunnel abutting the southern extreme. Many of its hardstand areas are relatively new, and (like all such airports) there is a network of buried services (including fuel lines) that service these areas. WIAL has a 24/7 arrangement with a specialist contractor for rapid small repairs to the runway surface.

2.2 Buildings

The main terminal building and adjoining carpark consist of a number of separate structures constructed over a period of more than 30 years. These structures were therefore designed to a number of different seismic standards, and have different dynamic characteristics. The main pedestrian flows through the terminal typically traverse at least two of these structures.

3 DAMAGE INDICATORS

Operationally, the duty manager has to be able to make very quick decisions on the appropriate response when earthquake shaking is experienced. While it is well understood that both the intensity of the shaking and the duration of the strongest part of the shaking are indicators of whether damage might have been experienced, the easiest parameter to measure and report rapidly is maximum ground acceleration. A digital seismometer has been installed close to the terminal, and this reports by text message to the appropriate managers.

The duty manager is therefore provided with the basis for initiating appropriate responses that range from "do nothing" to "close the airport". Because the airport's consultant has looked holistically at the vulnerabilities of both the building structures and the runway/taxiways/hardstands, the approximate levels/ranges of ground acceleration for different levels of damage to be possible have been estimated. With the immediate response now initiated, the next step is for the operations staff to undertake a walk-around to check for previously-identified key indicators of potentially serious damage. The rapid assessment instructions cover both the runway and the terminal building.

For simplicity of operation, three categories (A, B & C) of earthquake shaking response have been defined.

Detail of the response required for each category has been developed for both the terminal buildings and the runway and associated infrastructure, and are set out in Section 5 below.

In the following section, the considerations required to develop the response recommendations are described.

4 EXISTING CONDITIONS

4.1 The Terminal Buildings

There are a number of areas in the various buildings at Wellington International Airport where damage may be expected to occur. These include:

Carpark Buildings / Elevated Road and Ramp Structures:

Separations: there are seismic separations between the northern and southern carpark buildings and also between both the carpark buildings and the elevated road which is itself in three seismically separated sections. Typically, the seismic separations are covered by steel cover plates that are fixed to only one of the structures. Movement between the structures may cause localised damage that could include:

- Out-of-level cover plates creating a trip hazard caused by a plate not re-seating in its original location.

- Very localised cracking / crushing of concrete around the cover plate if relative movement is bigger than detailed.
- Failure of cover plate fixings by overloading caused by debris/wear-and-tear / incorrect installation, etc., causing the cover plate to not move as freely as expected.

Although this damage is typically considered to be of a minor non-structural nature, it would require remedial work primarily from an aesthetic/public usability viewpoint.

Road Joints:

These joints occur in the elevated roadway at the separation between the sloping ramps and the flat section of the elevated road. These are proprietary products designed to resist sustained traffic loading and are typically connected to both structures and consisting of composite rubber/metal gaskets.

These joints will sustain significant vertical loading following an earthquake when traffic resumes. Any minor damage at these joint locations would be considered non-structural, but will affect usability in terms of occupant comfort.

Carpark Ramp Movement Joints:

The circulation ramps which allow movement between levels are detailed to allow differential movement. This is achieved by the use of movement joints (with cover plates) and by supporting parts of the upper ramp on corbels designed to carry vertical loads only.

Stairs:

Top and bottom connection points of stairs where stair stringers may be bolted to the main structure are vulnerable to overloading of the fixings.

Building Services/Secondary Elements:

Damage may occur in services reticulation conduits where there is insufficient movement allowance in between structures. Fixings could fail so that sections of conduit hanging unsupported. Supports to hanging secondary elements, such as lights, directional/advertising signs, etc., could experience fixing failure, or cracking of the supporting structure immediately adjacent. Whether such damage is a structural issue depends on the location and size of the element.

Main Terminal Building:

The main terminal building extends north / south from the area adjacent to international departures at the northern end of the terminal to the narrowing down of the building at its southern end and is a single building. It is seismically separated from the elevated roadway at each of the four entry bridges at the departures level, and seismically separated from both the southwest pier link and the international terminal/Jetstar domestic gates.

The seismic separation between the elevated road and the entry bridges is bridged by a proprietary movement joint. Residual damage associated with building movement at this joint could be in the form of the joint being out of level or the central part of the joint popping out of its guide frames. Within the terminal, movement joints are either in view or hidden by carpet. Although this damage is typically considered to be of a minor, non-structural nature, it looks frightening to the public, and would require remedial work for public usability.

Non-structural damage could be expected at movement joints detailed in the wall framing/lining, and also in the ceiling systems.

The main concrete stairs have been designed as fixed at their upper level and free to slide at their lower level. While this allows for differential movement between floors of the building, there may be damage to the floor and wall finishes. This could be alarming to the public.

Parts of the airside baggage system are suspended from the structure of the main building. Missing bolts, bent bolts or localised new cracking of the concrete superstructure around these fixing points could be indications that fixings may have become overloaded.

Secondary hanging elements such as directional signage may be insecure in strong shaking.

Changes to internal space usage and reconfigurations over time (by tenant and/or landlord) may inadvertently lock internal walls to primary building elements such that they are more susceptible to damage under smaller levels of shaking.

The northern parts of the terminal are characterised by a number of smaller buildings with a subsequent increased frequency of seismic separations between each of these buildings.

4.2 The Runway Infrastructure

Categorisation of Ground Conditions

Ground conditions beneath the runway taxiway and hardstand areas can be categorised into three groups:

1. Southern end – relatively thin layer of beach deposits overlying bedrock and overlain by engineered rock fill.

2. Central - dunes and interspersed peat lenses overlying bedrock and overlain by engineered rock fill.

3. Northern Section - substantial depth of engineered fill overlying a thin layer of beach/harbour floor sediments overlying substantial depths (30 m+) of relatively dense marine silty sand deposits.

The engineered fill on which the runway is constructed was sourced from local hills, was compacted to good engineering practice, and is unlikely to consolidate further - even during high levels of shaking. The extent to which natural weak soil or loose sand was undercut before the placement of the rock fill is less-well established. Boreholes in the western apron indicate sands at relatively shallow depths (500-1300 mm), while the majority of historic runway/taxiway investigations ended in rock fill at depths around 1300-1500mm. Only two of 20 holes on the runways and taxiways terminated in sand.

It is expected that there will be localised areas of backfill associated with in-ground structures and services, particularly in the hardstand areas.

Potential Forms of Ground Disruption

1. Liquefaction of laterally extensive deep deposits at the northern end of the runway. This could result in a deep-seated slope failure of the northern end of the runway embankment - probably without any surface manifestation of liquefaction given the thickness of engineered rock fill. The ground would return to a normal state of stability after the cessation of the strong shaking. The physical manifestation would be a significant head scarp feature (a wide crack with a major step in the ground surface) running across the top of the runway embankment possibly of the order of 20 m back from the crest and probably with an arcuate horizontal profile. There would also be ground disruption on Cobham Drive. Such a failure would be obvious.

2. Liquefaction of localized dune sand deposits beneath central section of the runway. While some liquefaction might occur it is likely to be only at relatively high ground acceleration. The consequences and manifestation of liquefaction are likely to be subtle because of the limited lateral extent and thickness of the dune deposits and the competent covering of engineered rock fill. If liquefaction occurs there will be associated ground settlement but the curvature of the settlement bowl is expected to be gentle. The occurrence of such liquefaction is likely to be evidenced by loss of shape (and subsequent water-ponding) on paved areas and diffused (as opposed to concentrated) cracking in the pavement.

3. Liquefaction of beach sand deposits beneath southern section of the runway. These materials were investigated and considered in the design of the Moa Point Road underpass. Liquefaction of the beach sands could result in lateral spreading of the embankment towards the sea. Movement of the runway towards the south will be prevented by the underpass, but lateral movement of the western side of the runway towards Lyall Bay cannot be discounted in a major event. Movement of the fill supporting the wave trap beyond the Moa Point Road underpass could also occur. Lateral spreading will be evidenced by a series of long parallel rents in the runway embankment surface extending back from

the embankment crest. There is also likely to be disruption to the pavement of the section of Moa Point Road running parallel to the runway.

4. Consolidation of backfill. The possibility of consolidation of areas of poorly-compacted backfill beneath pavement areas cannot be discounted, but is likely to require high levels of ground acceleration. Such consolidation could be quite localised, and thus result in localised significant steps within paved areas.

5 INSPECTION RECOMMENDATIONS

5.1 Trigger Levels

Three levels of response (Categories) have been defined. The level of assessment for a Category is similar for each of the three classes of asset into which the airport has been divided.

The terminal buildings have been divided, for simplicity, into two classes. These classes reflect the age and type of construction of the buildings that make up the terminal complex.

The majority of buildings (Class 1) are of relatively recent construction (1980s to current), and are considered as being at, or close to, current design standards.

The Class 2 buildings were part of the original international terminal complex (circa 1974-1976), and have been assessed as being in the order of 50 % new building strength. As such, they will be subjected to both structural and non-structural damage at lower levels ground shaking intensity.

The ranges for peak ground acceleration to trigger each inspection Category are set out in the table below.

Table 1. Trigger levels (peak ground acceleration, *g*) by Category and infra/structure

Category	Runway Infrastructure	Terminal Buildings Class 1	Terminal Buildings Class 2
A	< 0.08 g	< 0.11 g	< 0.05 g
B	0.08– 0.3 g	0.11– 0.3 g	0.05– 0.15 g
C	> 0.3 g	> 0.3 g	> 0.15 g

5.2 Buildings

The airport operations management have been provide with both building layout sketches on which the seismic gaps have been highlighted and showing the locations of indicators of potentially serious damage. This should enable those undertaking rapid assessments to take an informed approach to otherwise perturbing evidence of movement such as disturbed carpet in main access ways.

Common vulnerabilities such as broken stock or overturned display cases in the duty-free shopping area (glass potentially across a main egress route) have also been highlighted.

The recommended responses by Category for the two classes of terminal buildings are set out below:

Trigger	Action
Cat C Class 1 (PGA < 0.11 g) Class 2 (PGA < 0.05 g)	Quick assessment of situation by operational staff, then carry on business as usual.
Cat B Class 1 (PGA 0.11 to 0.30 g)	A more comprehensive assessment by operations staff is undertaken with the potential to call for terminal inspection if required. External experts only called in if needed. Possible follow up structural

Trigger	Action
Class 2 (PGA 0.05 to 0.15 g)	inspection of buildings when convenient.
Cat A Class 1 (PGA > 0.30 g) Class 2 (PGA > 0.15 g)	 Full emergency called, all of terminal evacuated until inspected and cleared by structural engineer. Full emergency called, specific buildings evacuated until inspected and cleared by structural engineer.

5.3 **Runway and Main Taxi Inspection Procedures**

The following specific inspection procedures have been recommended. It can be seen that these are simple and pragmatic.

Trigger	Action
Cat C PGA < 0.08 g	Quick assessment of situation by operational staff taking into consideration factors like duration of shaking and observed damage, if any (i.e., toppling of furniture, etc.). If nothing significant observed, no action required. As a guide it is suggested that following an event PGA > 0.06 g that, as a minimum, a slow run (30 km/h) up the runway centreline be undertaken prior to the next movement on the runway.
Cat B PGA 0.08 to 0.30 g	Close runway and main taxiway and undertake the following: 1. A slow run (30 km/h) up the centreline. If all clear then proceed to step 2. If defect found keep runway closed and advise the Airport Engineer/Consultant from the attached contact list. 2. Undertake high speed (90-100 km/h) run along both main gear wheel paths (4.0 m from centreline) along manoeuvring areas (runway and main taxiway as a minimum). If no defects and no significant sudden change in ride quality (i.e., even smoothness, no sudden jolts) over the length of the runway/main taxiway, then open runway. If change in ride quality, AOC to undertake an on foot inspection to identify any defects (i.e., pavement cracking, distortion of runway grooves, cracks in the grassed areas or other obvious signs of damage). Advise Airport Engineer of observations and await instructions.
Cat A PGA > 0.30 g	Close runway and main taxiway contact Airport Engineer/Consultant from the attached contact list who will coordinate specialist inspection as appropriate. While waiting for specialist inspection, AOC to undertake the following: 1. A slow run (30 km/h) up the centreline. If all clear then proceed to Step 2. If defect found, keep runway closed and advise the Airport Engineer/Consultant from a contact list. 2. Undertake high speed (90-100 km/h) run along both main

Trigger	Action
	gear wheel paths (4.0 m from centreline) along manoeuvring areas (runway and main taxiway as a minimum). ▪ If no defects and no significant sudden change in ride quality (i.e., even smoothness, no sudden jolts) over the length of the runway/main taxiway, then open runway. ▪ If change in ride quality, AOC to undertake an on-foot inspection to identify any defects (e.g., pavement cracking, distortion of runway grooves, cracks in the grassed areas) or other obvious signs of damage. Advise Airport Engineer of observations and await instructions. If damage found, then proceed to Step 3. 3. Run heavy fire tender down runway and taxiway centreline - observed by walker to check for pavement deflection. 4. Drive around the perimeter and make note of any areas of slumping or other damage. In particular, check the two ends and the south-western embankment. 5. View subway and storm-water drains crossing the runway from one end, and check it is day-lighting at the other, and for signs of damage. 6. Runway to remain closed until specialist inspection has been completed and/or clearance given by Airport Engineer or authorised WIAL senior manager.

Photos of the current state of these movement joints, included as part of an inspection work instruction, would also assist in identifying recent damage caused by the earthquake, differentiating it from pre-existing cracks etc in the concrete.

5.4 Reference Data

It has been accepted that a dossier of photos of the current state of movement joints, included as part of an inspection work instruction, would also assist in identifying recent damage caused by the earthquake, and thus allowing the differentiation of it from pre-existing cracks, etc., in the concrete.

5.5 Practical Matters

It has been identified that it would be prudent to make sure that manhole covers to drains, which can normally be lifted without too much effort, are not rusted shut. A mirror mounted on a stick and a flash light would be all that is required for such inspections. These simple tools, along with a good set of drawings, should be stored in one place in case of such an emergency.

6 DISCUSSION

It is possible that, with time and more experience, it may be possible to harmonise the trigger levels between Class 1 buildings and those for the runway/airside pavements.

The thresholds set for the Class 2 buildings follow a similar logic to those derived for the Class 1 buildings. It may be possible to increase the PGA threshold levels for these buildings to bring them closer to the Class 1 buildings by requiring a more prescriptive/detailed (and perhaps location-specific) inspection regime to be undertaken.

7 SUMMARY AND CONCLUSIONS

The need for a critical facility such as an airport to be prepared to be able to respond immediately 24/7 to felt earthquake shaking has been increasingly well accepted in recent years. It is impractical for specialist assessors to be available in the time-frame necessary in an operational facility. A relatively small investment in some instrumentation and the identification of likely vulnerabilities can sufficiently inform duty staff to make well-informed decisions immediately after the earthquake. With time, a dossier can be assembled which can be referenced to see whether the latest earthquake has materially changed an existing situation – which is one of the first tasks of an experienced assessor.

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