

Sentinel – A Cost-Effective Approach to Structural Seismic Monitoring

P. Drummond

Canterbury Seismic, Christchurch, New Zealand.

ABSTRACT

Seismic monitoring of buildings provides essential data for assessing structural response during earthquakes, informing post-event safety decisions, and guiding long-term resilience strategies. Historically, such systems have relied on networks of high-cost accelerographs, limiting their application to a small number of critical or high-value structures.

This paper reviews established approaches to building seismic monitoring and key technical considerations relevant to engineering use. Within this context, Sentinel is presented as a cost-effective, scalable platform for structural seismic monitoring. By combining precision MEMS accelerometers, edge processing, and secure cloud-based data management, Sentinel delivers reliable, engineering-grade measurements at a fraction of the cost of traditional systems.

Field deployments demonstrate that Sentinel provides robust performance for post-earthquake assessment while lowering barriers to widespread adoption. The system enables rapid, building-specific evaluation of earthquake shaking using parameters already familiar to engineers, supporting proportionate response, clear communication, and improved resilience management across building portfolios.

1 INTRODUCTION

Seismic monitoring provides direct evidence of how buildings are influenced by earthquake shaking and plays an important role in post-event safety decisions and resilience planning. In earthquake-prone countries such as New Zealand, building-specific measurements of shaking intensity are particularly valuable to practising engineers responsible for post-earthquake assessment.

Accelerographs have been used to measure building response since the 1930s, and strong-motion data have underpinned much of modern earthquake engineering knowledge (Hudson, 1970; Trifunac & Brady, 1975). In several jurisdictions, including Japan, California, and Taiwan, building-mounted accelerographs are formally integrated into post-earthquake response frameworks (Okada et al., 2004; California Department of Conservation (CA DOC); Lee et al., 2001).

New Zealand has made a significant contribution through long-term national investment in strong-motion monitoring via the GeoNet programme, within the Built Environment Instrumentation Programme (BeIP), operated by Earth Sciences New Zealand (formerly GNS Science). These installations have produced world-leading datasets that inform research, policy, and engineering practice. However, the scale and cost of those deployments mean they are not readily replicated across the wider building stock, leaving most buildings without instruments.

At the same time, New Zealand engineering practice increasingly relies on performance-based assessment. Building capacity is commonly expressed in terms of New Building Standard (NBS), where spectral acceleration capacity can be expressed using the NZS 1170.5 design standard. This creates a clear opportunity to align measured acceleration with building capacity parameters already used in design and assessment.

This tool plus recent advances in sensor technology and data management enable a reconsideration of how seismic monitoring is implemented in New Zealand. This paper reviews established monitoring approaches, outlines key technical considerations, and introduces Sentinel as a practical system designed to support everyday engineering decision-making while keeping engineers central to interpretation and response.

2 BUILDING SEISMIC MONITORING APPROACHES

Building seismic monitoring has traditionally served two objectives: detailed research into structural behaviour and practical post-earthquake response. Early strong-motion programmes in the United States and Japan demonstrated that recorded acceleration data could reveal real structural behaviour and informed the development of modern seismic design methods (Hudson, 1970; Okada et al., 2004).

In some jurisdictions, accelerographs installed in buildings are formally linked to post-earthquake assessment. Japan integrates strong-motion data into rapid safety evaluation frameworks, while California mandates accelerographs in certain buildings through the California Strong Motion Instrumentation Program (CA DOC]). Taiwan similarly incorporates building instrumentation into national seismic monitoring efforts (Lee et al., 2001).

Monitoring systems also differ in their measurement objectives. Ambient vibration monitoring targets very low-amplitude motion and requires sensors with extremely low noise floors. Earthquake response monitoring focuses on moderate to strong shaking relevant to damage and safety assessment. The USGS classifies strong-motion accelerographs accordingly, with Class C instruments designed to reliably measure earthquake-induced motion above the noise floor (USGS, 2019).

Another key distinction is between distributed sensor arrays and single-point monitoring. Distributed arrays provide detailed insight into structural response but require complex design and processing. Single-point monitoring focuses on overall seismic input and provides a robust, readily interpretable measure of shaking intensity. For most buildings, particularly for post-earthquake decision-making, single-point monitoring, with a single sensor, offers a practical and scalable solution.

Although displacement and inter-storey drift are fundamental indicators of damage, deriving these parameters from accelerograph data requires double integration and careful signal processing, which is sensitive to noise and baseline drift (Boore et al., 2002). In routine New Zealand practice, engineers more commonly seek to establish whether shaking demand has approached or exceeded assessed capacity. Sentinel adopts this pragmatic approach by focusing on seismic input parameters from a single sensor, that can be directly compared with well understood NZS 1170.5 design and assessment thresholds.

3 KEY TECHNICAL CONSIDERATIONS

For seismic monitoring to be useful in practice, data must be reliable under real earthquake conditions and simple to interpret. Key considerations include sensor performance, timing accuracy, data retention during power or communication outages, and ease of deployment at scale.

Systems intended for earthquake response must reliably capture shaking above the instrument noise floor, retain data during outages, and present results in a form that aligns with engineering workflows. These requirements inform the design choices adopted in Sentinel.

4 SENTINEL SYSTEM DESIGN

Sentinel has been developed to make seismic monitoring practical and scalable while supporting, rather than replacing, engineering judgement. The system complements research-grade instrumentation such as GeoNet BeIP installations by addressing routine monitoring of the broader building stock with less equipment.

Sentinel uses precision MEMS accelerometers selected to meet international norms such as USGS Class C performance requirements (USGS, 2019). These sensors are optimised to measure levels of shaking that are perceptible to occupants and potentially damaging to structures, which are the conditions most relevant to post-earthquake assessment.

A central design choice is the emphasis on spectral acceleration as the primary engineering output. In New Zealand, response spectra underpin both seismic design and assessment under NZS 1170.5, and building capacity is commonly expressed in terms of NBS (MBIE, 2017). By presenting measured shaking in spectral terms, Sentinel enables direct comparison between recorded demand and assessed capacity without requiring engineers to process raw acceleration records or undertake displacement reconstruction.

Sentinel is typically deployed as a single sensor per building. While this configuration does not provide direct measurement of inter-storey drift, it provides sufficient information to guide proportionate post-earthquake response. Local edge processing ensures reliable event capture, while secure cloud-based data management supports portfolio-level review. Figure 1 right shows a hypothetical office building status screen with current status expressed as white, recommendation status since last event is “Do not evacuate”, and the cumulative horizontal measured shaking expressed as purple and green lines on the NZS1170.5 chart. Amber and Red lines denote the Services Limit State (SLS) and Ultimate Limit State (ULS) respectively at which alert levels of shaking lie. Vertical shaking is displayed on another further down (not shown). These are taken either directly from and engineers design, assessment, or the NZ Building Code for the IL classification of the building, and scale based on the NBS rating.

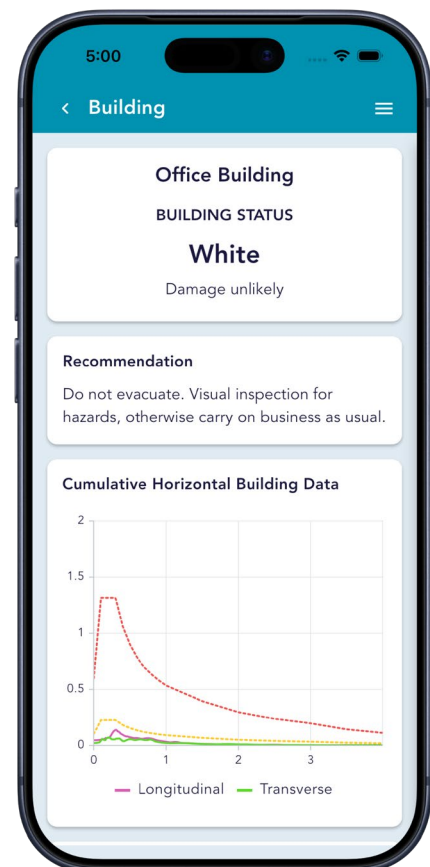


Figure 1: Building status

5 DEPLOYMENT AND USE

Sentinel is designed for deployment across individual buildings or entire portfolios. Low cost, compact form factor, and minimal installation requirements enable monitoring at a scale that has historically been impractical.

Following an earthquake, Sentinel provides building-specific measures of shaking intensity. Engineers can promptly compare these measurements with known or assessed capacity and determine whether site inspection or further analysis is warranted. This supports efficient prioritisation of engineering resources.

Presenting results relative to familiar thresholds also simplifies communication with non-technical stakeholders such as building owners, facility managers, insurers, and occupants. Expressing shaking as a proportion of assessed capacity provides an intuitive frame of reference while keeping engineers central to interpretation. Figure 2 shows status screens of multiple building responses, including an all of portfolio view where amber and red buildings are brought top-of-view for immediate prioritisation of response.

Sentinel also enables never-before possible advance planning. By defining response actions based on measured shaking, organisations can establish clear earthquake response plans. Ensuring a consistent approach to meet obligations under the Health and Safety at Work Act 2015 (HSWA). The system is deliberately aligned with New Zealand's post-earthquake building assessment framework, presenting shaking below the SLS as white-level, shaking above SLS as amber-level, and shaking exceeding the ULS as red-level, all shown in Figure 1 and Figure 2. This colour coding supports MBIE placarding workflows without replacing professional judgement (MBIE, 2017; NZSEE, 2017).

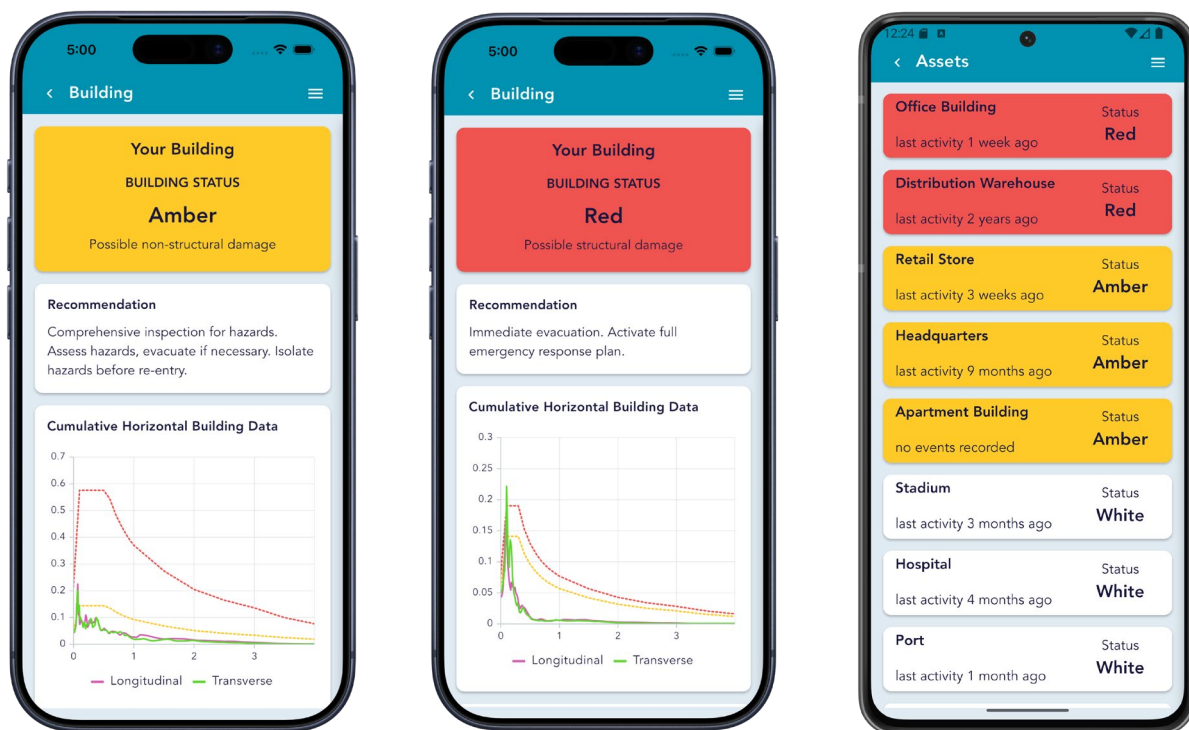


Figure 2: From left to right - building status amber, red, and all assets view

6 PERFORMANCE AND CASE STUDY

Sentinel performance has been evaluated through field deployments and comparison with established strong-motion recording practices. Validation confirms that the system reliably records earthquake-induced shaking and produces stable spectral acceleration measures suitable for engineering interpretation.

A Cook Strait earthquake of M5.7 shook Wellington on 6 October 2024 (Earth Sciences New Zealand / GeoNet) illustrated Sentinel's application at scale. During this event, 221 buildings equipped with Sentinel recorded building-specific seismic input. Based on measured spectral acceleration relative to assessed capacity, 161 buildings experienced white-level shaking (below SLS), 51 experienced amber-level shaking (above SLS), and 9 experienced red-level shaking (above ULS).

These classifications triggered pre-planned response actions, including engineer callouts under retainer arrangements. Buildings with low measured shaking resumed operations with confidence, while engineering resources were directed toward buildings where measured demand justified further investigation. All buildings experienced a streamlined, proportionate earthquake response informed by measured performance. Occupants experienced a pre-planned, well martial, data-drive earthquake response to instilled confidence.

7 DISCUSSION

Seismic monitoring can be affordably and practically aligned directly with established New Zealand engineering practice. By focusing on spectral acceleration, Sentinel integrates seamlessly with NBS-based assessment frameworks, enabling measured data to be the primary driver, ensuring follow on actions are built around a measured performance data point.

Single-point, single-sensor monitoring, enables affordable data-driven response to earthquake events. While dense instrumentation arrays provide valuable research insights, they are not required for many post-event decisions across the majority of New Zealand's building stock. The option of Sentinel complements national programmes such as GeoNet BeIP and other similar single-building multi-sensor dense arrays by enabling broader coverage across the building stock and supporting routine operational decision-making that can be utilised by all stakeholders.

The ability to predefine response actions based on measured performance supports proactive seismic risk management and more consistent, defensible post-event decisions across engineering, health and safety, and operational domains.

8 CONCLUSIONS

Advances in sensor technology and data management now allow seismic monitoring to move beyond specialist applications. Sentinel demonstrates how affordable, networked accelerograph systems can provide reliable, engineering-grade measurements that support everyday post-earthquake decision-making.

By aligning measured shaking with existing design and assessment frameworks, Sentinel enables proportionate, engineer-led response without requiring complex signal processing or extensive instrumentation. Field experience, including application during the 6 October 2024 Wellington earthquake, shows that the system supports streamlined, data-informed response at scale.

Overall, this work highlights the potential for cost-effective seismic monitoring to enhance resilience management across a much larger portion of the building stock, while keeping engineers central to interpretation, assessment, and advice.

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