Framed buildings with precast concrete floor systems

Interim Note – March 2017

Purpose and scope

This interim note provides information for owners and building professionals responsible for assessing and designing multi-storey ductile or flexible concrete moment resisting frame buildings with precast concrete floor systems that may be vulnerable to loss of floor support during an earthquake.

Who is this note aimed at?

The Ministry of Business, Innovation and Employment (MBIE), the Institution of Professional Engineers New Zealand (IPENZ) and three IPENZ technical societies (New Zealand Society for Earthquake Engineering, New Zealand Structural Engineering Society and New Zealand Concrete Society) consider it important that that the vulnerability of these types of building are fully understood by the following groups:

- building owners
- structural engineers
- Territorial Authorities and Building Consent Authorities

Issues of concern

- Loss of support of floors leading to partial failure (or full collapse of the floor) as a result of an earthquake
- Integrity of in-situ toppings within precast concrete floor systems
- Performance of diaphragms incorporating precast concrete systems
- Stiffness incompatibility between ductile frames and precast floor systems

Wellington building performance in the Kaikōura earthquake

Two floors of Statistics House, Wellington, suffered partial collapse as a result of the 14 November 2016 Kaikōura earthquake. An expert panel convened to investigate the collapse concluded that the partial collapses were “caused by a combination of:

- a highly flexible ductile frame with two bays of frame per precast floor span, which effectively doubled the impact of beam elongation due to plastic hinging; and
- [loss of seating for] the precast double tee flooring units [due to] spalling during the earthquake; and
- amplification of ground shaking, primarily due to basin-edge effects in the Thorndon basin area; and
- the duration of the earthquake.”

The expert panel recommended that:

- buildings with design features similar to Statistics House should be inspected as soon as possible to determine whether the Kaikōura earthquake has affected the seating for their precast floors
- existing buildings with precast floor systems that could be affected by beam elongation should be assessed to ascertain whether a similar failure could occur during a large earthquake.

Investigation into the Performance of Statistics House in the 14 November 2016 Kaikōura Earthquake on the MBIE website has the full report.

Inspections of potentially earthquake-damaged buildings

Targeted Damage Evaluation Guidelines have been specifically written to assist engineers to identify damage as a result of the Kaikōura earthquake. These guidelines were adopted for the inspections required by Wellington City Council (WCC) and should be used for inspecting buildings in central New Zealand that may have been affected by the Kaikōura earthquake.

Targeted Damage Evaluation Guidelines on the SESOC website has further information on inspecting these types of buildings.

Assessment of existing buildings

More detailed assessment procedures and guidance are being developed by MBIE, IPENZ and the technical societies as recommended by the Statistics House expert panel. In the interim, effort should be made to identify buildings where, based on findings from the Statistics House review, the performance of precast floor systems could be vulnerable during a large earthquake. If a capacity assessment is required, the assessment should be carried out by a Chartered Professional Engineer with the qualifications and experience required to assess its performance in accordance with *The Seismic Assessment of Existing Buildings* guidelines available on the EQ-Assess website.

Before industry guidance is released, the following actions need to be considered (as a minimum):

- ascertain whether or not a building has a precast concrete floor system and has its primary lateral resistance provided by a moment resisting frame
- investigate whether the precast floor system spans in the same direction as any frame that could potentially elongate during an earthquake or cause loss of seating
  (Buildings with shear walls providing the primary structural bracing system in this direction are less likely to be affected because frames are less likely to elongate.)

For buildings with such configurations:

- assess the impact that beam elongation and loss of seating would have on the precast floor system, particularly when there are multi-bay frames
- ascertain whether or not the design of the floor assemblies provides adequate allowance for movement (refer to MBIE Practice Advisory 5: Allow for movement – precast hollow core floor assemblies)
- review the support details of the precast flooring units
- assess the requirements for composite connection between the in-situ topping and the precast flooring units in accordance with the Concrete Structures Standard
- check the floor diaphragms are capable of transferring earthquake-generated loads to the moment resisting frames providing the lateral resistance.

It is noted that beam elongation includes both recoverable geometric elongation and irrecoverable beam lengthening as the longitudinal reinforcement progressively yields during loading cycles.

It is noted that previous assessments of ductile buildings with precast concrete floor systems may not have adequately accounted for the response of the floor system, and may therefore have overestimated the performance of the building.

Remedial actions for existing buildings

Guidance on standard methods of improvement are being developed by MBIE, IPENZ and the technical societies as recommended by the Statistics House expert panel. In the interim, building owners and engineers are reminded that anyone undertaking work to repair damage from the Kaikōura earthquake needs to consider the issues highlighted in this note.

Engineers are reminded to note the difference between undertaking remedial work to reinstate or enhance the gravity support for the floor (eg 'catch frames') and more comprehensive strengthening of the floor diaphragm system.

Design requirements for new buildings

As recommended by the expert panel, there is a plan to consider what, if any, controls should be placed on the design of flexible buildings within both the Concrete Structures Standard NZS 3101:2006 and the Earthquake Actions Standard (NZS1170.5). In the interim, designers are encouraged to consider the issues highlighted by the Statistics House report when making design decisions about flexibility of the lateral load resisting system and the compatibility with the floor system.

Next steps

For building owners

- ✓ **Do** be aware that you are responsible for ensuring your buildings will not injure people using them.
- ✓ **Do** identify multi-storey buildings that have precast concrete flooring systems.
- ✓ **Do** seek professional advice by engaging either the engineer(s) who designed the building or a Chartered Professional Engineer with the qualifications and experience required to advise you about your multi-storey, flexible building with precast floors.
- ✓ **Do** be aware that further detailed guidance on the assessment of building capacity and standard methods of improvement is currently under development

For engineers and other designers

- ✓ **Do** undertake inspections of damaged buildings in accordance with the guidelines developed for the Wellington City Council
- ✓ **Do** advise clients of any existing building designs you are aware of that may have the vulnerabilities identified in the Statistics House report
- ✓ **Do** keep up to date with the development of technical guidance for assessment and remedial actions. Once these are released, do assess capacity and design any remediation using that guidance.

In the interim:

- ✓ **Do** develop repair designs for earthquake damage as necessary, noting that this may need to be revisited once the guidance is released.

For Territorial Authorities and Building Consent Authorities

- ✓ **Do** keep up to date with the development of technical guidance for assessment and remedial actions.
- ✓ **Do** bring this note to the attention of owners of these types of buildings.
- ✓ **Do** be aware of the concerns and implications described in this note.
- ✓ **Do** check that design documentation for a building clearly describes how the building will meet its design intentions.

References and Further Information

SESOC Interim Design Guidance – Design of conventional structural systems following the Canterbury Earthquakes (available http://www.sesoc.org.nz/Design-Guides/SESOC-Interim-Design-Guidance-0.9.pdf)

SESOC, NZSEE & NZCS (2009) Seismic Performance of Hollow Core Floor Systems: Guidelines for Design Assessment and Retrofit (available https://www.nzsee.org.nz/db/PUBS/HollowCoreFloorSystems.pdf)

Section C5: Concrete Buildings in The Seismic Assessment of Existing Buildings: Technical Guidelines for Engineering Assessments (2016) (available www.EQ-Assess.org.nz)

R Fenwick, D Bull & D Gardiner (2010) – Assessment of hollow-core floors for Seismic performance, Department of Civil and Natural Resources Engineering Research Report 2010-02, University of Canterbury (available https://ir.canterbury.ac.nz/handle/10092/4211)

MBIE (2017) Investigation into the performance of Statistics House in the 14 November 2016 Kaikōura Earthquake (available www.mbie.govt.nz/publications-research/publications/building-and-construction/investigation-into-the-performance-of-statistics-house.pdf)

NZSEE, SESOC (2017) Engineering guidelines for targeted damage evaluation following the November 2016 Kaikōura earthquakes, Wellington City Council (available http://www.sesoc.org.nz/public_resources/)