

8 August 2025

CEL Reference 19003.05

Natalie Balfour
Natural Hazards Commission Toka Tū Ake
PO Box 790 Wellington

Subject: Final Report – Utility of ATC 145/FEMA P2335 guidelines for New Zealand buildings based on practitioner review

Dear Natalie,

I write in relation to our now completed project, *ATC 145 Guide for repair of earthquake damaged buildings to achieve future resilience* (Contract 3443).

This letter represents our Final Report for the project. The final ATC 145 report was published during May 2025 as *FEMA P-2335: Guidelines for Post-Earthquake Repair and Retrofit of Buildings Based on Assessment of Performance-Critical Damage* (the **guidelines**). The guidelines are now freely and publicly available, and can be downloaded from <https://www.atcouncil.org/docman/fema/340-fema-p-2335-508>.

We have added sections covering acknowledgements, keywords, outputs & dissemination, and publications and engagement. The final report also contains content previously provided that focussed on the utility of the 90% draft ATC 145/FEMA P2335 guidelines for New Zealand buildings.

1. Acknowledgements

My participation in the ATC 145 project was made possible entirely by the funding provided by Natural Hazards Commission Toka Tū Ake. This funding is gratefully appreciated.

Acknowledgement of Natural Hazards Commission Toka Tū Ake's support for my involvement is noted on the inside cover page of the final FEMA report, and also in ATC's preface to the document.

2. Keywords

Earthquake, structural engineering, damage, repair, concrete, post-earthquake inspection

3. Publications and engagement

Two conference papers summarising aspects of the work undertaken for the ATC 145 project have been presented to New Zealand engineering conferences. These are:

- Brooke, N. J., Tremayne, B., Elwood, K. J., and Pujol, S. (2021). “ATC-145: Framework for Assessing the Extent of Repair Required for Earthquake-Damaged Concrete Moment Frames.” Proc. SESOC Conference, Hamilton, New Zealand.
- Elwood, K. J., Sarrafzadeh, M., Pujol, S., Liel, A. B., Murray, P., Shah, P., and Brooke, N. J. (2021). “Impact of Prior Shaking on Earthquake Response and Repair Requirements for Structures – Studies from ATC-145.” Proc. NZSEE Conference, Christchurch, New Zealand, 12p.

In addition to these, the publication of the final report has been promoted to New Zealand engineers through the June edition of SESOC’s newsletter.

Unfortunately, FEMA themselves have not promoted the guidelines’ release to our knowledge. We understand this is due to political considerations in the United States.

4. Review of 90% draft guidelines to ascertain their utility in New Zealand

4.1. *Background on review*

The content of this report represents a summary of the findings of two senior New Zealand practitioners who were engaged to provide a review of the 90% draft guidelines, supplemented with observations made by Compusoft during our involvement in developing the guidelines.

The engineers engaged to provide reviews were:

1. Dion Marriott, Technical Director at Beca, and
2. Stuart Oliver, Technical Development Lead at Holmes

Both engineers have significant experience in the seismic assessment and retrofit of buildings, and of post-earthquake assessment. The reports provided by these engineers are appended to this letter. I note that the engineers have asked that these reviews be treated as internal documents by Natural Hazards Commission Toka Tū Ake and that they not be released publicly due to the limited involvement of the reviewers.

4.2. *Observations regarding the utility of the FEMA P2335 guidelines for New Zealand buildings*

Reviewers were asked to provide feedback on the utility of the guidelines with three areas of focus, namely:

1. Technical gaps/issues that might impact use of the guidelines in a New Zealand context.
2. How the guidelines would fit within the New Zealand regulatory framework that applies for post-earthquake evaluation and repair
3. Useability of the document - particularly from perspective of how familiar the content would be to New Zealand engineers

Feedback received often spanned more than one of the categories above, and hence the summary provided below is not divided based on these categories. Instead the summary is divided into convenient subject headings.

4.2.1. Coverage only of reinforced concrete buildings

Feedback noted that the guidelines currently only cover reinforced concrete buildings in detail (though the evaluation framework is intended to be applicable to other forms of construction) and recommended that detailed coverage of other construction types would be desirable for use in New Zealand.

4.2.2. Reference to U.S. technical documents

Feedback noted that the guidelines rely extensively on U.S. technical documents, notably including the U.S. Standards for concrete structures [1] and assessment of existing buildings [2]. Reviewers noted the unfamiliarity of these documents to many New Zealand practitioners, and also the cost of obtaining them.

4.2.3. Different Building Code frameworks

Figure 1 shows an overview of the evaluation procedure described in the guidelines, with “components in DC2” being building elements that have reduced capacity as a result of an earthquake. There are marked differences between the U.S. Building Code framework on which the guidelines are based and the New Zealand Building Code framework. These differences are identifiable even at the high-level represented by Figure 1:

- The U.S. does not have legislative requirements comparable to New Zealand’s earthquake prone building (EPB) regime. The EPB regime means that even a building with no significant structural damage may be required to be retrofitted if a Building Consent is required to complete (non-structural) repairs.
- Additionally, New Zealand does not have an equivalent of “benchmark codes” that are used in the U.S. to deem modern buildings to have sufficient capacity without further calculation.

Both of these points of difference would result in more engineering effort being required to apply the guidelines under current legislative settings in New Zealand.

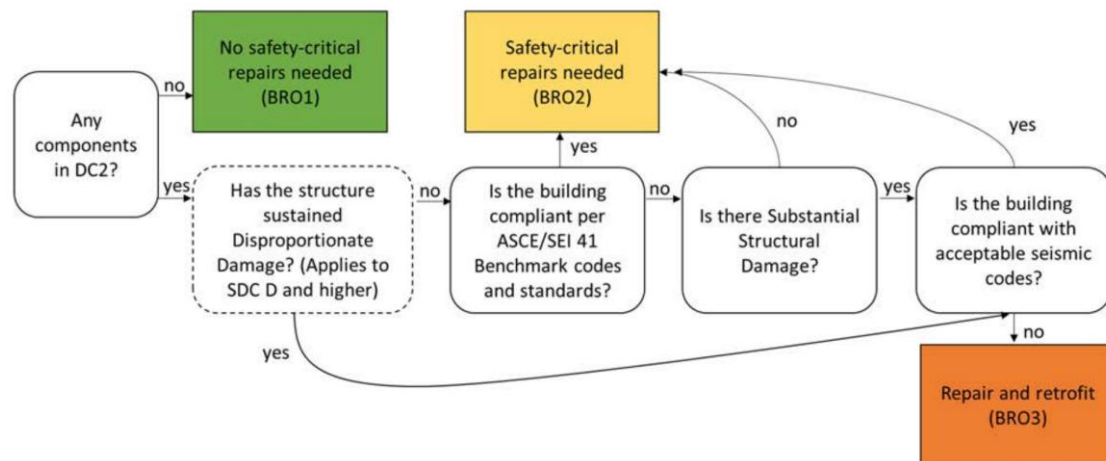


Figure 1: FEMA P2335 flow chart showing process for evaluation of earthquake damage

Concerns have also been raised regarding the potentially differing performance requirements of the New Zealand Building Code in comparison to U.S. requirements. In particular, it was noted that New Zealand explicitly considers serviceability performance within the Building Code, which is not the case in the U.S.

4.2.4. Coverage of construction types used in New Zealand

Reviewers noted that New Zealand has various common construction practices for concrete buildings that are not prevalent in the U.S. and hence are not adequately covered by the guidelines. These most notably include precast concrete floors, but also other aspects such as use of reinforcement that is more prone to low cycle fatigue. The absence of coverage of precast wall and precast frame structures was also noted.

4.2.5. Insurance requirements

Reviewers noted that a higher proportion of buildings in New Zealand currently have earthquake insurance compared to the U.S. It was noted that under currently common policy terms, the standard of repair prescribed in the guidelines would be insufficient.

4.2.6. Inspection requirements

Reviewers were concerned about the requirement to include computer analysis for most structures taller than 5 stories. They noted that such analysis would be relatively expensive, and that the requirement would stretch engineering resources after a major earthquake affecting a large New Zealand population centre.

4.2.7. Earthquake intensity data

The reviewers noted that the guidelines rely on measures of shaking intensity published immediately post-earthquake by the U.S. Geological Survey (USGS). While intensity information is also rapidly

published in New Zealand by GNS Science, the form of this information differs from that required by the guidelines.

5. Outputs & dissemination

Discussion is underway regarding organisation of one or more workshops to disseminate knowledge from the guidelines to New Zealand engineers. It is currently felt that a small group discussion with reviewers of the draft guidelines and Professor Ken Elwood to consider plans for adapting the guidelines to New Zealand should occur prior to these potential workshops.

6. Summary and close

Consultant reviews have provided useful guidance regarding ways in which the ATC 145/FEMA P2335 guidelines could be improved for use in New Zealand. Completion of the improvements identified would be a substantial task, with further scoping work required to identify how to most effectively undertake the work.

Notwithstanding, the consultant review confirms that the document as-published is a useful step forward. To quote,

The post-earthquake assessment, repair and retrofit procedures detailed in FEMA P-2335 appear to be well conceived. The procedures address a knowledge deficit that was identified following the 2010/2011 Canterbury earthquakes when structural engineers were attempting to quantify the residual capacity of earthquake damaged buildings.

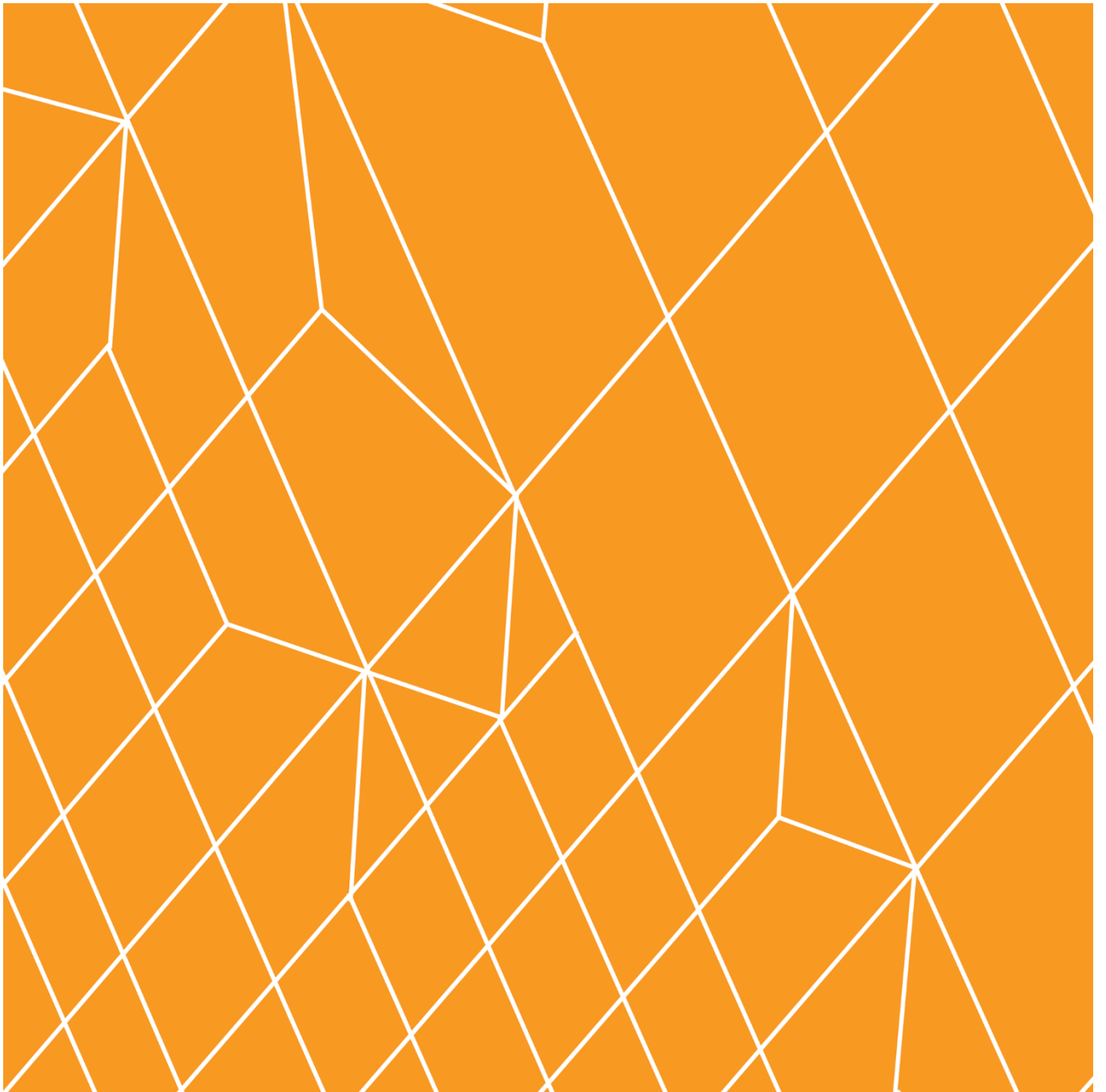
Natural Hazards Commission Toka Tū Ake's generous support that has made our involvement in this project possible is gratefully appreciated, and we would be happy to discuss the project further with you at your convenience.

Sincerely,



Dr Nicholas Brooke
PhD, CPEng, MEngNZ

Appendices – External review reports



Review of FEMA P-2335 90% Draft

Report

Revision 1
17 June 2024
148493.12



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Report

Review of FEMA P-2335 90% Draft

Prepared For:
Compusoft Engineering Ltd

Date: 17 June 2024
Project No: 148493.12
Revision No: 1

Prepared By:

A handwritten signature in blue ink, appearing to read "Stuart Oliver", written over a horizontal line.

Stuart Oliver
TECHNICAL DIRECTOR
Holmes NZ LP

Report Issue Register

DATE	REV. NO.	REASON FOR ISSUE
14 June 2024	0.1	Draft for Client Information
17 June 2024	1	Completed Document

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EXECUTIVE SUMMARY

Holmes NZ LP have been engaged by Compusoft Engineering Ltd to complete a review of FEMA P-2335 90% Draft Guidelines for Post Earthquake Assessment, Repair and Retrofit of Buildings.

FEMA P-2335 *Guidelines for Post Earthquake Assessment, Repair and Retrofit of Buildings* is been developed by the Applied Technology Council for the US Federal Emergency Management Agency (FEMA). The purpose of the document is to provide guidance to structural engineers and building officials when assessing and repairing earthquake damaged buildings.

The scope of work for this review of FEMA P-2335 90% Draft included the following:

1. Technical gaps or issues that might impact use of the report in a New Zealand context.
2. How the guidance would fit within the NZ regulatory framework that applies for post-earthquake evaluation and repair.
3. Document useability for New Zealand engineers.
4. Report which summarises the findings of the review (this document).

The post-earthquake assessment, repair and retrofit procedures detailed in FEMA P-2335 appear to be well conceived. The procedures address a knowledge deficit that was identified following the 2010/2011 Canterbury earthquakes when structural engineers were attempting to quantify the residual capacity of earthquake damaged buildings.

The scope of the document is limited to insitu concrete moment resisting frames, slab-column frames and wall buildings. The document does not provide detailed guidance on precast concrete building systems that are commonly found in many buildings and supplementary guidance on how to assess and repair these systems would be necessary.

FEMA P-2335 relies heavily on two US publications, ASCE 41 (ASCE, 2023) and ACI 318 (ACI, 2019). Few NZ engineers will be familiar with these US documents. The useability of the document could be greatly improved for NZ projects if the FEMA P-2335 methodology was updated to enable the analysis and assessment procedures detailed in NZSEE NZ Seismic Assessment Guidelines (NZSEE, 2017) to be used.

The FEMA P-2335 procedure relies on seismic demand information from the USGS website. The USGS website may not have the relevant information needed for NZ buildings. Data readily available from the GNS website would need to be reviewed to determine how it could be used to enable the FEMA P-2335 assessment procedure to be undertaken.

Much of the FEMA P-2335 assessment and repair procedures would be new to most NZ engineers. If aspects of the procedures were to be adopted and modified for NZ projects it would be help to support this with training and work examples of the damage assessment process.

1 INTRODUCTION

Holmes NZ LP have been engaged by Compusoft Engineering Ltd to complete a review of FEMA P-2335 90% Draft Guidelines for Post Earthquake Assessment, Repair and Retrofit of Buildings.

2 SCOPE OF WORK

The scope of work for this review of FEMA P-2335 90% Draft included the following:

1. Technical gaps or issues that might impact use of the report in a New Zealand context.
2. How the guidance would fit within the NZ regulatory framework that applies for post-earthquake evaluation and repair.
3. Document useability for New Zealand engineers.
4. Report which summarises the findings of the review (this document).

3 LIMITATIONS

Findings presented as a part of this project are for the sole use of Compusoft Engineering Ltd in its evaluation of the draft guidelines. The findings are not intended for use by other parties, and may not contain sufficient information for the purposes of other parties or other uses.

Our evaluations have been restricted to structural aspects only. Waterproofing elements, electrical and mechanical equipment, fire protection and safety systems, service connections, water supplies and sanitary fittings have not been inspected or reviewed, and secondary elements such as windows and fittings have not generally been reviewed.

Our professional services are performed using a degree of care and skill normally exercised, under similar circumstances, by reputable consultants practicing in this field at this time. No other warranty, expressed or implied, is made as to the professional advice presented in this report.

4 BACKGROUND

FEMA P-2335 *Guidelines for Post Earthquake Assessment, Repair and Retrofit of Buildings* is been developed by the Applied Technology Council for the US Federal Emergency Management Agency (FEMA). The purpose of the document is to provide guidance to structural engineers and building officials when assessing and repairing earthquake damaged buildings. This project consists of a review of an internal 90% Draft version of the document published September 2023.

5 DOCUMENT REVIEW

The following section summarises the findings of our review the FEMA P-2335 document. Appendix A includes a summary of review notes developed as part of the review.

The post-earthquake assessment, repair and retrofit procedures detailed in FEMA P-2335 appear to be well conceived. The procedures address a knowledge deficit that was identified following the 2010/2011 Canterbury earthquakes when structural engineers were attempting to quantify the residual capacity of earthquake damaged buildings.

5.1 Technical Gap Assessment for NZ Application

This section summarises potential technical gaps or issues that might impede the use of the FEMA P-2335 document by structural engineers and building officials in New Zealand.

Document Scope

The scope of the document is limited to insitu concrete moment resisting frames, slab-column frames and wall buildings. The document does not provide detailed guidance on precast concrete building systems including:

- Precast concrete structural walls
- Precast concrete moment resisting frames
- Precast concrete floor systems

The above structural systems are commonly found in many buildings and supplementary guidance on how to assess and repair these systems would be necessary.

Limited guidance is provided in the document for the damage assessment and repair of foundation elements.

Reliance on ASCE 41 and ACI 318

FEMA P-2335 relies on ASCE 41 (ASCE, 2023) and ACI 318 (ACI, 2019) as described below.

ASCE 41:

- i. Analysis of buildings as part of screening process to assess potential of damage to buildings and subsequent need for building inspection (refer Sections 3.4 and 3.5)
- ii. Design procedures for building retrofits (refer Section 4.4)
- iii. Determination of force and deformation limits for assessing structural elements (refer Section 5.4)
- iv. Recommendations for modelling parameters i.e. stiffness modifiers and damping ratios (refer Section 5.7)

Few NZ engineers will be familiar with ASCE 41. In particular the linear analysis procedures referred to in Section 3.4 of FEMA P-2335 are seldom used for NZ projects. This is principally because the NZSEE NZ Seismic Assessment Guidelines (NZSEE, 2017) are typically used when undertaking seismic assessments in NZ (noting these guidelines do permit an ASCE 41 Tier 3 assessment by means of the NDP). For the same reason few NZ engineers will be familiar with the ASCE 41 modelling parameters and acceptance.

ACI 318:

- i. To determine if a flexure-controlled wall is conforming or non-conforming (refer Section 5.4)
- ii. Determination of relevant Visual Damage State Database (refer Section 5.5 & App B)
- iii. Low cycle fatigue damage assessment i.e. defines minimum reinforcement ratio (refer Section 5.6)
- iv. Detailing recommendations for bar replacement undertaken and provisions of supplementary transverse reinforcement as part of a repair (refer Section 5.9)

ACI 318 is seldom used in NZ for the design of reinforced concrete buildings. NZ engineers would typically use NZS 3110 (SNZ, 2017) which is cited in NZBC B1/VM1.

It follows then if FEMA P-2335 was to be successfully used in the NZ context, then either (1) the FEMA P-2335 methodology would need to be updated so it had less reliance on ASCE 41 and ACI 318, or (2) additional guidance/training would need to be provided NZ engineers to make the document more accessible.

Preliminary Inspection Requirements

With reference to Section 3.3 of FEMA P-2335, as part of the preliminary inspection process, the document recommends the use of a structural analysis for buildings taller than 5 storeys, or buildings with structural irregularities, or ASCE 7 Risk Category III or IV buildings (similar to AS/NZS 1170.0 IL 3 or IL 4 buildings).

The recommended analysis options include ESA, MRSA, NLPO or NLRHA in accordance with ASCE 41. The time required for an ESA or MRSA is reasonably significant, with NLPO and NLRHA requiring considerably more effort. Should an earthquake near a large NZ city trigger the need for building damage assessments, experience following the 2010/2011 Canterbury earthquakes and the 2016 Kaikoura earthquake is, the engineering resource needed to complete such structural analysis would be limited. To help mitigate this the following could be considered:

- For certain classes of buildings permit more simplified targeted assessment – guidance for buildings in Christchurch developed in response to the 2020/2011 Canterbury earthquakes might be relevant.
- Review the threshold for which a structural analysis is required as part of the preliminary inspection process.

Quantifying Probable Seismic Demands

FEMA P-2335 references USGS resources for determining probable building seismic demands following an earthquake (refer Section 3.4). These resources are unlikely to be useful for buildings in NZ. Potentially information on the GNS website could be used by structural engineers to assist with quantifying probable earthquake demands. There might be a need to modify data available on the GNS website so it was more relevant for use as a predictor of probable seismic demands.

Similarly, Section 4.4.2 of the document which defines Disproportionate Earthquake Damage relies on data available from the USGS website. This definition would need to be revised taking into consideration data readily available from the GNS website and other relevant technical resources.

Disproportionate Earthquake Damage

Disproportionate Earthquake Damage (refer Section 4.4.2) and Substantial Damage (refer Section 4.4.3) definitions do not consider damage to horizontal elements of the lateral load resisting system (i.e. beams or diaphragms). Given the criticality of some horizontal elements of lateral load resisting system, it is recommended these definitions be reviewed to ensure the process delivers the outcomes that are been targeted.

Low-Cycle Fatigue Damage Assessment

With reference to Section 5.6.2 of FEMA P-2335, the document provides information on reinforcement grades commonly found in the US to assist with low-cycle fatigue damage assessments. Similar information on common NZ reinforcement grades would be needed. Furthermore work would be required to validate the strain-based screen fatigue check is appropriate for NZ reinforcement grades.

The document includes details of how to complete detailed fatigue checks for those cases when the simplified screening checks are not satisfied. The detailed fatigue checks are based on previous work completed by Mander (2018) for the Koh and Stephens (1991), and FEMA P-2335 provides recommendations on fatigue parameters that are appropriate for US reinforcement grades. Similar recommendations would be required for NZ reinforcement grades.

One of the inputs for the strain-based screen fatigue check is S_{o1} for MCE_R at the site. Guidance on how to compute this for NZ buildings would be needed, including if there is a need to consider building Importance Levels (ILs).

5.2 NZ Regulatory Framework Review

NZ legislation that are relevant to the post-earthquake evaluation and repair of buildings includes:

- Civil Defence Emergency Management (CDEM) Act 2002,
- National Civil Defence Emergency Management (CGEM) Plan Order 2015
- Building Act 2004

In addition to the above, the MBIE *Managing Buildings in an Emergency* (MBIE, 2020) guide describes the roles and responsibilities of government agencies and relevant NZ legislation. The document was written to provide guidance to TA's on what is required in terms of managing buildings in an emergency.

Section 77 of the National CDEM Plan describes the objective of managing buildings in an emergency is to:

77 Objective

The objective of building management in an emergency is to—

- (a) protect life and promote safety within and in the vicinity of each building; and
- (b) minimise damage to and loss of property; and
- (c) restore building functions as soon as possible to minimise social and economic consequences of the emergency; and
- (d) minimise losses or disruption of lifeline utility services that are in or near any building.

The paramount consideration in the performance of functions and duties is to protect people from further injury or death.

Section 133BU of the Building Act gives local TA's, Controllers (who are appointed in a state of emergency) and Recovery Managers (who are appointed during a transition period) the authority to direct building owners to complete post-earthquake damage assessments if it is believed that a building may have sustained significant damage and poses a risk to public safety:

133BU Owner directed to give information

- (1) A responsible person may direct the owner of a building or of any land in a designated area to give the responsible person information about the building or land if the responsible person believes that the further information is reasonably necessary to enable the responsible person to determine—
 - (a) the risks posed by the building and whether to exercise further powers under this subpart in relation to the building; or
 - (b) what works, if any, are needed to remove or reduce the risks.
- (2) The direction must—
 - (a) be in writing, in the form (if any) approved by the chief executive; and
 - (b) describe the information required, which may include a full structural assessment, a detailed engineering assessment of observed damage, or other technical assessment; and
 - (c) specify the time and date by which the information must be given (allowing a reasonable time for the conduct of any assessment required); and
 - (d) specify to whom the information must be given.
- (3) An owner of a building or land who is given a direction under this section must comply with the direction at that owner's expense.
- (4) On receiving information under this section, the responsible person may, in accordance with subsection (2), direct the owner of the building or land to give further information that the responsible person believes is reasonably necessary to comply with the first direction.

Outside a declared state of local or national emergency, TA's only have the authority to direct building owners to provide such information if the building is located in an area that has been designated for building emergency management under Section 133BC of the Building Act:

133BC Designation of areas to which this subpart applies

- (1) If a state of emergency or a transition period is in force for an area under the CDEM Act, a relevant CDEM decision-maker may designate the whole or a part of that area for the purposes of this subpart.
- (2) If an emergency arises and there is no state of emergency or transition period in force,—
 - (a) a territorial authority that is responsible for the whole or a part of the affected area may, with the approval of the Minister, designate the whole or any part of the affected area for the purposes of this subpart; or
 - (b) the Minister may, on the Minister's own initiative, designate the whole or any part of the affected area for the purposes of this subpart.
- (3) For the purposes of subsection (2)(a), a territorial authority may request the Minister's approval only for an area for which the authority is responsible, but 2 or more territorial authorities may make a joint request.

Section 133BC: inserted, on 17 December 2019, by section 12 of the Building Amendment Act 2019 (2019 No 27).

Outputs from Rapid Building Assessments can be used to inform if building owners need to provide further building information (i.e. post-earthquake damage assessments), this could include for example building placarding information (white – can be used, yellow – access restricted, red – entry prohibited).

Figure 1 below from MBIE (2020) summarises the recommended assessment process for non-residential buildings an area has been designated for building emergency management. The process makes reference to the following three post-earthquake evaluations:

- Interim Use Evaluation (IUE)
- Detailed Damage Evaluation (DDE) – developed in response to the 2011 Canterbury earthquake
- Target Damage Evaluation (TDE) – developed in response to the 2016 Kaikoura earthquake.

The TDE is similar to the FEMA P-2335 Preliminary Inspection and the DDE is similar to the FEMA P-2335 Detailed Inspection. It follows then FEMA P-2335 could be used to inform and update the existing DDE and TDE procedures.

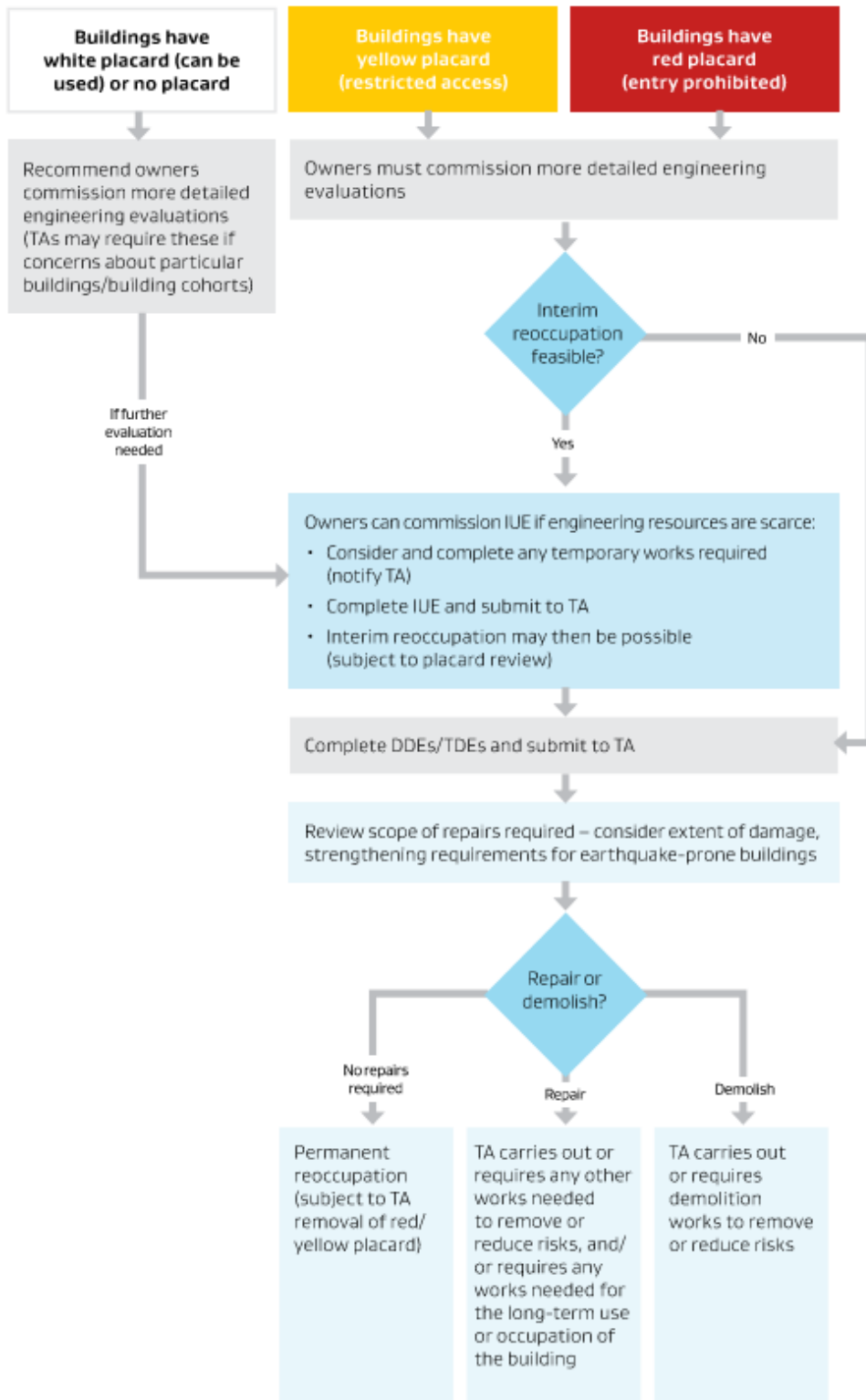


Figure 1 Building assessment process and subsequent actions when an area has been designated for building emergency management - except simple residential buildings (MBIE, 2020).

5.3 Document Useability Review

The damage assessment and retrofit process set out in FEMA P-2335 is reasonably straightforward to follow. The document contains a number of flow charts which detail the recommended assessment, repair and retrofit process flow.

The following have been identified as opportunities to improve the usability of FEMA P-2335 for NZ projects (refer also related comments in Section 5.1):

- Update the methodology so that so it had less reliance on ASCE 41. Few NZ engineers will be familiar with ASCE 41. For NZ projects it would be preferable to provide a methodology which uses the analysis procedures and acceptance criteria in the NZSEE NZ Seismic Assessment Guidelines.
- Update the analysis procedures in the methodology so that so it refers to NZS 3101 rather than ACI 318 for determining the relevent Visual Damage State Database and reinforced concrete detailing parameters.
- The FEMA P-2335 procedure relies on seismic demand information from the USGS website. The USGS website may not have relevent information needed for NZ projects. Data readily available from the GNS website would need to be reviewed to determine how it could be used to enable the FEMA P-2335 assessment procedure to be undertaken. This might require some aspects of the FEMA P-2335 assessment procedure to be modified.
- Provide training and work examples of the damage assessment process, including for the detailed fatigue checks which are not often completed as part of routine seismic design or assessment in NZ.

REFERENCES

ACI (2019), *ACI 318-19 Building Code Requirements for Structural Concrete*, American Concrete Institute, Farmington Hills, MI

ASCE (2023), *ASCE/SEI 41-23 Seismic Evaluation and Retrofit of Existing Buildings*, American Society of Civil Engineers, Reston, VA

MBIE (2020), *Managing Buildings in an Emergency – Guidance for Decision Makers and Territorial Authorities*, Ministry of Business Innovation and Employment, Wellington, NZ

NZSEE (2017), *The Seismic Assessment of Existing Buildings – Technical Guidelines for Engineering Assessments*, New Zealand Society for Earthquake Engineering, Wellington, NZ

SNZ (2017), *NZS 3101 inc. A1 – A3 Concrete Structures Standard*, Standards New Zealand, Wellington, NZ

APPENDIX A - DOCUMENT REVIEW NOTES

Please refer to Table A-1 below for a summary of the review notes developed for each section of the FEMA P-2335 90% Draft.

Table A-1 Document review notes

Section ID	Identified Technical Gap / Issue	Notes
1. Introduction		
1.2 Scope	Scope limited to cast-in-situ reinforced concrete MRF, slab-column frames and shear wall buildings.	
	Does not provide specific advice for precast concrete walls or MRF systems.	
	Does not provide detailed advice for foundation elements.	Potentially shallow foundations could be assessed using the procedures given for MRFs.
	Does not provide specific criteria for assessing damage to precast concrete floor systems.	NZ specific advice will be needed noting the poor performance of precast concrete floor systems in recent NZ earthquakes.
	Does not include consideration of the effects of liquefaction, lateral spreading or foundation settlement.	
1.4 Policy Considerations	While much of the content in this section is applicable to NZ, content related to US building codes is not relevant.	Would be useful to include similar content for NZ context.
1.5 Related Documents	Section will need to be updated to include relevant NZ documents and guidelines.	Relevant NZ documents might include NZ Seismic Assessment Guidelines, MBIE Managing Buildings in Earthquakes Guidelines, Wellington City Council Targeted Building Assessment Program Engineering Guidelines
2. Overview		
2.1 Post-earthquake Assessment Process	Generally applicable to NZ, minor updates to content would be needed to address items raised in Sections 3 & 4 below.	Similar comment would apply to the rest of the content in this section.
2.3 Reporting		Level of recommended reporting looks reasonable. Would be useful to compare with what was required in the Wellington City Council Targeted Building Assessment Program Engineering Guidelines

Section ID	Identified Technical Gap / Issue	Notes
3. Identification of Earthquake Damage		
3.3 Preliminary Inspection	Preliminary inspection process may not be sufficient to rule out damage to precast concrete floor units.	Preliminary inspection process is limited to visual inspections.
	<p>As part of a preliminary inspection the document recommends the use of a structural analysis for buildings taller than 5 storeys, or buildings with structural irregularities, or ASCE 7 Risk Category III or IV buildings (similar to AS/NZS 1170.0 IL 3 or IL 4 buildings).</p> <p>Should a significant earthquake near a large NZ city trigger the need for building damage assessments, experience following the 2010/2011 Canterbury earthquakes and the 2016 Kaikoura earthquake is, the engineering resource needed to complete such structural analysis would be limited and this would likely cause significant delays.</p>	<p>The purpose of the structural analysis is to help identify locations of the structure that are likely to be damaged. Refer to Section 3.3.6 for more information.</p> <p>Recommend the criteria for triggering a structural analysis as part of a preliminary inspection will need to be reviewed to ensure it is delivering the appropriate outcomes.</p>
3.4 Structural Analysis	Document makes reference to the linear and non-linear analysis in ASCE 41. Few NZ engineers will be familiar with the ASCE 41 linear analysis procedures, and only a limited number of NZ engineers will be familiar with the ASCE 41 nonlinear procedures.	Useability of document would be significantly improved if the document was updated for NZ users whereby the analysis procedures in the NZ Seismic Assessment Guidelines were used en lieu of ASCE 41.
	Document references USGS resources for determining probable seismic demand following an earthquake. Unlikely to be useful for NZ earthquakes.	<p>Could provide reference to suitable GNS resources.</p> <p>Guidance provided to apply ground motion demands to structural analysis model will still be applicable.</p>
3.5 Identification of Possible Damage Locations	Document makes reference to ASCE 41 modelling and assessment parameters determining the scope of inspection. A limited number of NZ engineers will be familiar with ASCE 41.	Useability of document would be improved if the document was updated for NZ users whereby parameters in the NZ Seismic Assessment Guidelines were used or if the relevent ASCE 41 parameters were included in the guideline (this may not be a trivial task).
	ASCE 41 guidance for the seismic assessment of precast concrete floor systems is limited and not sufficient for NZ buildings. Would need to provide additional guidance on scope of inspections for precast concrete floors.	
3.8 Intrusive Inspections	Additional guidance for precast concrete floor systems is needed.	

Section ID	Identified Technical Gap / Issue	Notes
4. Evaluation of Earthquake Damage		
4.2 General	Section will need to be updated to reference relevant NZ Building legislation i.e. Building Act, CDEM Act etc	
4.3 Component Damage Classification	Document makes reference to ASCE 41 modelling parameters when determining component damage classes. A limited number of NZ engineers will be familiar with ASCE 41. Assessment parameters in the NZ Seismic Assessment Guidelines may not be sufficient in some cases to define the DC2 damage class,	
4.4 Component Damage Classification	Section currently refers to IEBC. The document would be more useable if it were updated to reference relevant NZ building legislation.	
	Disproportionate Earthquake Damage definition would need to be revised so it aligns with data readily available from GNS and relevant NZ building legislation.	
	Disproportionate Earthquake Damage and Substantial Damage definitions does not consider damage to horizontal elements of the lateral force resisting system (i.e. beams or diaphragms). Given the criticality of some horizontal elements of the lateral force resisting system suggest these definitions be reviewed.	
	Document refers to ASCE 41 NSP and LSP analysis methods, and FEMA P-2018 mechanism analysis for determining the pre-damaged and damaged capacities of the building. A limited number of NZ engineers will be familiar with these analysis methods.	Could investigate if the analysis methods in the NZ Assessment Guidelines (i.e. SLAMA, equivalent static and nonlinear pushover) could be used instead.
4.4 Seismic Retrofit	Document refers to ASCE 41 for retrofit design procedures. The document would be more useable if it were updated to reference NZ retrofit guidance documents.	
5 Reinforced Concrete		
5.2 Structural Systems Behaviour	Refer scope limitations noted in Item 1.2 above for structural systems not covered..	

Section ID	Identified Technical Gap / Issue	Notes
5.3 Intrusive Inspections	Makes reference to ACI 318 seismic detailing provisions. A limited number of NZ engineers will be familiar with ACI 318 and suggest NZS 3101 be better referenced for NZ users.	
	Definition of Conditions Always Requiring Inspection are similar to the SSW definitions NZ Sesimic Assessment Guidelines. There could be value in aligning the definitions.	
5.4 Performance Critical Force and Deformation Limits	Document makes reference to ASCE 41 assessment parameters when determining force and deformation limits. A limited number of NZ engineers will be familiar with ASCE 41.	Useability of document would be improved if the document was updated for NZ users whereby parameters in the NZ Seismic Assessment Guidelines were used or if the relevent ASCE 41 parameters were included in the guideline (this may not be a trivial task).
5.5 Classification of Damage	Makes reference to ACI 318 when determining appropriate Visual Damage State Database. A limited number of NZ engineers will be familiar with ACI 318 and suggest NZS 3101 be better referenced for NZ users.	The Visual Damage States database is an excellent way to assist engineers with the assessment of earthquake damage.
5.6 Low-Cycle Fatigue Damage Assessment	Section does not provide guidance on reinforcement grades commonly found in NZ. Would be helpful to provide advice on NZ reinforcement grades.	
	Makes reference to ACI 318 as part of low cycle fatigue checks.	
	Strained based screen fatigue check makes reference to MCE_R . NZ building standards do not define MCE_R so this check would need to be align with NZ ULS design procedures (including building Importance Levels)	
	Strained based screen fatigue check would need to be reviewed to ensure it is appropriate for NZ reinforcement grades.	
5.7 Modelling Parameters	Section makes reference to ASCE 41. A limited number of NZ engineers will be familiar with ASCE 41.	
5.9 Repair	Makes reference to ACI 318. A limited number of NZ engineers will be familiar with ACI 318 and suggest NZS 3101 be better referenced for NZ users	

Section ID	Identified Technical Gap / Issue	Notes
Appendix A: Defining Inspection Indicators and Safety Critical Limits		
A.2 Defining Safety Critical Limits	Section makes reference to ASCE 41. A limited number of NZ engineers will be familiar with ASCE 41.	
Appendix B: Visual Damage States		
B.2 Guidance on Database Usage	Makes reference to ACI 318 & ASCE 41. A limited number of NZ engineers will be familiar with these documents (similar comment applies to Section B.4)	
B.4 Visual Damage State Data Sets	NZS 3101 detailing requirements for beam column joints are more stringent than is required in ACI 318 i.e. require greater quantities of joint stirrups. It is unclear if the damage states and photographs in Section B.4.12 need to be supplemented with data from joints more typical of NZ design practice.	
Appendix C: Fatigue Capacity Models and Background		
C.2 Basis of Fatigue Screening Check	Procedure was derived based on strain parameters developed by Mander (2018) for the Koh and Stephens (1991) fatigue life equation. These would need to be reviewed to ensure it is appropriate for NZ reinforcement grades	
	Makes reference to MCE_R . NZ building standards do not define MCE_R so this check would need to be align with NZ ULS design procedures (including building Importance Levels)	
Appendix D: Relationship to the IEBC		
C.1 Context	This appendix is not relevant to NZ projects.	A similar section developed for NZ buildings would be very helpful



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18 June 2024

Attention: Nicholas Brooke

Dear Nicholas

FEMA P-2335 Review

This letter is a summary of a review of the 90% Draft of FEMA P-2335 *Guidelines for Post-Earthquake Assessment, Repair and Retrofit of Buildings*.

Appended to this letter is a list of review comments to consider. The review of this document has considered the following:

- Potential technical gaps, or missing guidance in this document that may be required for engineers to implement the Guidelines in New Zealand.
- How the guidance would fit within the New Zealand regulatory framework that applies to post-earthquake evaluation and repair. Additionally, some thoughts are noted regarding the insurance-market in New Zealand.
- Useability of the document – that is, the ease to which the guidelines can be readily applied by practicing engineers in New Zealand.

Yours sincerely

A handwritten signature in black ink that reads 'D Marriott'.

Dion Marriott

Technical Director - Structural Engineer

on behalf of

Beca Limited

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Document Section	Comment
General	<p>If these guidelines were adopted in NZ, repair requirements to reinstate stiffness may need to be considered for DC1 & DC2, to ensure specific SLS objectives (amenity) continue to be met, as well as durability requirements, to ensure the repaired building continues to comply with the Building Act (and likely required by insurance policies). The Guidelines appear to consider loss of stiffness in concrete structures as not being important. It would be useful to clarify this point.</p> <p>These guidelines acknowledge that a building that has repaired DC2 damage, or unrepaired DC1 damage may experience greater displacement demands under more frequent serviceability earthquakes. This is due to ‘softening’ of the damaged components, resulting in buildings that may be more susceptible to serviceability damage. These guidelines state that repairs are only required to restore the strength of components – restoring stiffness is not a performance-critical requirement. This will require careful consideration in NZ, where insurance cover is high. An Owner’s insurance policy relating to damage criteria and reinstatement standards may exceed the standards of adequate safety and maintaining/restoring strength and displacement capacity used in the Guidelines.</p> <p>Where this guidance document references content from US-specific standards, it would benefit NZ users of these guidelines to re-produce that content within the document to aid in usability/readability. This will avoid NZ users needing to locate the relevant content within standards such as ACI318 (which may be unfamiliar to some).</p> <p>ASCE41 is a reference standard used in these guidelines – ASCE41 is used to assess the pre-damaged, and damaged structure. The concrete provisions in ASCE41 are focused on cast in-situ US construction practice. NZ-specific updates may need to be added to include concrete components typical of NZ concrete construction i.e. precast concrete walls, frames, floors.</p> <p>Foundations / geotechnical damage is also important. Our experience is that it is ground movements and settlements should also be considered is assessing earthquake damage to structures.</p> <p>The Japanese JBDPA damage assessment methodology (using Damage Indices) has been found to be a useful approach to identifying and quantifying localized and overall damage and loss of capacity. This should be considered/evaluated for use in NZ too.</p> <p>Some of the methodology in the Guidelines would take some effort and training to apply in New Zealand. For example, the regulatory processes are different. Key terminology such as Damage Classes, Damage States, Substantial Structural Damage, Disproportionate Structural Damage, Performance-Critical Limits and Building Repair Outcome are not familiar to New Zealand engineers and need to be clearly understood to apply the methodology.</p> <p>We recognise these Guidelines are currently limited to concrete buildings; however, Guidance on structural steel should be included if possible, for NZ.</p>

2.1.2	<p>This document makes reference to the IEBC to define when earthquake repairs are required, and to what level/performance the repair is to achieve. These repair requirements are based on two IEBC definitions: 1). “Disproportionate Earthquake Damage” (DED) and 2). “Substantial Structural Damage” (SSD). The New Zealand Building Act does not contain any such definitions; thus, the structural “triggers” and repair targets discussed in FEMA P-2335 would not be able to be applied in NZ, unless comparable definitions are introduced in the Building Act, OR NZ-specific definitions are introduced in industry guidance.</p> <p>Additionally, the repair requirement for Substantial Structural Damage (SSD) is related to whether a buildings’ pre-damaged performance meets the BPOE (<u>B</u>asic <u>P</u>erformance <u>O</u>bjective for <u>E</u>xisting Buildings). The New Zealand Building Act does not currently contain a comparable existing building seismic performance threshold.</p>
2.2.1	<p>Structural elements that are assessed as having performance-critical damage include <u>ANY</u> horizontal or vertical element that acts to resist lateral and/or vertical loads. These guidelines require that <u>all parts</u> of the structure be considered when assessing earthquake damage (regardless of whether they are part of the primary lateral resistance or not). New Zealand has a long-established assessment process in which components that do not reliably contribute to lateral resistance (i.e. not part of the primary system) need only maintain their gravity load-carrying capacity, considering the displacement demand of the building i.e. deformation incompatibility. Thus, these guidelines may need to reflect the NZ philosophy and provide a distinction between elements that require repair to reinstate the lateral resistance of the structure.</p>
2.2.2	<p>The performance-critical damage threshold is defined as the deformation at onset of strength degradation. This threshold adopts a modified form of the acceptance criteria in ASCE41, some of which may not be relevant for NZ construction. NZ-specific indices may need to be established for NZ construction practice (precast dominant). For example, US-specific component limit states may not be applicable to precast construction involving strong or weak (ductile or brittle) connections that involve emulation of monolithic construction i.e. precast walls constructed with grouted reinforcement within drossbach ducts.</p>
2.2.6 (related sections: 4.5.2 & 4.5.3)	<p>This section states that repairs that are necessary to improve cosmetic, durability or serviceability issues do not qualify as performance-critical repairs. This appears to overlook durability-related structural deterioration that could result in a reduction in capacity of structural components over time. Damage that is left unrepaired (that may be prone to deterioration) may no longer continue to meet the durability requirements of the NZ Building Act.</p>
2.2.6.1	<p>Will performance-critical repairs fully restore lost strength and deformation capacity? or just restore an acceptable level of pre-earthquake capacity? Experience indicates the latter is more likely achievable. That is, these guidelines imply that where rebar is not being replaced at DC2, or damage is less than DC2, the rebar has sufficient residual deformation capacity – this implies an acceptable level of pre-earthquake capacity, rather than restoring lost strength and deformation capacity.</p>
3.3	<p>This section on inspection seems very short and we would expect more detail to be included of what detailed inspections should include. Crack mapping and level and verticality surveys are normal practice. These are not discussed in any detail.</p>

3.3.1	This section recommends collecting earthquake ground shaking measurements at the site using ShakeMap (USGS) for PGA & PGV intensity estimates. NZ would need to make similar data/processes available in NZ.
3.3.5	This section includes a number of criteria for rapidly identifying the building as Undamaged if meets one or more criteria – one of the criteria includes the building being classified as a “Benchmark Building”. NZ assessment standards do not contain this definition within its assessment framework. An equivalent definition may need to be created. Note that Section 4.4.1 also includes criteria for “benchmark buildings” and acceptable seismic codes. Similar documents would need to be defined for NZ context.
3.3.6	This section indicates that structural analysis is recommended to help identify locations requiring detailed inspection, where the structure is not exposed. Buildings taller than 5-stories are suggested to be analysed (including regular buildings). To require detailed analysis on such structures will require considerable effort – to believe that analysis is required to ensure that the engineer can identify locations of potential damage seems optimistic. Specific criteria that dictate when analysis be performed for NZ-practice should be considered.
3.5.5	This section references the use of ASCE41 linear assessment methods (m-factors element ductility factors) to identify inspection locations. This assessment method is not used in NZ, and an alternate linear-based (or NLPO/SLaMA) based method of assessment may need to be substituted here.
4.4.4	This section includes a process to determine pre-damaged condition for determination of DED and SSD. Item c (LSP & m-factors) would not be applicable to NZ practice.
5.1	The Scope of this chapter appears to be limited to cast-in-place reinforced concrete construction. NZ-specific updates would need to include precast construction. This includes precast vertical lateral elements, and precast concrete diaphragms. These guidelines appear to contain a very deliberate mention of precast diaphragms on last paragraph in 5.2.5.
5.2	Table 5-1 would need to be expanded to include typical NZ construction practice (at least): Precast walls (weak/ductile or strong joints) Precast floors Precast frames (beams and columns)
5.2.7	This section on system and damage behaviour explicitly exclude precast structural walls and precast frames with “weak connections”. The definition of “weak connections” is not defined, but presumably includes precast connections in which the connecting element is the weak element i.e. yielding rebar in drossbachs. These systems would need to be included for the guidelines to be applicable to NZ. Other common NZ-Specific condition that do not appear to be included are: 1). Precast tile up construction i.e. precast walls joined via weld-plate connections, located either between panels, and/or at the base of the panel. These are not only “weak connections” but also brittle. 2). Structural steel roofs (within concrete buildings) that lack a dedicated roof diaphragm, and which are connected to precast concrete walls or frames.
5.3.2	NZ’s building stock contains a lot of buildings with Hollowcore/Dycore floors with thin topping slabs which are very prone to significant shrinkage cracks. This can make it difficult to recognise pre-existing damage vs. earthquake damage across the diaphragm,

	particularly following earthquakes of low-intensity (where less cracking of the floor is expected). Additional commentary will be required to support NZ engineers.
5.3.3	NZ contains a large number of buildings that contain precast tilt up walls, with very low flexural reinforcement, particular across the panel joints. Thus, fracture at a single crack is an issue during inspection that will need to be covered by these guidelines for NZ.
5.3.4	Conditions that always require inspection will need to include NZ-specific issues. Possible examples may include: Light-weight structural steel roof systems connected via weld-plate connections to precast elements. Precast floor support. Precast cladding panel connections.
5.4.1	This section classifies elements into deformation-controlled or force-controlled, for the purpose of defining performance-critical limits. ASCE41 is adopted here. Additional guidance for NZ-specific concrete components will need to be included as some of these components will not be contained in ASCE41. Particularly, precast construction (ASCE41 is largely focused on cast in-situ concrete construction).
5.4.3	NZ-specific deformation-controlled limit states will need to be established for components not contained in ASCE41. Similarly, Table 5-3 will need to include NZ-specific components.
5.4.4.3	Beam-column joint strength provisions differ considerably between ASCE41/ACI318 and NZ. Clarification would be required as to what strength provisions to use in this section.
5.5.1	This section on classification of damage would benefit from a number of photographic examples of DC2 damage states specific to loss of precast floor seating, to support NZ engineers.
5.5.2	The last paragraph on Visual Damage States, states that “considerable judgement may be required” to relate observed damage to images from laboratory tests in classifying DS2. Acknowledging this...should this then be a requirement for an independent Peer Review as part of this process in NZ?
5.6.1	The fatigue criteria references ACI318 minimum reinforcement content. These ACU provisions will need to be restated into a NZ annex for those NZ engineers who do not use (or not familiar with) ACI318. Additionally, these Fatigue categories may be difficult to apply to NZ precast construction in which weak connections are used, comprising of rebar within drossbach ducts, which are often located inside a reinforcing cage (and may not be visible). Not only will exposure of the yielded bars within the drossbach be less likely to occur, but fatigue issues could go unassessed on account of absence of bar-buckling. Strain ageing issues associated with NZ-reinforcing steel will require consideration.
5.6.2.1	The Strain-based screening fatigue check uses seismic hazard parameters specific to the US (S_{a1} , $S_{a1,MCE}$). Equivalent parameters for use in NZ will need to be made available to perform this check in NZ. The component-specific screening fatigue check for RC Walls references ACI318 detailing. Equivalent limits will need to be established for NZ, including applicability for precast walls with weak (drossbach) connections.

5.7.1	<p>The commentary to this section notes that ATC studies have shown that median peak displacement demands in repaired/damaged structures do not see an appreciable increase provided the damage has not exceeded DS2. This section goes on to state that an exception arises for serviceability performance objectives, in which increase peak displacements may occur for lower intensity, more frequent (serviceability) earthquakes. What will this mean with respect to the insurance market in NZ, if buildings are expected to be more susceptible to serviceability damage?</p> <p>Related to 5.7.1 Section 5.9.1 states that repairs are only required to restore the strength of components – the repair does not specifically need to restore the stiffness of the component. Again, this may be an issue within the insurance market in NZ. This section refers to ACI562-2021 for repairs to restore stiffness – this may need consideration in NZ.</p>
5.9.3	<p>Crack repair using epoxy injection is not deemed a performance-critical repair, and Section 5.9.2 further clarifies that epoxy injection does not restore stiffness of the damaged component (though, some exemptions are noted in 5.9.4.2). Epoxy injection is a common repair method in NZ. If epoxy-injection is not recognized by this document as restoring stiffness, serviceability performance could come into question (see comment to 5.7.1 above)</p>
5.9.5.1	<p>Rebar replacement methods will need to include guidance for NZ-specific construction, such as precast concrete components with weak (drossback) connections.</p>
Appendix B	<p>This Visual Database would need to expand to include precast construction (frames, walls & floors) to support NZ engineers.</p>
Appendix C	<p>The basis for whether the residual fatigue life of reinforcing steel is sufficient, is only concerned with maintaining an acceptable risk against collapse at MCE. Serviceability performance may be important in NZ for insurance purposes. This needs to be considered.</p> <p>This appendix implies that an undamaged building that is being assessed for fatigue, does not retain its full deformation capacity – instead, it contains an acceptable level of pre-earthquake capacity. This will require careful consideration in NZ, particularly as it relates to Owner’s insurance policies.</p>