Guidance on Detailed Engineering Evaluation of Non-residential buildings

Part 3
Technical Guidance

Draft Prepared by the Engineering Advisory Group

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This draft document is NOT for distribution.
The contents do not represent government policy

Foreword

To come

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1 INTRODUCTION

1.1 Background and purpose

This document provides the technical support for the Detailed Engineering Evaluation Process outlined in Part 2 (published separately as the Detailed Engineering Evaluation Procedure [i]. Part A provides the background and procedures. The intention of this document is to give designers detailed technical guidance on the evaluation of the effects of damage on the performance of buildings in future earthquakes.

New buildings are traditionally designed using the New Zealand Building Code[ii] (NZBC). The compliance documents referenced in the NZBC include the loadings standard and material design standards. Together these standards comprise the verification methods that, if followed, are deemed to satisfy the performance requirements of the NZBC. These standards are however not generally applicable to the evaluation of existing buildings, unless they are a contemporary design, that is, are generally compliant in detailing. Buildings with non-compliant detailing or those constructed from archaic materials are not generally able to be assessed using the NZBC.

Assessment and strengthening of existing buildings in New Zealand has generally been in accordance with the NZSEE 'Red Book' guidelines[iii]. This document has been specifically developed for this purpose. It gives guidance for the assessment and retrofit of a variety of buildings including materials and forms that are no longer permitted under the current NZBC.

Since the publication of the Red Book, the University of Auckland and the University of Canterbury have been jointly researching the performance of existing buildings, with funding from the Foundation of Research, Science and Technology (FRST). As an output of this programme, the NZSEE recently published a revised guideline for assessment of unreinforced masonry buildings[iv], authored by the University of Auckland Engineering Department.

None of the documents described above addresses the question of how to assess buildings that have been significantly damaged. Damaged structures may not perform significantly differently in possible future earthquakes. For example:

- Reinforcement in reinforced concrete structures may have significantly reduced residual elongation capacity due to low cycle fatigue.

- Masonry that has cracked has lost its cohesion, a significant part of its strength.

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[i] Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury Part 2 Evaluation Procedure, Draft prepared by the Engineering Advisory Group, Rev 5, 19 July 2011
[ii] New Zealand Building Code, Department of Building and Housing,
[iii] New Zealand Society for Earthquake Engineering Assessment and Improvement of the Structural Performance of Buildings in Earthquakes. June 2006
[iv] New Zealand Society for Earthquake Engineering *Assessment and Improvement of Unreinforced Masonry Buildings for Earthquake Resistance*, Draft 2011

A limited number of international guidelines exist for the assessment of damaged structures. Several examples have been developed in the US by the Federal Emergency Management Agency (FEMA)[v],[vi],[vii]. These documents provide comprehensive guidance, but have limited application in the New Zealand context due to variations in building form and materials. Designers may elect to use these documents where no other guidance is available in this document, but are advised to carefully check applicability.

A locally derived means of addressing the assessment of damaged structures is therefore required. The purpose of this document is to provide this guidance to Structural Engineers.

1.2 Scope and use of this Document

1.2.1 Audience

This guidance is intended for the structural engineering design, construction and insurance sectors, local authorities, and their professional advisers and contractors. In the immediate future, the document is clearly aimed at the Canterbury earthquakes recovery process. In the longer term, it is hoped that this document will form the basis of a national guideline for future earthquake assessment and repair.

1.2.2 Scope

The guidance is intended to be applicable to all buildings which could be subject to consideration as Earthquake Prone Buildings in terms of the Building Act[viii], that is, all buildings except those which are:

> "...used wholly or mainly for residential purposes unless the building:-
> (a) comprises 2 or more storeys; and
> (b) contains 3 or more household units."

Notwithstanding this, the guidance could be applied to all buildings.

1.2.3 Outline of document

As shown in Figure 1-1, the document is divided into three parts:

Part 1: Overview – provides background on seismicity, risk issues and statutory matters
Part 2: Detailed Engineering Evaluation Procedure – provides a description of the evaluation process through both Qualitative and Quantitative Procedures.
Part 3: Detailed Engineering Evaluation Technical Guidance – provides technical support for the Detailed Engineering Evaluation Procedure in Part 2.

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[v] Federal Emergency Management Agency, FEMA 306 *Evaluation of Earthquake Damaged Concrete and Masonry Buildings – Basic Procedures Manual*, 1998

[vi] Consortium of Universities for Research in Earthquake Engineering (CUREE), EDA-02 *General Guidelines For The Assessment And Repair Of Earthquake Damage In Residential Woodframe Buildings,* February 2010

[vii] Steel Advisory Council, *SAC95-02 Interim Guidelines (FEMA 267B)*, 1995

[viii] Building Act 2004, Department of Building and Housing.

1.3 Future Expectations

It has been a stated intention of this document that it achieve an '80%' coverage. The intention of this is to be able to provide as much information to engineers as soon as possible, in order to keep the recovery moving. Even as it is being written, engineers are already completing repairs and evaluating structures.

Clearly, the best time to write a comprehensive guidance document is before it is needed, not after the event. However, in the absence of any existing guidance, it has been necessary to pull together as much information as possible in a short time. This has involved both review of international practice and short-term research completed with funding from the Foundation of Research Science and Technology.

Part 1: Overview

1. Introduction
2. Damage Summary
3. Seismicity
4. Risk
5. Building Safety Ratings
6. Legislative Framework
7. Building Safety Evaluation Process
8. Building Reoccupation
9. Glossary
10. References

Part 2: Detailed Engineering Evaluation Procedure

1. Introduction
2. Objectives
3. Scope
4. The Procedure
5. Damage Thresholds for Repair or Strengthening
6. Resilience
7. Reporting
8. References

Appendix A – Generic Building Types and Expected Damage
Appendix B – CCC Compliance Schedule

Part 3: Detailed Engineering Evaluation – Technical Guidelines

1. Introduction
2. Building Types
3. Methods of Analysis
4. Rehabilitation
5. Foundations
6. Unreinforced Masonry Buildings
7. Non-ductile Reinforced Concrete Moment Frame Buildings
8. Ductile Reinforced Concrete Moment Frame Buildings
9. Reinforced Concrete Wall Buildings
10. Structural Steel Moment Frame Buildings
11. Structural Steel Braced Frame Buildings
12. Structural Diaphragms
13. Secondary Structural Elements
14. References

Chapter Organisation

7.1 Introduction
7.2 Notation
7.3 Description
7.4 Seismic Response Characteristics and Common Deficiencies
7.5 Assessment and Analysis
7.6 Repair and Strengthening Strategies
7.7 References

Figure 1-1: Organization of Chapters and Parts

2 BUILDING TYPES

2.1 Introduction

The guidance is intended in time to cover all of the most common forms of construction that could have been used in the region. Although it is designed to deal with all ages of buildings, the most problematic cases are those for which current Standards have no application. This includes:

- Unreinforced Masonry
- Non-ductile Reinforced Concrete frame and wall structures
- Foundations, with emphasis on light industrial structures

This document initially sets out to deal with the most common types of structure only, in the interests of best aiding a rapid recovery. A more comprehensive coverage of building types may be an outcome of future studies.

A listing of the most prevalent types of structures considered in this document, with subsets as appropriate, is as follows:

Table 2-1: Building Types and Abbreviations

Type	Subtype	Abbreviation
Unreinforced Masonry		URM
Non-ductile Reinforced Concrete Moment Frames		NDCMRF
Ductile Reinforced Concrete Moment Frames		DCMRF
Reinforced Concrete Wall	Bearing Wall systems	RCW1
	Gravity Frame systems	RCW2
	Infill wall systems	IW
Structural Steel Moment Frame		SSMRF
Structural Steel Braced Frame	Concentric Braced Frames	CBF
	Eccentric Braced Frames	EBF

A further summary of the building types considered and the approximate periods when they were used is in Figure 1 below, together with an analysis of the likelihood of their being earthquake prone prior to September 4..

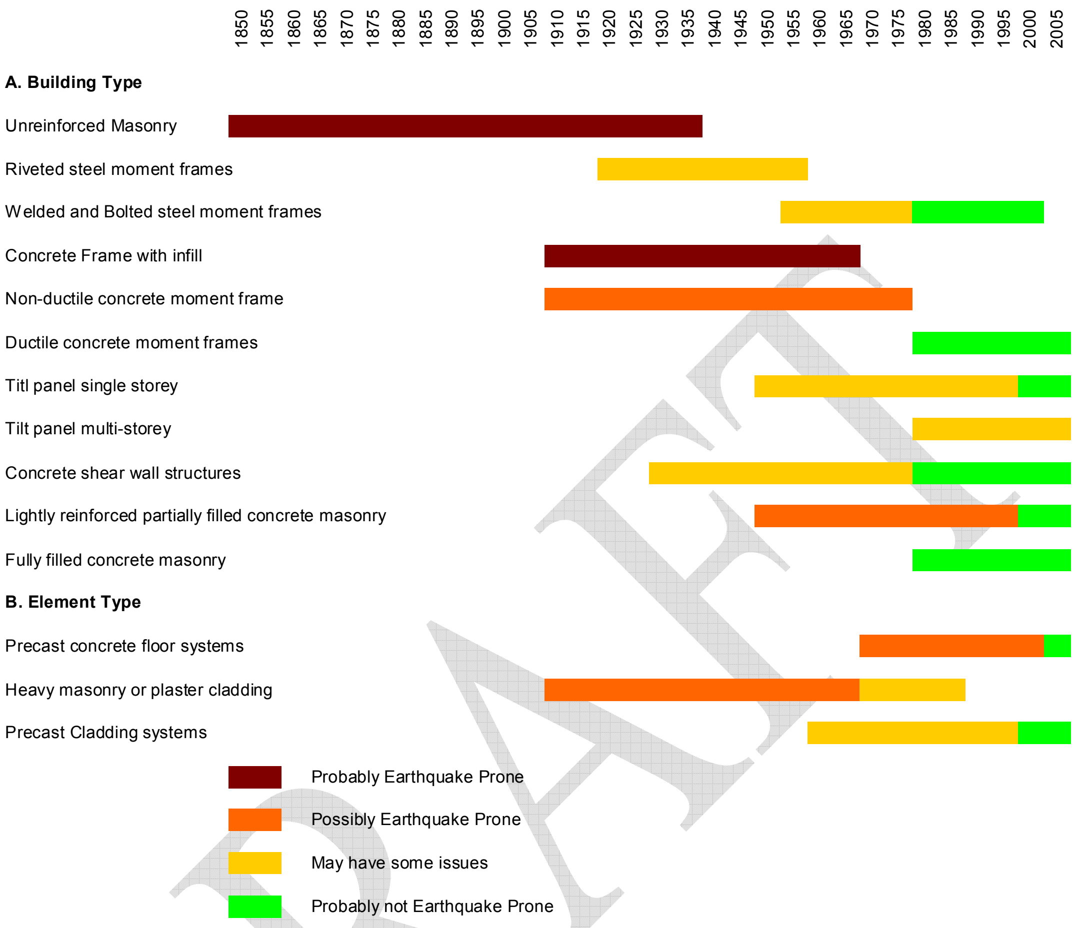

Figure 2-1: Building Types and approximate time of construction

A subjective analysis of the prevalent building and building elements forms Appendix A of Part 2, Detailed Engineering Evaluation Procedures. Each of the systems is described along with potential issues and possible fixes. This is partly based on historic observations of performance and partly from recent observations from the Canterbury earthquakes.

3 METHODS OF ANALYSIS

3.1 Introduction

Analysis of buildings for seismic actions is covered in NZS 1170[ix] as referenced in Section B1 of the NZBC[x]. This has been recently updated by revision to B1 to incorporate revisions to the Seismic Hazard Factor, Z for the Canterbury earthquake region (Christchurch City Council, Selwyn District Council and Waimakiriri District Council).

Under the terms of NZS1170, acceptable methods of analysis include:

- Equivalent Static method (linear elastic)
- Modal Response Spectrum Analysis (linear dynamic)
- Numerical Integration Time History (non-linear dynamic)

Certain limitations are placed on the application of these, according to height, building period and structural regularity.

It is recommended that all of the above methods may be used for the assessment of damaged buildings, with the following comments:

1. All boundary conditions must be considered and addressed in the analysis. In particular, the foundation systems must be identified and modelled appropriately where that would have a significant influence on the behaviour of the building.
2. Due regard must be given to diaphragm flexibility.
3. Due regard must be given to the impact of foundation flexibility, with input form a geotechnical engineer where there is any doubt as to the likely performance or ground conditions.
4. Adequate consideration must be given to the impact of damage from the earthquakes.

A further analysis method that is useful for the analysis of existing and damaged buildings is displacement based design. A simplified method of direct displacement based assessment is presented in section 9 – Reinforced Concrete Wall Buildings.

[ix] Standards New Zealand *NZS1170.5:2004 Structural Design Actions Part 5: Earthquake Actions, New Zealand,* SANZ
[x] New Zealand Building Code, Department of Building and Housing,