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SEISMIC ASSESSMENT OF BUILDINGS IN WELLINGTON: EXPERIENCES AND CHALLENGES

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ABSTRACT :

In response to requirements of the New Zealand Building Act 2004, Wellington City Council (WCC) has developed a comprehensive policy for the identification and improvement of earthquake risk buildings in the city.

As part of the policy WCC is taking a lead to screen pre 1976 buildings using the qualitative, attribute based, rapid assessment Initial Evaluation Procedure prescribed by *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes,* a guideline developed by New Zealand Society for Earthquake Engineering. The plan is to assess all 3,800 buildings within the identified age group which is considered potentially at risk, over a three year period. Approximately 1,100 assessments have now been completed.

The objective is to identify all buildings that are *earthquake-prone*, a term defined in legislation to describe buildings that meet less than 1/3rd of the current earthquake standard for new buildings. The building owners are notified once their building has been identified as potentially earthquake-prone and are given 6 months to provide evidence why the building should not be classified as earthquake-prone. In the absence of contradictory evidence, the building will be designated as earthquake-prone on expiry of this period and the owners will be required to upgrade the building within a timetable that depends on the building's use and importance.

Given the socio-economic implications of the building assessment, and its outcome, WCC has taken a sensitive approach to these assessments and to advising building owners. This paper discusses the approach and methodology adopted by WCC, its implications, and challenges. It records the emerging issues, the steps taken to mitigate these, and the experiences gained in the process.

KEYWORDS: rapid assessment, plans and policies, building act, NZSEE guidelines, city council

1. BACKGROUND

Earthquake standards for buildings in New Zealand, as for many other countries around the world, have developed significantly over the last seventy to eighty years. New Zealand first introduced earthquake design provisions in 1935 but it was not until 1976 that the first modern earthquake standard (NZS, 1976) was introduced requiring explicit consideration of ductility, ductile detailing, factors likely to adversely influence performance during earthquake shaking and capacity design.

A consequence of the gradual improvement of earthquake design standards has been that there are a significant number of older buildings in New Zealand, (built prior to 1976) that have a seismic standard significantly less than would be adopted for new buildings today.

It has been estimated (NZSEE, 2006) that buildings having a seismic resistance less than one third of new building standard (ie. < 33*%NBS*) will subject occupiers to a risk in the order of twenty times greater than for a building fully complying with the current earthquake standard (ie.100*%NBS*). Occupiers of buildings meeting say 67*%NBS* will be exposed to 5 – 10 times the risk.

New Zealand has had legislation covering buildings with expected poor seismic performance in place since 1970, but until 2004 the legislation only covered buildings of unreinforced masonry or concrete. In 2004 a new act of Parliament (NZBA, 2004) broadened the coverage to almost all buildings. Only buildings with relatively few occupants (eg. buildings which are being used wholly or mainly for residential purposes, are less than two stories high and contain less than three household units) are exempt. These buildings tend to be typically of timber construction. An important change in 2004 was requiring seismic performance at a level linked to the current standard. This means that as the earthquake loading standard for new buildings is updated, so is the minimum strength requirements for existing buildings.

The Building Act 2004 (NZBA) defines those buildings with a seismic resistance less than 33*%NBS* as being *earthquake prone*. It also requires that all, 80 Territorial Authorities (local Councils) in New Zealand adopt an *earthquake-prone building* (EPB) policy The policy is required to define the Territorial Authority's approach towards earthquake-prone buildings, and its priorities to mitigate the risk caused by these. It was expected that each Territorial Authority would develop a policy that was focused on its own particular needs based on their priorities, possible socio-economic implications, the benefit/ cost of implementation of the policy, seismicity of the area etc.

As part of the implementation of the NZBA, the New Zealand Department of Building and Housing worked together with the New Zealand Society for Earthquake Engineering (NZSEE) to produce a guideline document outlining recommendations for the assessment of the seismic performance of existing buildings. This document provides guidance for those developing strategies for identifying EPBs and also those assessing existing buildings. It also outlines an initial evaluation procedure (IEP) based on qualitative assessment.

In compliance with the NZBA, and after extensive consultation with structural engineering community and the general public, the Wellington City Council (WCC) developed and adopted a comprehensive policy for the identification of earthquake-prone buildings and time frames for mitigation of the risk (WCC 2006).

2. MAJOR ATTRIBUTES OF THE WELLINGTON CITY COUNCIL POLICY

After consultation, WCC decided to take an active approach to the identification of EPBs by conducting IEP assessments at its own cost. If the IEP assessment indicates that a building has a seismic resistance less than 34*%NBS* it is classified as ***potentially*** earthquake prone. Owners are notified and given 6 months to dispute the WCC IEP assessment by providing further evidence. At the end of this period Council staff will consider all the available technical information and if the building is still determined to be an EPB, the building owners are served with a notice informing them that the building has been classified in terms of the NZBA as an EPB and requiring the building to be strengthened or demolished within a specified time frame. The level of retrofit required is not defined by the NZBA but by implication the minimum required level is 34*%NBS* although the WCC encourages building owners to consider a higher standard. It is building owner's responsibility to strengthen the building at their own cost.

The policy requires the EPB status of the building be held in a register available to the public and to be disclosed in the Land Information Memorandum (LIM) for the property. Copies of the notice are given to those who have an interest in the building, including occupiers, and a copy is affixed to the building The register is updated once the building is retrofitted.

If the IEP assessment indicates a performance greater than 34*%NBS*, WCC accepts that the building is not an

EPB, unless some time in the future further information comes available that suggests otherwise. The WCC has defined a priority level and a time frame for strengthening of buildings based on the importance of the building, and the standard to which the building was constructed or strengthened. Table 1 sets out the adopted scheme. At the time of preparing this paper the WCC is considering altering the timeframes from 5, 10 and 15 years to 10, 15 and 20 years respectively.

Buildings which had been earlier served earthquake-prone building notices under previous legislation have been given shorter time frames.

Table 1 Priority for Assessing and Strengthening Earthquake-Prone Buildings

Importance Level (AS/NZS1170)	**Time Frame for Intervention**		
	Building Age and Condition		
	Pre 1965 Pre NZS1900 (Chapter 8): 1965 Standard	**Pre 1976 NZS1900 (Chapter 8): 1965 Standard**	**Critical Structural Weakness***
1. Low degree of hazard e.g. farm buildings and isolated structures, fences, walls			
2. Not in other categories e.g. most apartment buildings	**10 years**	**15 years**	**15 years**
3. Contain crowds or high value to community e.g. some schools, universities, medical centres	**5 years**	**10 years**	**10 years**
4. Highest priority with post-disaster functions e.g. hospitals, civil defence centre, emergency shelter	**5 years**	**5 years**	**5 years**

* Critical structural weakness is defined as individual buildings built post-1976(NZS4203 structural design code) with an identified detailing deficiency that renders it earthquake-prone.

Heritage buildings are also required to go through the IEP assessment process. However, because of their heritage value, and limitations imposed on how strengthening can be undertaken due to heritage considerations, the WCC may contribute towards their strengthening by providing limited funding on application from building owners.

3. IEP ASSESSMENT METHODOLOGY

The IEP developed by New Zealand Society for Earthquake Engineering (NZSEE, 2006) is an innovative, rapid, attribute based method to screen out earthquake-prone buildings with an acceptable confidence level. The process is based on an exterior visual inspection of the building to identify critical structural weaknesses (CSWs) using sound engineering judgment. The process imposes penalty points for each CSW. Other factors that affect the result are seismicity of the area, local sub-soil type, building construction materials and detailing.

The methodology first compares the complying building standards with the requirements of the current earthquake loading standard, NZS1170.5: 2004 and then identifies various CSWs such as vertical irregularity, plan irregularities, short column problems, pounding, and soil induced hazards. Then the building is rated based on the severity of these CSWs. The procedure also includes a discretion factor for the assessor to compensate if he/she judges the building be over penalized or under penalised by different attributes. The final result is in terms of the percentage of New Building Standard (%*NBS*). The method is such that the “score” can be updated as more information on the building comes to hand, eg after review of the construction drawings.

4. METHODOLOGY FOR SCREENING BUILDINGS

WCC was initially planning to undertake the initial assessment of the building stock within three years. This has now been extended. Following is the methodology adopted and some results from screening of the buildings:

4.1. Desk Study

A desk top study was completed to identify buildings most likely to be categorised as earthquake prone. This concluded that the buildings most at risk were those designed prior to 1976. From its building register, WCC has identified some 3,800 fitting within the NZBA definition that were built or strengthened to design standards pre-1976. A number of these buildings have been previously strengthened to meet former legislative requirements which were at a lower level. A number of these will again be classified as EPBs requiring further retrofit.

4.2. Use of Expertise

WCC has contracted two engineering consultancy firms - which have experience in seismic design, and were part of the team which developed the NZSEE Guideline - to conduct the IEP assessments of the buildings identified by the WCC from the desk study.

4.3. Piloting

Before starting the IEP assessment process, a piloting study was conducted to assess the consistency of approach between the contracted consultants, and to ensure that there was a clear understanding of the issues. The pilot consisted of 19 buildings in 4 different streets with a range of age, construction type and usage. A few buildings which had been previously strengthened were also included in the pilot. Approximately half the buildings were assessed by both Consultants involved. After completion of the pilot assessments, all members of the team met and discussed the results and any issues that arose as a result of the assessments. The objective is to make the process as consistent as possible across all buildings

4.4. IEP Assessment

The WCC provides a copy of the aerial photograph of each building, a summary of the information WCC has researched regarding the site, a list of building consents/permits for that address and whether the work has been completed, information regarding the number of buildings on the site to be assessed (if known), and any other information that could be useful to the consultants for the assessment..

Consultants visit the building from outside, take notes and photographs, identify the CSWs, check the details provided by the WCC regarding building structure, all by visual inspection. An IEP assessment spreadsheet is completed back in the office. Before finalizing and submitting to the WCC, one experienced person reviews all of the IEPs and necessary amendments are made. The IEP results are recorded in the database before submission to WCC.

Sometimes, where the structural system is not clear or the building is too big and complicated, or strengthening has been carried out, the Consultants also review the drawings retrieved from the WCC archive before finalising the assessment.

4.5. Monthly Meetings

A regular monthly meeting is held between WCC and both the Consultants to discuss issues arising, and to sort out these issues. IEP assessments with results in the range 25-35%*NBS* are also discussed at this meeting before finalizing the assessment. Some of the issues that have arisen in the past in the review process are discussed below.

4.6 Results

Out of the 3,800 buildings requiring an IEP assessment, assessment of some 1,100 buildings have been completed at the time of writing this paper. Out of those that have been assessed, 550 have been found to be potentially earthquake-prone (Table 3).

Based on the IEP assessment and collected data, a few general observations that can be drawn are:

- The old part of the business district suffers higher risk because of the large number of unreinforced masonry buildings (URM) and on the presence of deep flexible soils.
- The assessed buildings can be broadly classified into 7 groups according to their structural system and material of construction, as listed in Table 2. Figure 1 presents the distribution of the different building types in Wellington. Reinforced concrete (RC) frame and shear wall buildings are grouped together in the figure. The occupancy includes residential, institutional, commercials etc and is not restricted to building type, however, timber buildings are most common for residential purposes.
- Steel bracing is the most common type of strengthening employed during previous retrofits.
- Most unreinforced masonry (URM) buildings have been confirmed as potentially EPB. URM buildings strengthened to previous requirements of two-third of NZSS1900 Chapter 8 (NZSI, 1965), an earlier requirement, standing on deep flexible soils have also been found to be potentially EPB.
- Wooden buildings generally score well compared to their counter parts, unless they are standing on steep slopes.
- Many buildings in the central business district are potentially susceptible to pounding effects. Pounding has not typically been addressed during past retrofits and this is a further penalty for these buildings.

Table 2 Building Classification

No	Materials	Structural System	Remarks
1	Wood	Light timber frames	1-4 storey high, but mostly limited to 2 storey high
2	Masonry	URM (strengthened or non-strengthened),	1-4 storey high, usually limited to 2-3 storey high, with or without rigid diaphragms
3	Reinforced concrete	Reinforced masonry, load bearing construction	1-4 storey high, usually limited to 2-3 storey high, rigid diaphragms
4		Moment frame construction with masonry infill	1-8 stories high, hollow core slab, light metal roof,
5		Moment frame construction without masonry infill walls	2-14 stories high, hollow core slab, precast infill panels, sometimes ductile detailing seen
6		Shear wall construction	2-14 stories high, hollow core slab, sometimes ductile detailing seen
7	Steel	Moment resisting or braced frames	Mostly industrial sheds

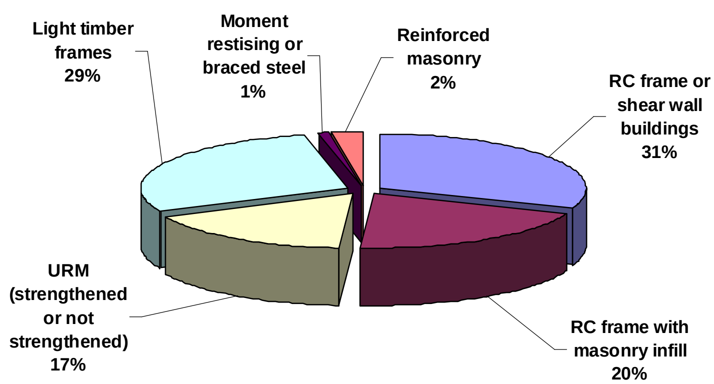

Figure 1: Building typology breakdown

4.7. Advising the Building Owner

The WCC writes to all owners of *potentially EPB's* enclosing the IEP assessment and a brochure explaining the Council's earthquake-prone building policy. Owners are invited in the ensuing six months to provide any information, specific to their building, that may affect the initial evaluation. The WCC intentionally uses the word "potential" to reflect that the initial assessment is based (typically) on only external observation of the building and it is possible that further information, unknown to the WCC assessor will show that the building is not earthquake-prone.

4.8. IEP Follow-ups

Once notified that their building is a potential EPB, it is building owner's responsibility to provide more information to WCC if they want to challenge the assessment of their building. Some property owners have been very prompt in forwarding WCC information regarding their building. This is particularly noticeable when the building in question is for sale. The WCC then generally forwards this information to the Consultant who did the initial IEP assessment for advice on whether the issues have been addressed. If further discussion is required, WCC organizes a meeting between WCC, the building owner and/or their professional advisors, and the Consultant who undertook the original IEP assessment to discuss the issues and the level of information required. The range of responses received by 30 June 2008 is shown in Table 3.

4.9. Avoiding Conflict of Interest

The WCC does not prevent the Consultant who did the IEP from working for the building-owner when responding to the WCC assessment, however, if this occurs, the review of the response is carried out by the other Consultant to avoid a conflict of interest. The Consultants are free to decline to carry out the IEP assessment of any building for the WCC on the grounds of previous interest in the building or for any other reason. This has helped protect independence of the Consultants. Council staff make the final decision as to whether a building is EPB or not.

Table 3 Analysis of Potentially Earthquake-prone Building Responses

Total number of IEPs completed	1118
Number of building identified as potential EPB	550
Number of buildings where information received or time extension requested by the owner	258
Number of buildings where information received demonstrating that the building is unlikely to be EPB	46
Number of buildings where no response received within 6 months	251
Number of building served EPB notices	42

5. ISSUES AND CHALLENGES

During the course of completing the IEP assessments to date, many issues have arisen that were not foreseen during the development of the NZSEE Guidelines. These issues and how they have been tackled are discussed below:

5.1. A Commentary on the IEP Process

The NZSEE Guidelines provides broad criteria for identification of structural deficiencies; however, it does not elaborate how these should be interpreted during the field work. This caused some non-uniformity among the building assessors. To mitigate this problem, and ease the process, a commentary on IEP assessment methodology has been developed.

5.2. Pounding

Pounding has become a major issue in many areas of the city, particularly in the urban areas, as there was no requirement for a gap between adjacent buildings before 1976. Though the problem of pounding is amplified by mixed construction, unequal building and storey heights, the methodology does not apply a penalty if the structural system, height of adjoining buildings and floor height are similar. There seems no universally accepted methodology to quantify the level of risk imposed by pounding.

It has been observed in earthquakes that buildings within a row suffer relatively less damage than the buildings at the end of the row. However, during the IEP assessment buildings within a row are also being penalized. This is because the circumstances could change if adjoining buildings are demolished for any reason in the future.

5.3. Chimneys

Many old buildings have unreinforced chimneys. The NZSEE Guideline does not specifically address this issue. However, it is recognised that the chimneys could pose significant risk to life safety to the occupants of the building given the right circumstances.

5.4. Multi Use Buildings

There are cases when a large building has been subdivided involving separate occupancies. If one part is commercial, it could be assessed and identified as being an earthquake-prone building if it achieved a score less than 34%*NBS,* whereas another part could be a single residential unit and would not be assessed and therefore the owner would not be notified. The implication is that one building owner would be required to strengthen part of the building but other owner would not be required to do so by law. By just strengthening one part of the building, the performance of the building as a whole might be inferior to that if no retrofit had been carried out.

5.5. Socio-Economic Issues

As part of the process outlined, many building owners have now been notified that their building is potentially earthquake-prone. This notice has panicked many. It is understandably concerning for a building owner to learn that the building they live in or a building they own is classified in this way. Of course it will be an economic burden to many of the building owners because these buildings may need upgrading or at least consultation with an engineer to challenge the potentially EPB status.

Many URM buildings have previously been strengthened to two thirds of NZSS 1900, Chapter 8 (NZSI, 1965) as required by previous legislation and regulations. Owners in many cases have spent significant sums to strengthen the building to comply with previous legislation. It is distressing for them to know that the building which was strengthened just few years previously, is again an EPB and they have to spend yet again a significant amount of money to revoke this status.

WCC which is also an owner of a large number of building that could be earthquake prone has recognised that the original time frames for addressing seismic issues may be too short. As noted above, a proposal to extend the time frames given in Table 1 is currently under consideration.

5.6. Social Engineering if Pounding an Issue

A solution to the problem of pounding could be found by tying adjoining buildings together if the structural system and floor height permit. The major hurdle to this solution is that both adjoining building owners will need to reach agreement and this will prove to be difficult, particularly when one of the buildings is not EPB.

6. LESSONS LEARNT

- ***Potential Buyers Eager to Know about Building Status:*** A heightened awareness about the strength of buildings and their seismic performance has been observed in the general population particularly potential buyers.

- **Consistency is important:** The IEP assessment methodology requires an assessor to make many subjective judgments. A robust system of verification of results, consistency checks, cross checks, and continuous discussion among the assessors is required to avoid such inconsistencies.

- **Communication:** Face to face discussion with the building owner and/ or their engineers helps develop mutual understanding and to resolve issues promptly.

- **EPB Register:** The very act of identifying EPBs will improve the occupiers' understanding of seismic risk and allow them to make informed decisions.

CONCLUSION

The paper has discussed the earthquake-prone building policy adopted by the Wellington City Council. It has also discussed the basis behind the formation of this policy. This policy can be debated from different perspectives, however it should be accepted that the screening out of weaker buildings is the first step towards mitigation of the risk, as it raises awareness of the issue among building owners and occupiers.

The paper also presented the issues, challenges, and experience gained during the screening process, the implications of this issue and how these were resolved. The authors believe that these experiences would be useful for others involved or contemplating similar activities in other parts of the world.

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