EARTHQUAKE RISK (PRONE) BUILDINGS – THE GISBORNE EXPERIENCE

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SUMMARY

Recent completion of the Earthquake Risk (Prone) survey of unreinforced masonry buildings in the Gisborne District provides an opportunity to review the results achieved and, bearing in mind the re-draft of the Red Book, reflect on observed behaviour of local buildings in two "moderate" or close to "moderate" earthquakes. This paper gives a brief summary of the results of the Gisborne survey then discusses some of the actual damage sustained by the unreinforced masonry building stock in comparison with ground accelerations recorded in the 1966 "Gisborne" and 1993 "Ormond" earthquakes. Further comparison is made against theoretical loadings as represented by the 1965 and current design codes, and strengths as represented by the "Red Book" and its successor. The paper concludes with comment on the Earthquake Risk (Prone) Buildings survey process and "capture" threshold strength levels to be embodied in future legislative changes.

INTRODUCTION

Gisborne District Council, as a "unitary authority", is charged with administering the regulatory functions normally undertaken by a Regional Council, in addition to the normal functions of a "territorial" local authority. To enable this dual role to be accomplished, the Environment & Planning Department of GDC is kept separate both politically and functionally from the other departments.

Administering the regulatory requirements of the Local Government Act and now the Building Act is therefore a function of the Environment & Planning Department whose Chief Building Inspector, Mr G W Lodge (now retired), undertook this responsibility. The author acted as consultant structural adviser to the Chief Building Inspector throughout the Gisborne District Earthquake Risk (Prone) Buildings assessment and notification programme which began in 1982 and was completed in September 1995.

This programme, being part of Council's regulatory role, depends very much on the letter of the law as embodied in Acts of Parliament. It therefore requires a very different approach in the assessment and classification of a building, to that taken by a consultant in devising remedial works required to rehabilitate a building under the Guidelines published by the NZNSEE, once the building has been classified.

HISTORY

Following the 1966 Gisborne earthquake, the former Gisborne City Council obtained ministerial consent to invoke the emergency provisions of Section 624 of the Local Government Act (1974) in order to remove the immediate danger of the severely damaged brick buildings in the City. These sadly included the old Post Office and the Gisborne Opera House, launching pad for Sir Robert Kerridge's fame and fortune. It was not until 1983 that an initial survey in Gisborne City identified 140 buildings as being potential "Earthquake Risk Buildings". In March 1989 the City Council adopted a series of recommendations invoking the full powers of Section 624 requiring the owners of earthquake risk buildings to remove the danger by demolition or strengthening. The time frames included a time to carry out "interim securing" work and a time for demolition or full "strengthening" to meet modern code requirements. These time frames were based on the provisions of the NZ National Society for Earthquake Engineering's "Recommendations and Guidelines for Classifying, Interim Securing and Strengthening" [December 1985], commonly known as the "Red Book".

THE CLASSIFICATION PROCESS

Under the above NZNSEE Recommendations, Earthquake Risk (Prone) Buildings are classified on the basis of:

(a) Structure
(b) Occupancy

The structural assessment was carried out in Gisborne by reviewing drawings and inspecting each building for deterioration of materials, alterations not shown on drawings, and accumulated damage due to ground movement, weathering and previous earthquakes etc. An assessment, either calculated or by its known performance in recorded earthquake events, was made as to whether or not the structure would withstand "Moderate Earthquake" loadings, i.e. up to half those of NZSS

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1900 Chapter 8 (the old design loadings code introduced in 1965). One of the most important benchmarks in this assessment was the extent of damage sustained in the 0.28 g ground accelerations of the 1966 Gisborne quake. Equally it was quickly recognised that with a Seismic Force Factor 'K' of 4 from Table 5B of NZS 1900 Ch. 8, parapets were the key parts of buildings to check. If the building's strength was greater than the ½ NZSS 1900 Chapter 8 benchmark, it did not come within the scope of the Earthquake Risk (Prone) Buildings legislation and was automatically eliminated from further consideration. If less than the benchmark, a Structural Points Rating was completed and an Occupancy Classification made.

The Occupancy Classification takes into account the number of people (determined by owner/tenant interview) likely to be put at risk by a building, the number of hours the building is occupied in a normal week, and the size (floor area) of the building, to determine an "Occupancy Intensity" rating. The resulting Occupancy Classification has a far greater influence on the time-frames for Interim Securing and Strengthening than does the Structural Rating.

Sixty-five buildings were assessed and classified under the provisions of Section 624 of the LGA and the NZNSEE Guidelines and of these, peer review of twelve classifications was carried out by Works Consultancy, Napier.

A few typical buildings are shown in Figures 1-3.

LEGISLATIVE CHANGES

The Building Act 1991 implemented from 1 July 1992, appeared to bring with it a fundamental change in the intent of Earthquake Risk (now "Prone") Building legislation, by introducing to its EPB definition the words *"likely to suffer catastrophic collapse causing bodily injury or death"* in lieu of the words *"likely to constitute a danger to persons"* as in the ERB definition of Section 624(3) of the old Local Government Act. The new emphasis on *"catastrophic collapse"* brought with it a reduced time of 10 days for owners to object to notices, down from 60 days in the original legislation.

Effectively this change in wording meant that many buildings that would have been (and had been) included as "Earthquake Risks" under the previous legislation would be excluded under the "Earthquake Prone" legislation. The change also meant that the supporting effect of adjacent buildings or groups of buildings had to be taken into account in determining whether a particular building was likely to suffer catastrophic collapse or not.

To determine why the wording of Section 66 of the Building Act differs from that under Section 624 of the Local Government Act, clarification was sought from the Building Industry Authority (BIA). The personal opinion from its legal adviser was that if determinations were carried out on a building using both pieces of legislation it was not considered that there would be any difference in the outcome.

FIGURE 1 MASONIC HOTEL (built 1900-1929). First building assessed in Gisborne (1982); comprises 5 building complex; major strengthening after 1966 Gisborne earthquake

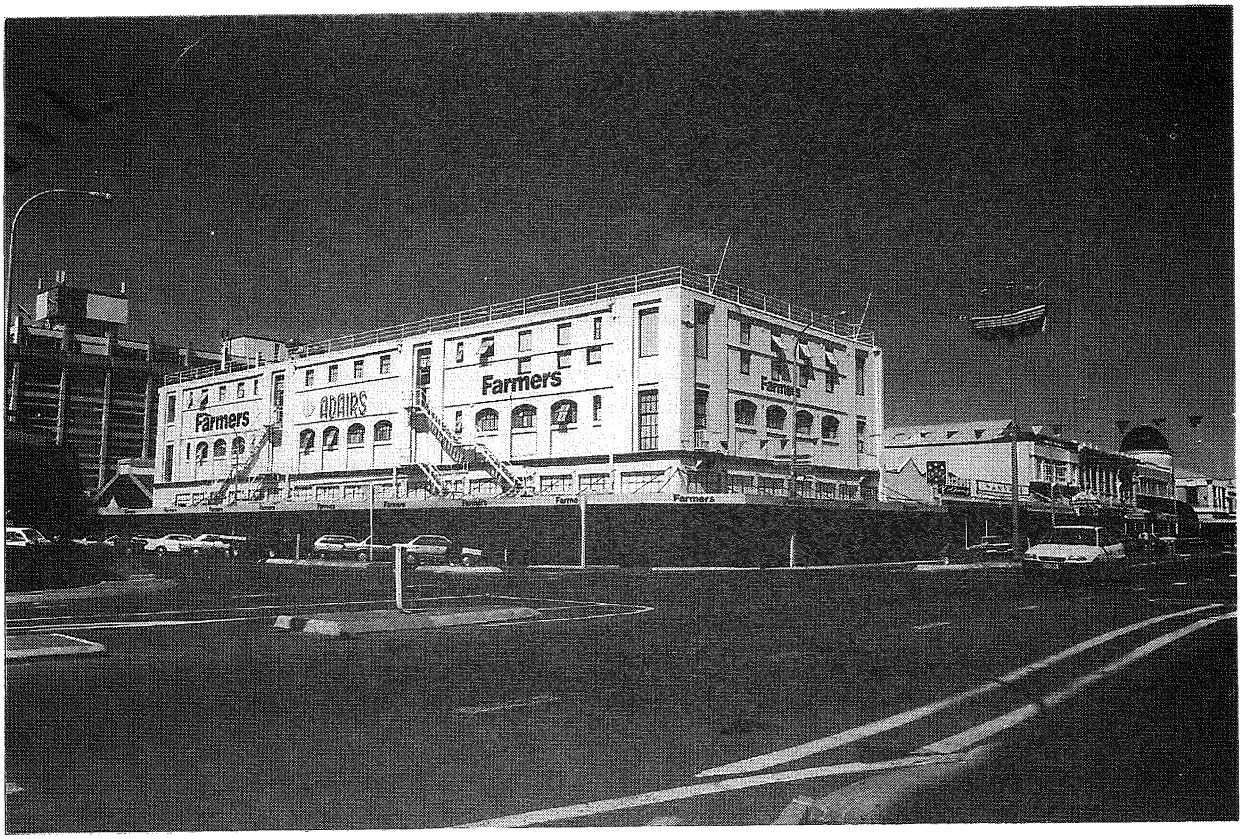

FIGURE 2 FARMERS/ADAIRS (built 1923-29). Major strengthening after 1966 earthquake; further strengthened during 1993 refurbishment on take-over by Farmers

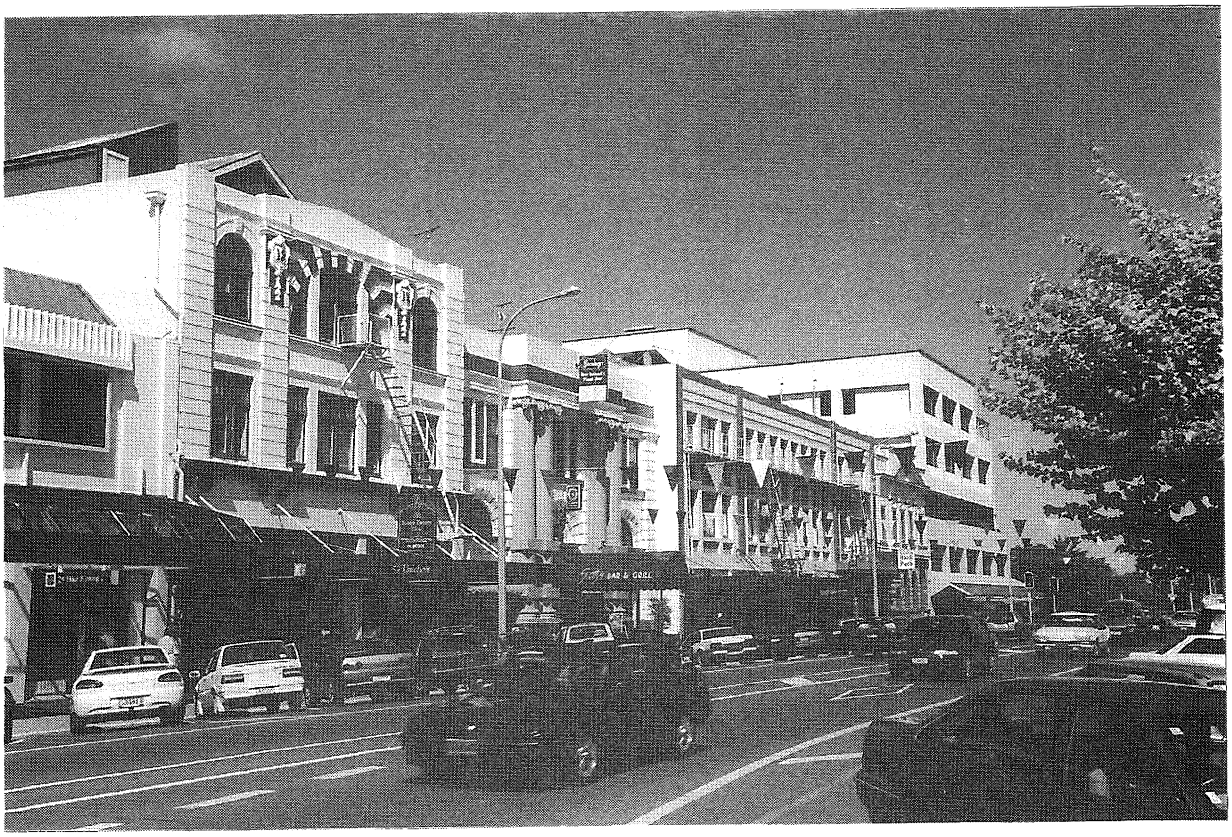

FIGURE 3 GLADSTONE ROAD HISTORIC PRECINCT (built 1909-1916). Category II Historic Places Trust classification; 4 ERB's no EPB's; Eastern Co-op building (No. 9-11) second from far end, adjacent to Quay Pt bldg (1988)

If this were so, then one can only consider that the rewording of the replacement legislation was meant to clarify the intent of the old legislation, i.e. it is only those buildings that are likely to suffer *"catastrophic collapse causing bodily injury or death"* in a moderate earthquake that can be subject to a notice to remove the danger.

Subsequent to the BIA opinion, and considerable controversy at national level over the GDC interpretation of Section 66 of the Building Act, the NZNSEE has "reluctantly" agreed that the GDC interpretation of Section 66 of the Building Act 1991 is legally correct, if not the most desirable outcome. The relationship between earthquake risk (ERB) and prone (EPB) buildings is shown in Figure 4 where it can be seen that EPBs are a subset of ERBs.

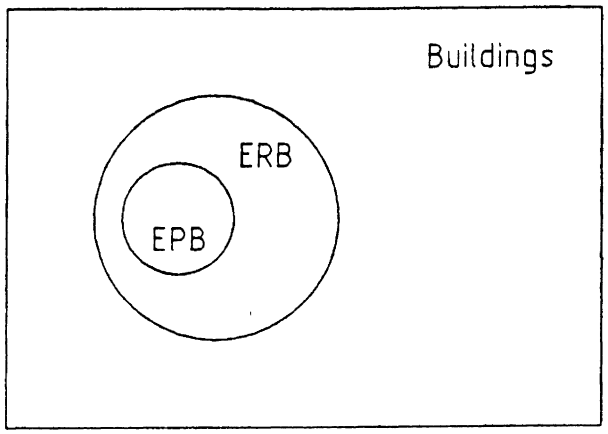

FIGURE 4 Relationship between earthquake risk and earthquake prone buildings [from NZNSEE, 1995]

APPLICATION OF SECTION 66 OF THE BUILDING ACT 1991 TO GISBORNE BUILDINGS

As a result of the above legislation, it was concluded that Earthquake Prone Building Notices could only be issued for buildings with major deficiencies which may lead to *"catastrophic collapse causing bodily injury or death"* under a *"moderate earthquake"*.

In Gisborne, the March 1966 quake (MMVI-VII, Peak Ground Acceleration 0.28 'g' in NE-SW direction) [1] exceeded *"moderate earthquake"* levels (4 x .06 'g' = .24 g for parapets) in the direction of the major axis (NE-SW) for all parts of a building and the August 1993 quake came close to it. (MMV-VI, PGA 0.22 'g') [2]. It could be claimed that those buildings still standing have been tested to *"moderate earthquake"* standard in that direction (parallel to Peel Street) and have survived. That could not be said, however, for the NW-SE direction quake (0.22 'g' 1966 and 0.19 'g' 1993 respectively). This is the direction most critical for Gladstone Road (main street) buildings as a whole and for parapets fronting Peel and the other side streets. As evidenced by parapet damage in the 1993 quake, it is expected that there are still parapets in Gisborne likely to suffer partial collapse in a "moderate earthquake" in the NW-SE direction.

It is likely that Gisborne is unique in New Zealand in being able to compare theoretical design assumptions against two well documented seismic events and these comparisons will be developed later in this paper.

THE DILEMMA OF THE 2-STAGE UPGRADING PROCESS

At the time of implementation of the Building Act, GDC staff processing the Earthquake Risk Buildings inspection, classification and issuing of notices had become dissatisfied with the second stage requirements of strengthening according to the "Red Book", following on from the Interim Securing first stage of upgrading. The reason for this dissatisfaction had been that a reasonably sound building with just one portion not able to withstand the forces of a moderate earthquake would be locked into a full upgrading process (over time) up to modern design code standards, a process which was likely to be very expensive or economically prohibitive. An adjacent similar building, just able to withstand the forces of a moderate earthquake as defined in the Acts, could remain as is with no upgrading required. It is still our contention that this 2-stage upgrading process is excessive and that a single stage of "Securing" to $^{2}/_{3}$ NZSS 1900 Chapter 8 (i.e. just over ½ NZSS 1900 Chapter 8), sufficient to withstand a *"moderate earthquake"* as defined in both the Local Government Act and Building Acts, would be much more equitable in addressing Earthquake Prone Buildings under the current legislation.

In my opinion, the more effective tool for requiring full strengthening appears to be Section 46 of the Building Act. (refer also B J Brown [3]). Under this section, structural upgrading becomes part of the economic viability equation for a change of use at the owner's or purchaser's behest. Sooner or later (most likely within the time frames specified in the "Red Book") and with "securing" in place under Section 66, an old unreinforced masonry building will no longer be economically viable without a change of use requiring structural upgrading or, alternatively, demolition and redevelopment.

THE MAY 1994 CHANGES TO GISBORNE'S EARTHQUAKE PRONE BUILDINGS POLICY

Three factors were evident from the above discussions:

1. The 2-stage upgrading requirements were excessively onerous on building owners. (In a provincial centre like Gisborne owners are often Family Trusts or individuals rather than nationwide corporates).

2. Some buildings already issued with Earthquake Risk Building notices would not come within the jurisdiction of the new Earthquake Prone Buildings legislation.

3. Not all parts of all buildings in Gisborne had been tested by natural events to "moderate earthquake" standards.

To redress these findings, the following recommendations, in essence, were put to Council, May 1994, and adopted, to:

(a) Delete the second stage requirement of "strengthening" to modern code standards.

(b) Retain a requirement to "Secure" to ½ NZSS 1900 Chapter 8 with a recommendation to secure to $^2/_3$ NZSS 1900 Chapter 8.

(c) Review all notices issued to date to comply with the new legislation.

(d) Continue with the inspection and assessment of unreinforced masonry buildings not yet assessed in order to establish a uniform assessment over all of Gisborne's unreinforced masonry (commercial) buildings.

It was at the time of developing these policies in response to the apparent (and now confirmed) legal meaning of Section 66 of the Building Act 1991, that the controversy over No. 9-11 Gladstone Road arose, the ex Eastern Co-op Building Society building. Early in 1994 a verbal opinion had been given that the building was an **ERB**, based on a preliminary inspection and the assumption that the provisions of Section 624 of the LGA had been re-embodied in Section 66 of the Building Act 1991. This enquiry sparked an in-depth investigation of the wording of Section 66 and the development of the above policy changes prior to advising the owner that the building was then not considered to be an **EPB**. Rather than causing the owner some relief as would normally be the case, this reversal became the subject of an appeal to the Planning Tribunal [4], 14 & 15 August 1995, as the owner wished to use the ERB classification as a lever to enable him to demolish the building against a Preservation Order on the building as part of an "Historic Precinct". The EPB classification and Preservation Order were both upheld.

RESULTS OF THE GISBORNE DISTRICT EPB SURVEY

Following the May 1994 change in policy, the review of all previously issued notices was completed a month ahead of schedule in November 1994. The final completion of assessment and notification of all potentially earthquake prone buildings in the District was completed in September 1995, approximately two months behind schedule due to the number of buildings requiring inspection in outlying areas trebling from the number previously anticipated. Final statistics are shown in Table A.

COMPARISON OF ACTUAL *vs* THEORETICAL EARTHQUAKE RESISTANCE OF BUILDINGS

The legal definition of a moderate earthquake according to both pieces of legislation cited above is *"an earthquake that would subject a building to seismic forces one-half as great as those specified in NZS 1900 Chapter 8:1965"*. From that NZ Standard, the basic seismic loading coefficient for the Gisborne region is 0.12 g, i.e. Zone 'A'. Although Section 66 of the Building Act does not mention "parts of a building" (a fundamental difference from the previous legislation), it is appropriate to investigate parts of buildings as well as the building as a whole when making an assessment of its earthquake resisting capabilities. Again from NZS 1900 Chapter 8, the factors for parts of a building include:

Table 'A' Gisborne District EPB Survey Results

A. Gisborne City	
No. of Buildings issued with Earthquake Prone notices	30
No. of Buildings demolished during process of survey	13
No. of Buildings secured during process of survey	10
No. of Buildings structurally upgraded during process of survey	5
Total No. of Gisborne City buildings assessed	149
B. Outlying District	
No. of Buildings issued with Earthquake Prone notices	4
No. of Buildings demolished during process of survey	-
No. of Buildings secured during process of survey	-
No. of Buildings derelict/disused	5
Total No. of Outlying buildings assessed	29
Total No. of Buildings assessed in survey	**178**

1.0 for the structure/frame as a whole;
2.0 for infill panels; and
4.0 for cantilevered parapets.

½ NZS 1900 Chapter 8:1965 loadings therefore amount to:

½ x 0.12 g x 1.0 = 0.06 g for the structure as a whole;
½ x 0.12 g x 2.0 = 0.12 g for infill panels;
½ x 0.12 g x 4.0 = 0.24 g for cantilevered parapets.

By comparison, NZS 4203 (1984) requires an amplification factor of 1.8 x C_d giving a parapet loading of 1.08 'g', and the current design code NZS 4203 (1992) requires an amplification factor of 2.0 x C_h giving a loading of 1.28 'g' for parapets on multi-storey buildings (2-4 storeys) in the Gisborne region (see Figure 5).

Applying the above loadings and amplification factors to typical brick parapets of 1, 1½ and 2 bricks thickness, theoretical stable parapet height limits based on simple stability analysis assuming no tensile capacity in the mortar, would be as shown in Table B. Actual 1966 Gisborne and 1993 Ormond quake effects are also related to known heights of parapets left intact having survived these two seismic events, and these are compared with the above theoretical stable heights. The amplification factors cited for both NZS 4203 codes and the 1966 and 1993 events are subject to variation according to interpretation of a number of variables but have been cited as "middle of the road" values. It would be useful to obtain readings from strong motion recorders located in the yard and on the ground and top floors of a 3-storey unreinforced masonry building in Gisborne to enable comparison of the response of a non-ductile structure against the relatively ductile Post Office building.

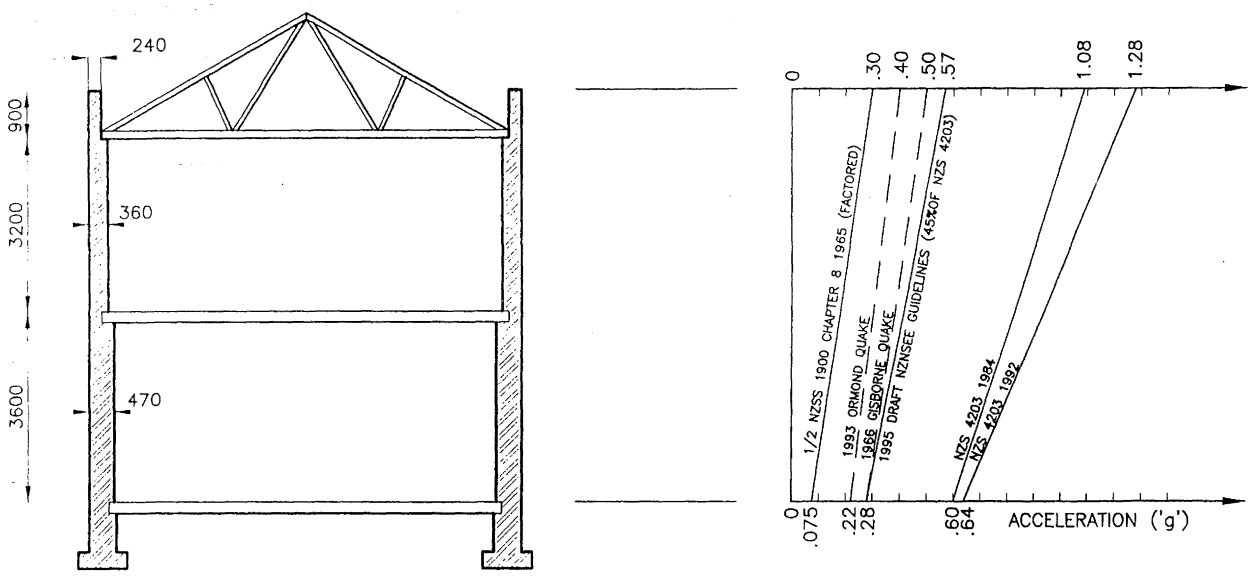

FIGURE 5 Typical Earthquake Risk building: comparison of lateral accelerations applied by design codes versus accelerations derived from measured ground accelerations during the 1996 Gisborne and 1993 Ormond earthquakes.

Table B Maximum Theoretical Stable Parapet Height

	Loading			Parapet Thickness		
Design Code/Event	Basic	Factor	Part	1 brick + plaster (240 mm)	1½ bricks + plaster (340 mm)	2 bricks + plaster (460 mm)
½ NZSS 1900 Ch. 8 (1965)	0.06 'g'	4	0.24 'g'	0.85 m	1.20 m	1.80 m
NZS 4203 (1984)	0.60 'g'	1.8	1.08 'g'	0.19 m	0.27 m	0.40 m
NZS 4203 (1992)	0.64 'g'	2.0	1.28 'g'	0.16 m	0.23 m	0.34 m
	P.G.A.+					
1966 Gisborne Quake	0.28 'g'	1.8*	0.50 'g'	> 1.5 m**	> 1.6 m**	1.8 m
1993 Ormond Quake	0.22 'g'	1.8*	0.40 'g'	> 1.5 m**	> 1.6 m**	1.8 m

\+ Peak Ground Acceleration.

* An amplification factor of 1.8 was estimated in 1993 for the top of the six storey Post Office structure (a ductile reinforced concrete frame building); based on actual strong motion recorder readings [2].

** Highest known parapets surviving on Gisborne buildings through these events.

CONCLUSIONS

From the above comparisons it is clear that the actual performance of the low to medium rise (up to 4 storeys) brick buildings in Gisborne is generally considerably better than what would be expected from calculations based on past and present design codes. While I have not attempted to assess what might happen to these buildings in seismic events of longer duration, conclusions that could be drawn from the above observations include:

1. That considerable additional strength exists in unreinforced masonry than is currently recognised in assessment procedures, e.g.

   (i) Support from adjacent buildings similar in height and construction (but note this would not apply to street front parapets).

   (ii) Mechanical interlocking of brickwork providing some effective tensile capacity.

   (iii) Pseudo-ductility of loosened brickwork with mechanical interlock.

2. That the loadings imposed by the 1966 Gisborne quake (MMVI-VII) are roughly equivalent to the full 1965 design code.

3. That surviving unreinforced masonry buildings in Gisborne have been tested at least to the threshold seismic loading specified under Section 66 of the Building Act and therefore EPB notices can only be issued to those buildings showing accumulated damage or exhibiting exceptional soft-storey or eccentricity effects, e.g. corner buildings.

4. That the current design loadings code is not really applicable to relatively low rise non-ductile unreinforced masonry structures without modification specific to these buildings. Suitable code modifications can and are being embodied in the revised NZNSEE Draft Guidelines for Assessing and Strengthening Earthquake Risk Buildings" [NZNSEE, 1995].

PROGNOSIS OF FUTURE REQUIREMENTS

Future requirements for assessment and monitoring of Earthquake Prone Buildings in the Gisborne District will be governed by three factors:

(i) Ongoing monitoring of securing/demolition activity in accordance with the requirements of Section 66 of the Building Act 1991 and the Earthquake Prone Building requisitions issued through the survey just completed.

(ii) Monitoring and reassessment of buildings made vulnerable by the removal/re-development of adjacent buildings/sites.

(iii) Reassessment of the unreinforced masonry building stock in the light of likely future upgrading of Earthquake Prone Buildings legislation.

From the mid 1980's, rumblings in building/engineering circles have indicated that an upgrading of the ½ NZSS 1900:1965 Chapter 8 Design Loadings Code threshold level for earthquake risk buildings legislation is likely to be progressively introduced. Structural damage sustained during recent Californian and Edgecumbe earthquakes suggested that even the loading levels specified in the NZS 4203:1984 Loadings Code were not going to be adequate. Since then, further experience gained from the North Ridge (California) quake, the Edgecumbe, Weber, and Ormond (NZ) quakes and the Kobe (Japan) quake, together with a change in structural design philosophy from allowable working stress to material strength limit state design, has resulted in a stabilisation of loadings for many structures under the new NZS 4203:1992 Loadings Code.

Notwithstanding this consolidation of loading requirements, it is now widely recognised that the relaxation in the definition for Earthquake Prone Buildings brought about by Section 66 of the Building Act (1991) in lieu of Section 624 of the Local Government Act (1974) was both unintended and undesirable. A review of the Section 66 legislation is currently underway and due for the first draft to be reported back to the Minister of Internal Affairs by mid-1996. Concurrently the NZ National Society for Earthquake Engineering "Red Book" is being revised and the draft {NZNSEE, 1995] has been circulated for comment. In my opinion, this is a much improved set of Guidelines for Assessing and Strengthening Earthquake Risk Buildings and incorporates many lessons learned from 10 years of applying the original guidelines.

In summary, it is inevitable that a revised Section 66 of the Building Act will be legislated for within the next two to three years, and that the parameters of this legislation will be at least as tough as, if not tougher than, the original Section 624 of the Local Government Act. When the new legislation is passed GDC, along with most other local authorities throughout New Zealand, will be obliged to reassess its unreinforced masonry building stock in accordance with that legislation.

Until then the ongoing monitoring of notices issued and monitoring of redevelopment sites will be continued in the Gisborne District. The format of GDC Land Information Memorandum (LIM) forms has been modified to facilitate this monitoring by including a section on ERB's to bring the presence of notices issued to the notice of prospective purchasers of Earthquake Risk (Prone) Buildings.

ACKNOWLEDGEMENTS

Special thanks are due to Mr Gary Lodge, retired Chief Building Inspector, Gisborne District Council, who worked tirelessly and co-operatively with the author over more than a decade in assessing the unreinforced masonry buildings of the Gisborne District. Thanks are also due to Mr Bill Turner, Manager, Engineering & Works, GDC, for allowing the preparation and presentation of this paper.

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