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Spectra Limited
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Attention: Bevan Meddings
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Dear Bevan

RADIO NETWORK BUILDING, 106 GEORGE ST, DUNEDIN
DETAILED SEISMIC ANALYSIS

We have carried out a detailed structural analysis of the Radio Network Building, which makes up part of Westpac House 106 George St, Dunedin. The three storey structure was built in 1987 as an addition to the original seven storey building built in 1965. It is a separate building to the main building being separated by a 50mm gap on floors 1 & 2 and by 10mm on the ground floor.

Analysis Results

We have found that the building achieves **100%NBS** earthquake resistance.
There is an element in the building that will fail under earthquake loading that is less than the earthquake loadings determined from NZS1170.5 the current earthquake loadings standard. Failure

We advise that the connections of rafters in the roof to the stringers on the walls or steel beam supports will fail at shaking that is less than current earthquake standard.

Failure of these elements will not cause building collapse and thus do not affect the %NBS rating of the building but the roof could suffer significant damage and allow the ingress of water in the interim between damage occurring and repair being carried out.

Building and Analysis

Our review is based on obtained copies of the original 1987 structural drawings. The geotechnical conditions at the site are well described on the construction drawings from boreholes carried out for design.

The building is situated on what was once the Otago Harbour foreshore. It is constructed on wide shallow foundation beams which are founded upon approximately 9m of volcanic loess over a thin layer of harbour floor mud over basalt cobbles and boulders in a sand matrix.

The building model included provision in the supports to represent the foundation materials supporting the building.

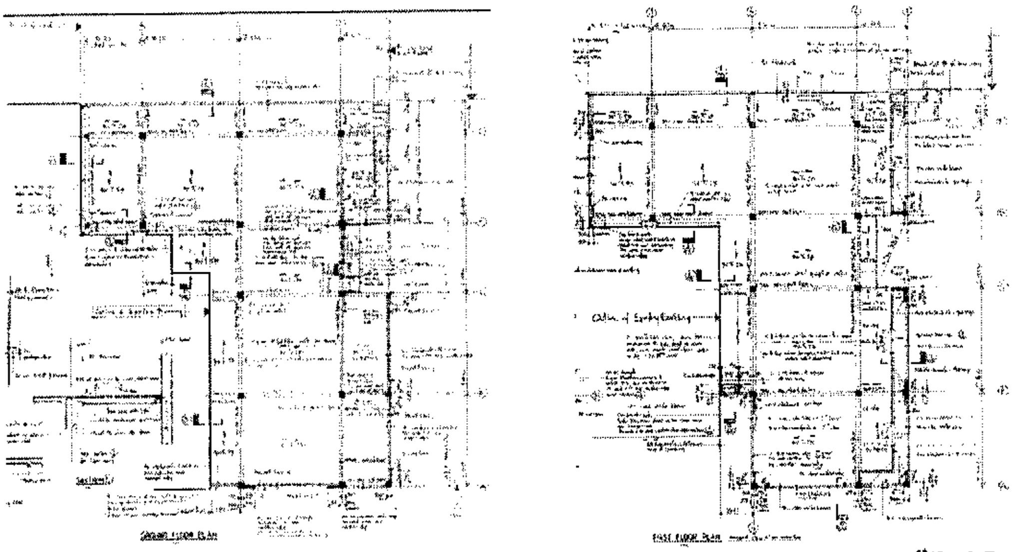

Figure 1: Excerpt from the original construction drawings showing the ground and 1st/2nd floor layout of the building. The offset column can be seen on the ground floor plan at grid 4D.The hole for the separate stairwell structure can be seen on the 1st floor plan between grid points 1C-2D.

The structure was modelled using structural analysis software called ETABS and subjected to the loading regimes set out in AS/NZS1170, which the current New Zealand design loadings Standard.

The building was analysed by the 'modal response spectrum method' as set out in NZS1170.5 Earthquake Actions.

Material strengths and stiffnesses used were as specified in the New Zealand Society for Earthquake Engineering (NZSEE) document "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes", June 2006.

Dunedin shares the lowest probability in New Zealand of experiencing the design earthquake loading, and is thus assigned the lowest 'Z factor' value of Z = 0.13 allowed in NZS1170.5. This means that the accelerations and therefore the forces applied to buildings here are relatively low in a New Zealand context.

The minimum code requirements are to preserve life and to prevent collapse rather than to ensure further use of the building. It is possible that even if a structure remains standing after a large earthquake, that there may be a large amount of damage and the structure may be on a lean and require demolition after the earthquake. Design according to current codes is to ensure "life-safety" rather than to protect the building for further use.

Meaning of %NBS

The Building Code provides for new office buildings with a design working life of 50 years as category (IL2) to have "Ultimate Limit State" (ULS) strength to meet a 1 in 500 year earthquake demand and "Serviceability Limit State" (SLS) strength to meet a 1 in 25 year earthquake demand.

Relatively frequent earthquakes with minor ground shaking, such as those described for Serviceability Limit, should not interfere with building functionality. This means that no damage needing repair should occur to either the structural or non- structural elements.

At the Ultimate Limit State, substantial damage is allowed, such as unrecoverable displacement or cracking, as long as there is a margin against collapse and appropriately low life-safety risk.

Buildings are generally required by legislation to have a minimum design life of 50 years. The chance of a 1 in 500-year event being exceeded in any 50-year period is approximately 10%.

The following table by NZSEE provides the basis of a proposed grading system for existing buildings, as one way of interpreting the %NBS building score. It can be seen that *Earthquake Prone* buildings (%NBS less than 33%) have more than 10 times the risk of collapse than a similar new building. And for buildings that are potentially *Earthquake Risk* (67%≥%NBS≥33%), the risk of collapse is 10 to 5 times greater than that of an equivalent new building. Broad descriptions of the life-safety risk can be assigned to these building Grades accordingly.

Relative Earthquake Risk

Building Grade	Percentage of New Building Strength (%NBS)	Approx. Risk Relative to a New Building	Risk Description
A+	≥100	≤1	low risk
A	80 to 100	1 or 2 times	low risk
B	67 to 80	2 or 5 times	low or medium risk
C	33 to 67	5 to 10 times	medium risk
D	20 to 33	10 to 25 times	high risk
E	≤20	more than 25 times	very high risk

Results

1. Inter-story drift is the difference horizontal movement between two adjacent floors of a building in an earthquake.The accurate estimation of inter-story drift ratio and its distribution up the height of the structure is critical for seismic performance evaluation purposes since the structural damage is directly related to the inter-story drift.

   The current provisions in NZS1170.5 limit inter-story drift to 2.5% of the storey height between any two adjacent floor levels. The interstorey drifts in Radio Network House under current Standard earthquake loading are around 0.6%; well within the 2.5% limit between any two adjacent floor levels from NZS1170.5.

   NZS 1170.5 requires that earthquake attack from two perpendicular directions be examined and this was carried out for the Radio Network House analysis. The building experiences almost equal displacements during north/south or east/west earthquake directions with displacements on the top floors being of the order of 5mm with interstorey drift of around 0.6%, compared to the 2.5% limit in NZS1170.5.

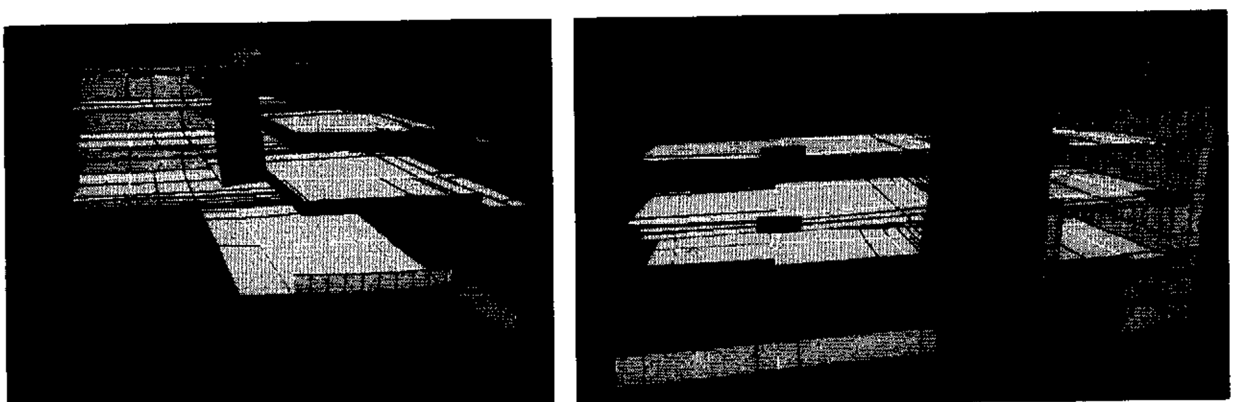

Figure 2: Showing two views of the 1987 addition to Radio Network House with exaggerated deformation under north/south earthquake shaking, which is the worst for both earthquake directions.

2. When two buildings are located close to each other, they may hit each other during strong earthquake shaking, causing damage. This effect is called pounding. Theoretically, if the two buildings have the same characteristics, then under the same earthquake motions they should move together, in phase, without hitting, in the same way that windscreen wipers on a car move together.

However, due to different foundation conditions, different structural types and differing building heights, buildings seldom have the same characteristics.
Pounding will not occur during a design level earthquake, if the distance between the buildings is greater than the sum of the maximum displacements of each building alone. The computed maximum displacement of each building is affected by assumptions, about the structural stiffnesses and the soil conditions, which affect the length of time for the structure to complete one sway back and forth.

The stair well on the east side (Blackett Lane) of the building has been built as a separate entity to the remainder of the building. It is shown as separated by 33mm on the construction drawings.

Clearly the concrete frame main building and the tall slender walled stairwell will have different stiffness characteristics and will thus not sway in time with each other. The gap on Floors 1 and 2 around the stair well is 33mm on the north and south sides and 20mm on the west side.
The total displacements that are estimated to occur at the top levels of the building under full NZS1170.5 earthquake loading are around 2.5mm for the main block and 2.5mm for the stair well. In theory then the two structures should not pound into each other in a design level earthquake.

The calculated displacements of the floors of the building indicate that no pounding should occur between Radio Network House and the adjoining Westpac House building. The buildings are separated by a 50mm seismic gap with a steel sliding plate cover over the gap. Displacements under NZS 1170.5 earthquake loading for this Dunedin building are in the order of 5mm.

3. At grid position 4-D on the plans in the basement a column has been positioned so that it is offset from the columns above it to accommodate an existing pilecap of the 1965 building. A consequence of this is that in addition to the flexural forces in the column imposed by lateral earthquake loading further flexure is imposed by the vertical load from the columns above being applied at an eccentricity from the centre of the lower column. The presence of this column contributed to the IEP %NBS rating that this building achieved on its initial investigation. Detailed analysis of the building has shown that the capacity of the column to resist the combined flexural forces is over 100% of that required to resist full current Standard earthquake loading.

4. A potential critical structural weakness that buildings may possess, that has been brought to the forefront by the Christchurch earthquake is the vulnerability of the stairs to collapse preventing egress from the building even though it may remain standing post-earthquake.

   We have assessed the performance of the stairs as recommended by the Department of Building & Housing in accordance with the Report to the Royal Commission on Stairs and Access Ramps between Floors in Multi-storey Buildings.

   The stairs in this building are of precast concrete construction and are only tied to the building at the landings. The stairs were included in the ETABS model and their connection forces to the landings assessed. The precast stairs have steel angles cast into their ends which are welded to steel angles cast into the landings. The welds have sufficient strength to remain intact during earthquake shaking to code levels. The interstorey drifts under earthquake loading are not large enough to cause failure at the stair connection to the landing.

5. The building has a light timber framed steel roof. The roof has rafters which are connected to Westpac House along its eastern wall. Under earthquake loading the rafters are subjected to tensile loading which is greater than the capacity of their connections to their supports. Failure of the rafter connections will not cause failure of the building so does not lower the %NBS rating of the building but we recommend that rafter connection strengthening be carried out to avoid damage occurring to the roof at a relatively low degree of earthquake shaking. The existing connection detail for the rafters is via a multigrip plate, connected in such a way that it will offer little resistance to tensile forces in the rafter. A satisfactory connection could be achieved by fitting pairs of Lumberlok CT160 cleats at each rafter/stringer connection.

Conclusion

The building has an assessed %NBS score of **100%NBS** and would therefore be a Grade A+ building, which is regarded as exposing the occupants to **low risk** of earthquake damage.

We recommend providing an improved connection detail between the outrigger rafters in the roof and their supporting stringers on the east and west sides of the building.

Our opinion of the stair details is that they do not represent a critical structural weakness in the building.

For further information please do not hesitate to call me.

Yours faithfully
Hanlon and Partners Ltd

Lyndsay McGrannachan
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Structural Engineer