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Spectra Limited
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Dunedin 9054

Attention: Bevan Meddings
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Dear Bevan

WESTPAC HOUSE, 106 GEORGE ST, DUNEDIN
DETAILED SEISMIC ANALYSIS

We have carried out a detailed structural analysis of Westpac House 106 George St, Dunedin. The eight storey building was built in 1965 with a three storey structure built in 1987. The additional three storey building is separated from the main building being separated by a 50mm gap on floors 1 & 2 and by 10mm on the ground floor has been analysed and reported on independently.

Analysis Results

We have found that the building achieves **100%NBS** earthquake resistance.

Building and Analysis

Our review is based on obtained copies of the original 1965 structural drawings. The geotechnical conditions at the site are well described on the construction drawings from boreholes carried out for design.
The building has a strong central core comprising the stair well and lift shafts with columns on the corners of the core. Tapered prestressed concrete beams extend out to the east and west from the central core supporting floors constructed from prestressed concrete floor beams overlain with a cast insitu topping to form a stiff diaphragm attached to the central core at each level. Columns on the north and south faces of the building also support tapered prestressed concrete beams and hence the floors.

The building is situated on what was once the Otago Harbour foreshore. The central core and main load bearing columns are supported on steel encased concrete piles that extend some 17m down to a stiff layer of volcanic cobbles in a clay matrix.
The shops and banking areas and basement surrounding the central core are constructed on 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.

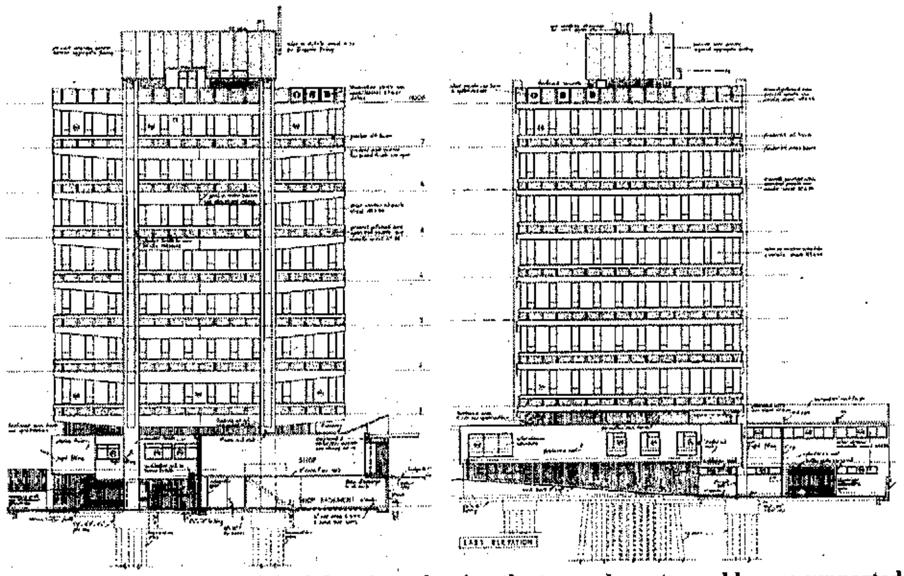

Figure 1: Excerpt from the original drawings showing the tapered prestressed beams supported by the exterior columns over their piled foundations. The east elevation shows the piled foundation support for the central core.

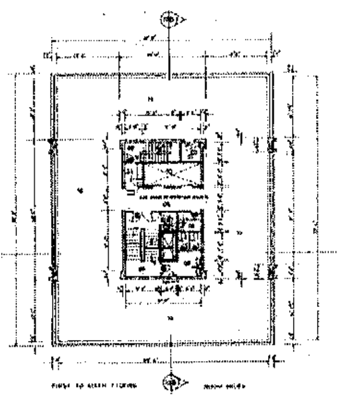

Figure 2: Showing the floor layout. The central stairwell/lift shaft provides stiff shearwalls that provide the buildings strength to resist lateral earthquake and wind forces.

The structure was modelled using structural analysis software called ETABS and subjected to the loading regimes set out in AS/NZS1170, which is 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 in 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 Westpac House under current Standard earthquake loading are around 0.8%; 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 Westpac House analysis. The building experiences almost twice the displacement during a north/south direction earthquake with 25mm displacement at roof level and 13mm at roof level for an east/west earthquake direction with corresponding interstorey drift of around 0.8% north/south and 0.4% east/west, compared to the 2.5% limit in NZS1170.5.
   The reason for this is that the central core is almost twice the length in the east/ west direction than the north/south direction providing a larger area of shearwall for lateral displacement resistance. The exterior perimeter columns are also twice as stiff in the east/ west direction than the north/south direction.

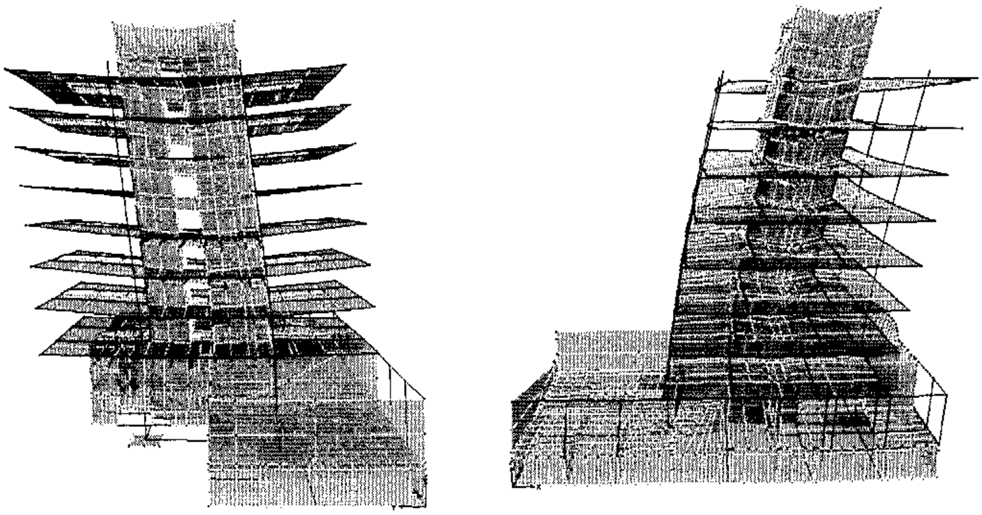

Figure 3: Showing two views of Westpac House with exaggerated displacement under earthquake loading. The left hand view is east/west earthquake loading viewed from north. The right hand view is north/south earthquake loading viewed from west.

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 calculated displacements of the floors of the building indicate that no pounding should occur between Westpac House building and the adjoining Radio Network House. 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 3.5mm for an east/west direction earthquake and 6mm for a north/south direction earthquake at the height of the top floor of Radio Network House. Added to the previously calculated displacements of 5mm for both directions for Radio Network House the combined displacements are less than the seismic gap provided between the two buildings.

3. 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 were precast with exposed reinforcing extending out their ends to be included in the 'cast in-situ' stair landings and are only tied to the building at the landings. The stairs were included in the ETABS model and their capacity to resist the connection force to the landings and the stairs own flexural strength capacity was assessed.

The reinforcing provides 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.

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.

Our opinion of the stair details is that they do not represent a critical structural weakness in the building under current earthquake loading for Dunedin.

For further information please do not hesitate to call me.

Yours faithfully
Hanlon and Partners Ltd

Lyndsay McGrannachan
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Structural Engineer