HANLON AND PARTNERS LTD
CONSULTING STRUCTURAL & FIRE ENGINEERS
BI Chisholm BE MIPENZ IntPE CPEng (Civil & Structural)

219 HIGH STREET, DUNEDIN
Ph: 03 4777-475 Fax: 03 479 2597
Email: office @ hanlons.co.nz

29 June 2012

Spectra Limited
P.O. Box 613
Dunedin 9054

Attention: Bevan Meddings
bevan@spectra.net.nz

Dear Bevan

JOHN WICKLIFFE HOUSE – 265 PRINCES ST, DUNEDIN
DETAILED SEISMIC ANALYSIS

We have carried out a detailed structural analysis of John Wickliffe house, 265 Princes St, Dunedin –at your request.

Conclusion

John Wickliffe House and its stairs have 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.

Building and Analysis

Our review is based on obtained copies of the original 1975 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 piles that are founded at varying depths, dependant on the occurrence of a layer of hard gravels at around 12m below basement floor level. From the bottom of the piles to the bottom of the bore holes, at around18m, there are no liquefiable soils. Volcanic materials occur below the gravels and there is unlikely to be liquefiable soils below that.
There is information in the literature that indicates that the confining effects of 15m to 20m thickness of overburden material would prevent theoretical liquefaction below that depth from affecting surface founded structures and inducing settlement.

The building is in fact four individual buildings that are separated by a “seismic gap” around each of the four blocks but share piled foundation blocks between them. The buildings are separated by 25mm up to level 2 and then by 75mm for the remainder of their height.

Blocks A, B and D are concrete frame structures of concrete beams and columns with ‘cast insitu’ concrete floors spanning between the beams. Block C, which is essentially the lift shaft and main stair well for the building has concrete walls between the columns which stiffens the structure compared to being open between the columns. Most of the other walls in the building are partition walls that do not add to the structural strength of the building.

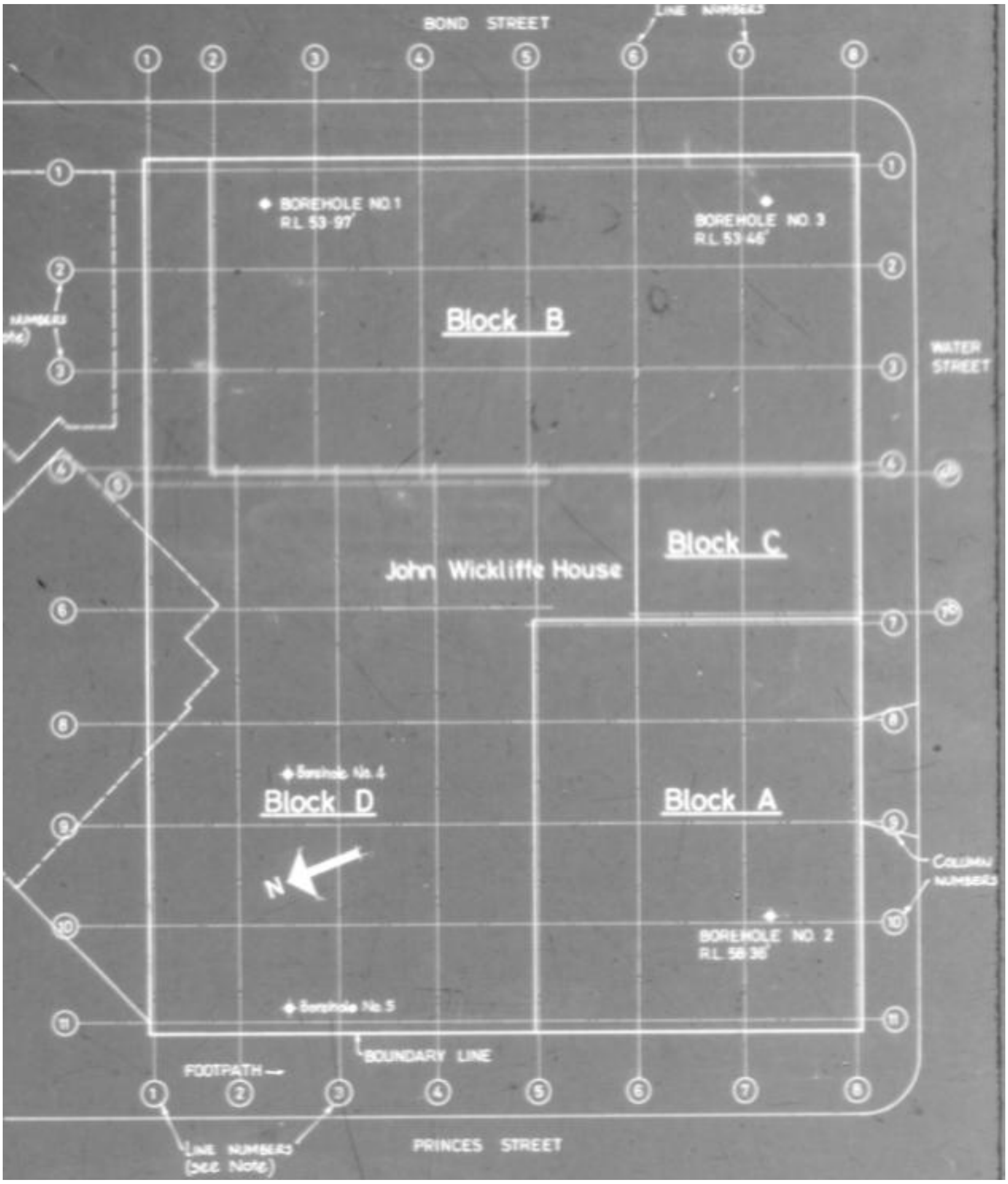


Figure 1: Excerpt from the original construction drawings showing the layout of the separate blocks. The blocks are referenced thus in the following text.

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. It also means that load combinations, other than earthquake loading, prescribed in past and current Loadings Standards govern the strength design of buildings, and the buildings have sufficient strength for earthquake loading from the other more onerous design requirements.

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 John Wickliffe House under current Standard earthquake loading are around 0.5%; 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 John Wickliffe 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 100mm with interstorey drift of around 0.5%, compared to the 2.5%

limit in NZS1170.5.

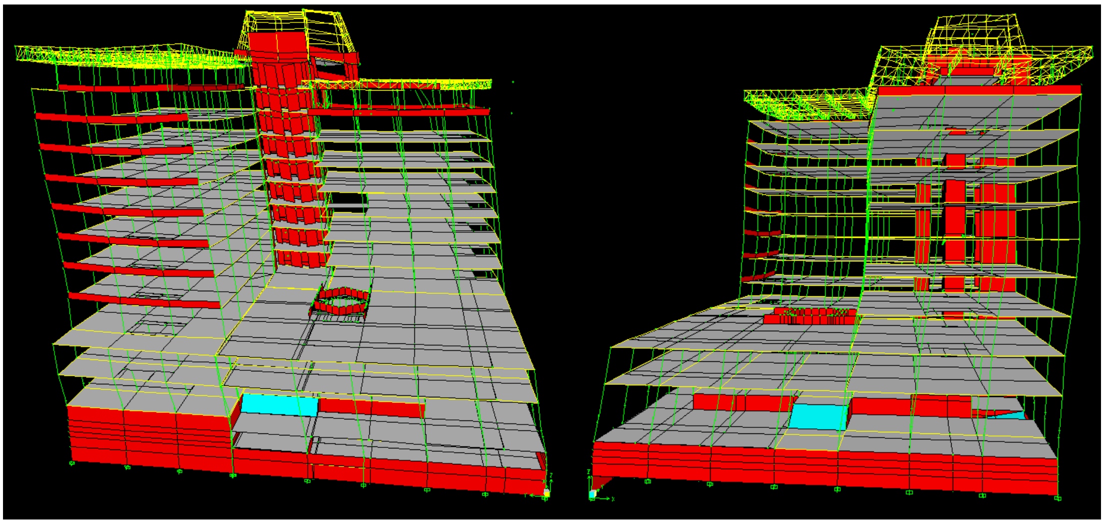


Figure 2: Showing two views of John Wickliffe House with exaggerated deformation under east/west earthquake shaking on the left and north/south earthquake shaking on the right.

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.

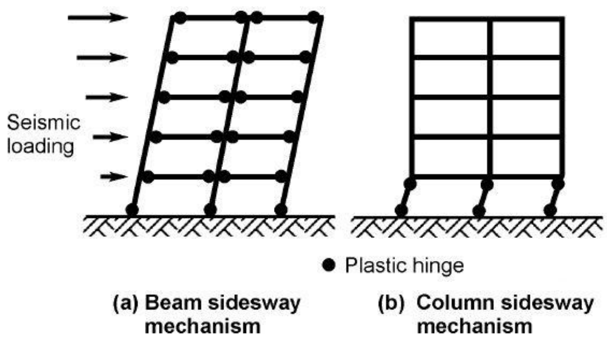
   The “seismic gap” from floor 2 to floor 10 around the separate blocks that make up John Wickliffe House is 75mm. The total displacements that are estimated to occur at the top levels of the building under full NZS1170.5 earthquake loading are around 100mm for Block B and 120mm for Blocks A and C. Because of the different shape orientation and size of the blocks that make up John Wickliffe House it is very unlikely that they will vibrate together ‘in phase’. The conclusion must then be that pounding will occur between the blocks in a design level earthquake.

   The worst situation with pounding buildings is when the floor levels in each building are different and the columns of one building are hit at mid height, breaking the columns and causing the storey to collapse. This is not the case at John Wickliffe House where all the blocks floors are at the same levels. Concrete crushing and breaking during impact can be expected to occur and jolting will be felt from the impact. The pounding should not cause collapse of the building.

3. It is evident from the earthquake demand / capacity ratios for the various elements of the building that a form of ‘capacity design’ has been carried out in the design of the building members.

   In the capacity design of structures design ‘hinges’ are allowed to form in places that will not cause building collapse and the members are made stronger in the places where hinge formation would lead to collapse of the building. Where the hinges are allowed to form special measures are taken to ensure the members stay intact and hold up the building, allowing the occupants to escape.

In the diagram below the frame with the beam sidesway mechanism will not collapse with the formation of plastic hinges where they are indicated but the column sidesway mechanism will.



The capacity/demand (c/d) ratio of the various members throughout the building gives an indication of which members will fail before the others under a set loading, eg the 1170.5 design earthquake loading. A capacity/demand ratio greater than 1 means the member will not fail under that loading and less than 1 means that failure will occur. Members with a lower c/d ratio will fail before those with a higher c/d ratio.

In John Wickliffe House the beams have been designed such that they have a lower c/d ratio than the columns meaning that a beam sidesway mechanism will be likely to form rather than the column mechanism. This means that although members in the building may have failed, collapse is avoided and the occupants are able to escape.

The analysis shows that the beams do have sufficient strength to resist the current earthquake loading (around 120%) and their c/d ratio is lower than most of the columns which all have a c/d ratio greater than 2.0 leading to the conclusion that capacity design has been undertaken.

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 steel construction and will remain intact during earthquake shaking. 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.

For further information please do not hesitate to call me.
Yours faithfully
Hanlon and Partners Ltd

Lyndsay McGrannachan
BE (Hons), BSc, PG Dip, CPEng, MIPENZ