



Dunedin law courts – seismic strengthening and refurbishment

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ABSTRACT

In the immediate aftermath of the Christchurch Earthquake sequence, the Crown set about reassessing its heritage buildings that were in public use to determine both the potential risks and the resilience of the buildings. The Dunedin Law Courts is a building seen as holding an essential function (of legal process) after a seismic event and the number of users required a high Importance Level. The response was to strengthen the building to a level well in excess of the minimum for heritage buildings. Key features of the solution included strengthening of the tower, jet grouted piles under the tower, insertion of a concrete diaphragm at the sub ground level, tying the masonry work together as a whole using diaphragms at each floor level and the roof level with FRP tendons and sheet reinforcement and featuring concealed structural steel support of the tourelle features. Each of the structural solutions was carefully engineered and located so their effects on the heritage fabric were minimised and the work was hidden from view. The end result reflects careful coordination with all design team members, including incorporation of its iconic heritage value.

1 PROJECT OBJECTIVES

The Dunedin Law Courts, built in 1902, was designed prior to the establishment of any formal New Zealand seismic design provisions. (typically, only buildings built in Wellington before 1935 considered any form of seismic design). Since then, there have been considerable advances in the field of earthquake engineering and these new codified requirements will impact on any proposed additions or major alterations which constitute a “change of use”.

The local authorities require the buildings under these classifications to be brought up to “as near as reasonably practical” to current standards, as set out in the New Zealand Building Code (2000). Per Dunedin City Council’s current Earthquake-prone Buildings Policy, the council will accept 67%NBS, or better, of the current design code for a new building built on the site as being “reasonably practicable”.

The building has been considered as an Importance Level 3 (IL3) building as described in NZS1170.0, and as required by the Ministry of Justice, due to its heritage status.

1.1 Structural Design to Support the Project Outcomes

The structural strengthening design of the building supports the Client's project outcomes in a number of ways:

- Improvement of the seismic capacity of the existing structure to at least 70%NBS for IL3
- Strengthening works concealed under replaced architectural finishes
- The new structure to not change the general layout or appearance of the existing building, particularly the exterior of the building and to areas deemed to have significant heritage value

1.2 Scope of Design

The specific works the Ministry required to be undertaken to the building included the following:

- Seismic strengthening of the building
- Allowance for liquefaction and lateral spreading
- Securing parapets and ornamentation
- Provision of roof and ceiling diaphragms and to provide diaphragm connections
- Seismic strengthening of the tower
- Providing additional structural elements to the building to carry the calculated loads in discrete areas of the building
- Strengthening of existing masonry shear walls
- Tying the exterior leaf of masonry to the interior leaf
- Courtroom floor strengthening
- Coordinating with the design team to minimise disruption to the existing building fabric and make good to all disturbed surfaces

2 BUILDING DESCRIPTION

2.1 Building Description

Dunedin Law Courts is an existing 2-3 storey building situated at 1 Stuart Street, Dunedin. The building was constructed in 1902, is fairly regular in plan, with dimensions of approximately 32m x 56m, and stands at a height of about nine metres to the first floor ceiling. The ground floor contains lobbies, security areas, offices, restrooms, and court rooms with two-floor high stud ceilings. The first floor houses judges' chambers, offices, a library, breakroom, and restrooms.

Wall construction materials include unreinforced masonry (URM) brick for interior walls, 2-4 leaves in thickness. Exterior walls primarily consist of an interior layer of unreinforced brick, an air cavity, with a combination of unreinforced Breccia and Oamaru limestone for the exterior layer. The exterior boasts several large limestone ornamentations hanging proud of the face of the building at the first floor level, at the bottom of roof trusses, as well as, at the top of some of the roof ridges. Roofs are constructed of timber trusses with timber sarking and clad with slate tiles. Foundations are typically unreinforced concrete strip footings below the unreinforced block walls and isolated unreinforced brick piers which support the ground floor timber framing.

A 4-story URM brick and Oamaru stone tower integrated within the main structure is located at the Northern end of the building.

The building is classified as a Category 1 heritage structure.



Figure 1: Photo of northern exterior of the Dunedin Law Court Building.

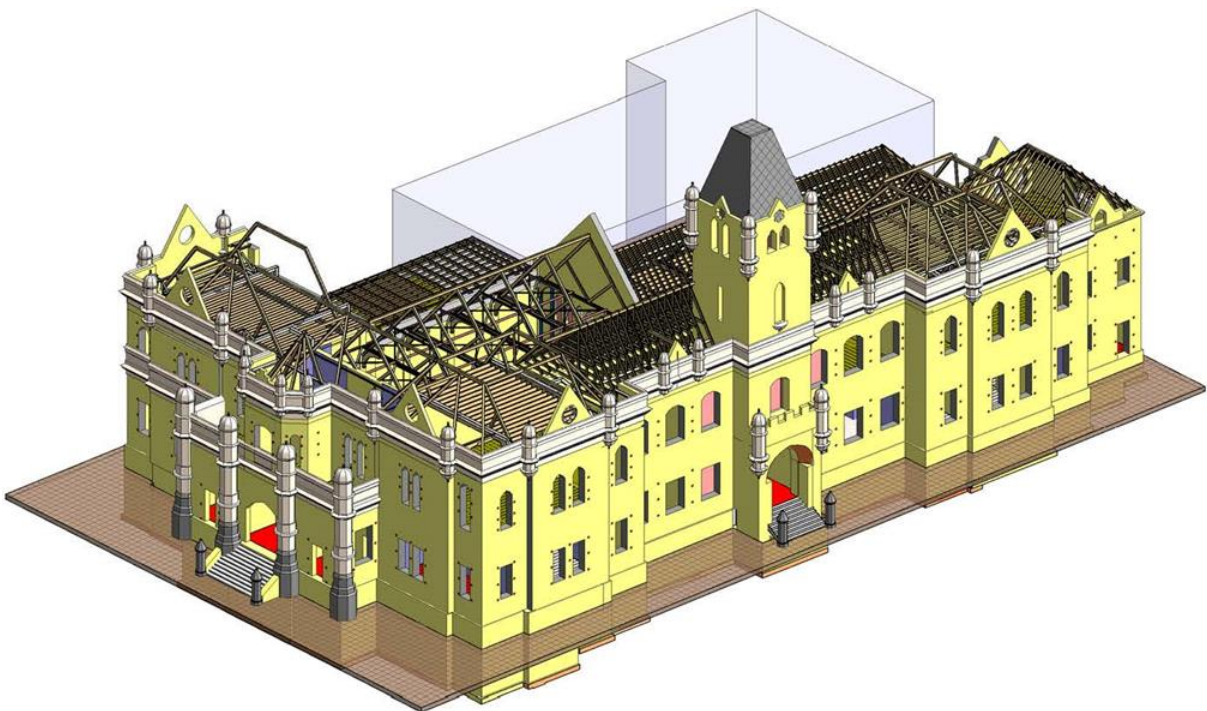


Figure 2: 3D REVIT model showing the general structural form of the Dunedin Law Courts.

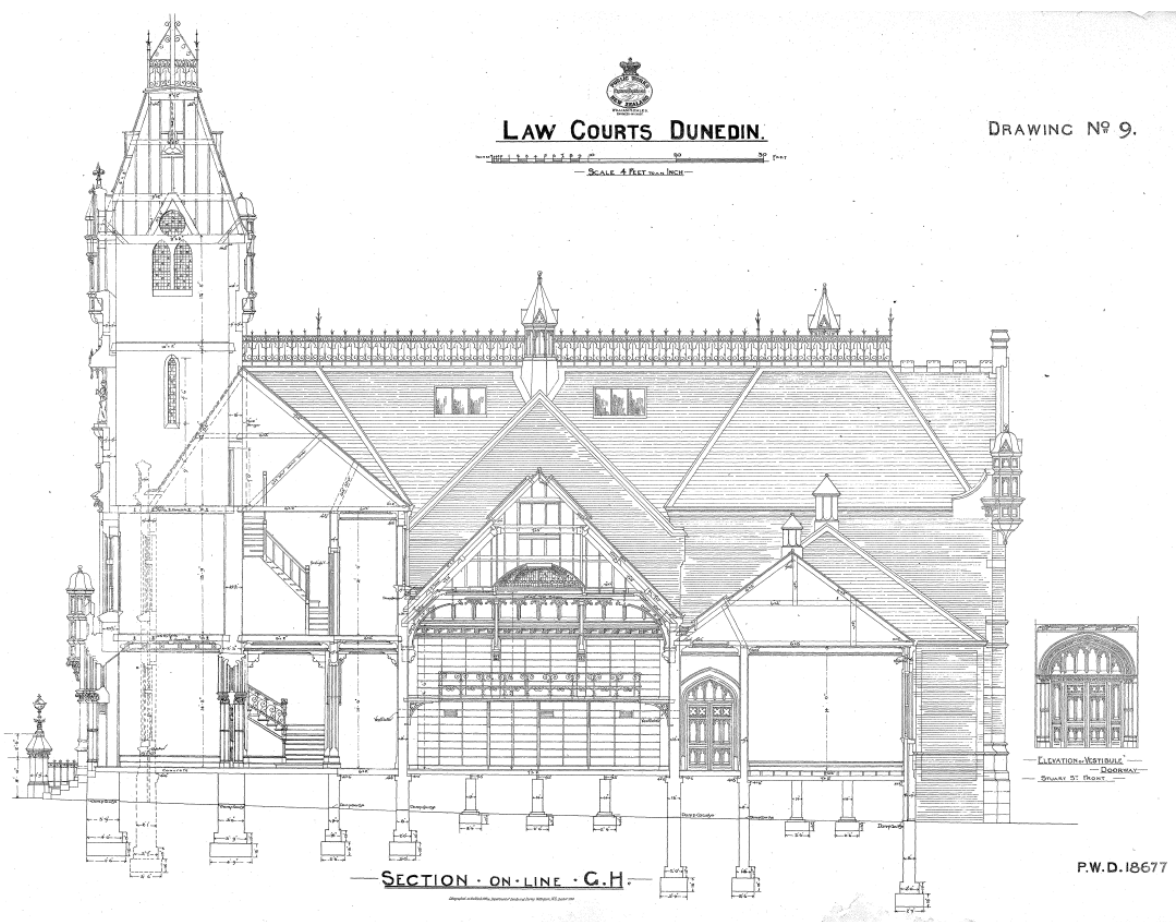
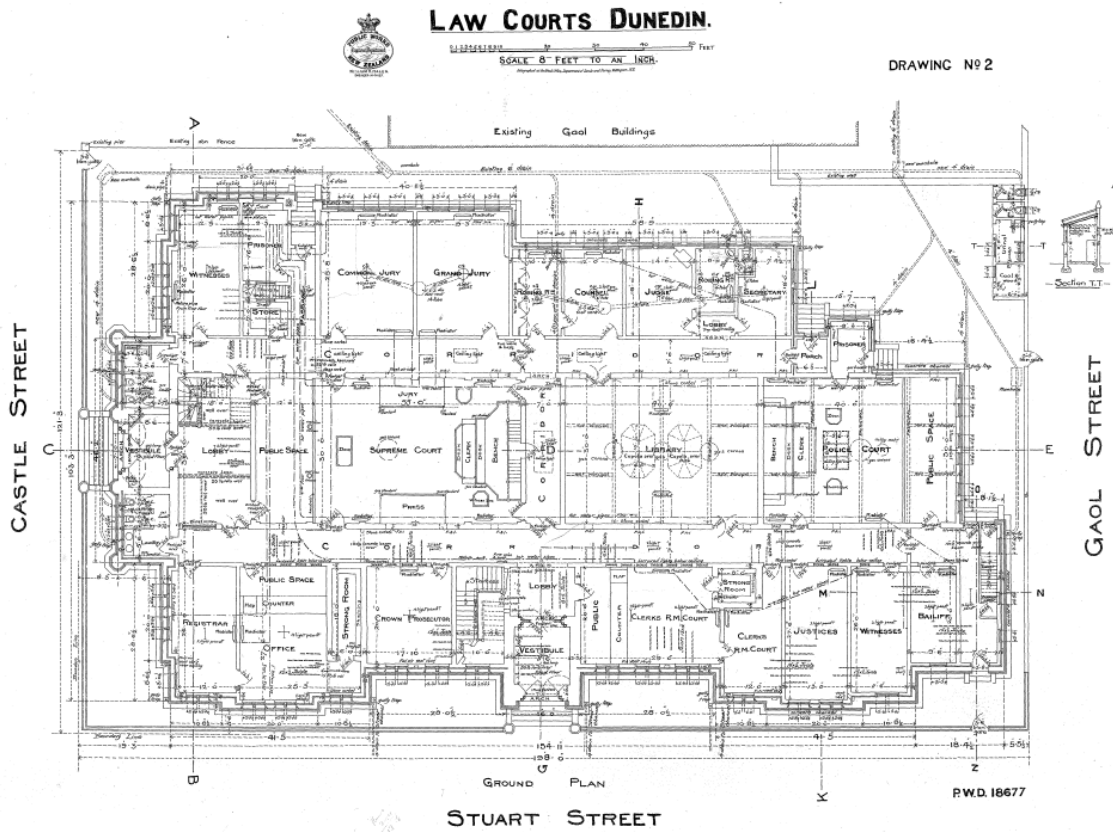


Figure 3: Original drawings showing plan and cross section

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3 SOIL CONDITIONS

3.1 Soil Profile

The generalised stratigraphy beneath the site comprises three varieties of fill underlain by alluvial and estuarine soils that overlie completely weathered bedrock of the Dunedin Volcanic Group. The soil profile at the site is represented below.

Table 1: Soil Profile at Dunedin Law Courts Site

Layer No.	Description	Depth to Top of layer (m)	Layer Thickness (m)
1	FILL Stiff clayey SILT with rare fine gravel and sand.	0	Up to 2.0
2	BOULDER FILL Fragmented basalt with silt observed in SPTs. Driller reports basalt boulders. Probably dense.	0 - 2	0 – 1.8
3	RECLAMATION FILL Loose to medium dense, variable sand-dominated soils including SAND fill (BH2), silty SAND, silty GRAVEL with rare sand & gravel.	0.2 – 3.8	1.8 – 6.7
4	HARBOUR MUD Soft to stiff SILT, dilatant	5.6 – 6.9	0.6 – 4.7
5	ALLUVIAL SILT Stiff to hard inter-bedded clayey SILT, sandy SILT and SILT & SILT with rare sand-gravel (also includes occasional estuarine (harbour mud) silt lenses.	6.8 – 10.5	Unproven but estimated as approx. 10.0m

Water levels within the boreholes and piezometer varied from 1.7 to 2.2m below ground level.

3.2 Liquefaction

A liquefaction assessment was carried out. The results of the liquefaction analyses indicated:

- There is no liquefaction predicted under the SLS seismic event (1/25)
- There is predicted to be liquefaction under the 1/1,000 and 1/2,500 ULS seismic events
- within the harbour muds under the entire site
- Soft harbour muds around 5 to 7m depth in BH1401-1402 are considered to be non-liquefiable under the 1/1,000 and 1/2,500 ULS seismic events (see Section 5.4.3)
- There is predicted to be liquefaction under the 1/1,000 and 1/2,500 ULS seismic events within the reclamation fill in the eastern parts the site only (BH1 and BH-1403), where this stratum is looser. The reclamation fill in the other investigated parts of the site was generally too dense to liquefy

3.3 Lateral Spread

The western end is underlain by dense boulder fill and has a reasonable thickness of non-liquefiable crust. The eastern end is underlain by shallow liquefiable soils. Hence there is a potential for lateral movement at one end of the site and not so much at the other end.

The expected lateral spread is about 10mm in a 1 in 1000-year event and 20mm-30mm in a 1 in 2500-year event. There is not expected to be any lateral movement in an SLS event. Advice on these figures allowed for a potential spread from down to half or up to twice these figures.

4 STRUCTURAL DESIGN

The structural designs utilised a combination of current New Zealand design standards and new draft assessment guidelines that were available in 2015. Elements of key concern and their strengthening methodologies are described below.

4.1 Foundations

A detailed geotechnical investigation of the site was completed by GeoSolve in June 2014, confirming the seismic subsoil category to be Class C (Shallow Soil). Based on the findings of this report, the calculated free-field settlement at the ULS event (with a return period of 2500 years) is 150mm-200mm at the east end of the building. The worst-case Liquefaction Severity Numbers occur at the east end of the building, and have “severe, high risk of substantial damage to the site and/or dwelling”. This level of severity also occurs at the 1:1000-year event at this site location.

The report also analysed the likely lateral spreading over the length of the structure, the strain of which is 20-30mm at the 1:2500-year event, with advice to double this as sensitivity options. As the foundations are unreinforced, they have limited ability to undergo the relative and varying applied deformations generated by the lateral spreading. If the foundations are inadequate, the walls will have no ability to resist the tension loads in the event of lateral spreading and settlement, as the later will cause the mortar bed to be in tension, rendering it inadequate for shear resistance in-plane

In the worst case, if the foundations are pulled askew by the settlement and lateral spreading, then the gravity support of the structure would be compromised, and a partial or full collapse could occur.

A 200mm thick reinforced concrete slab was located at the ground level to effectively tie the walls together at foundation level.

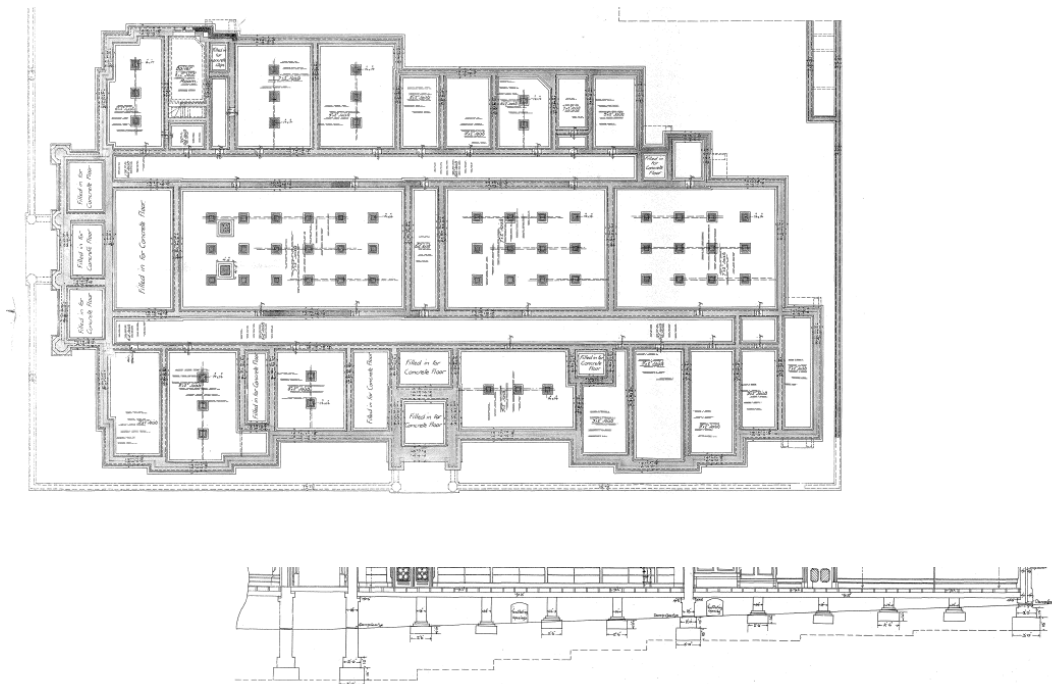


Figure 4: Original drawings showing plan and cross section views of the existing foundations

The soils under the foundations of the north tower were also discovered to not be stiff enough to prevent settlement under the ULS tower loads. The settlement calculated by Geosolve under the tower loads would cause the tower to tilt past reasonable limits, given the seating of the floors and roof on the tower walls. To remediate this effect, the soil beneath the tower was stiffened with jet grouted, unreinforced piles, extending down approximately 10 metres.

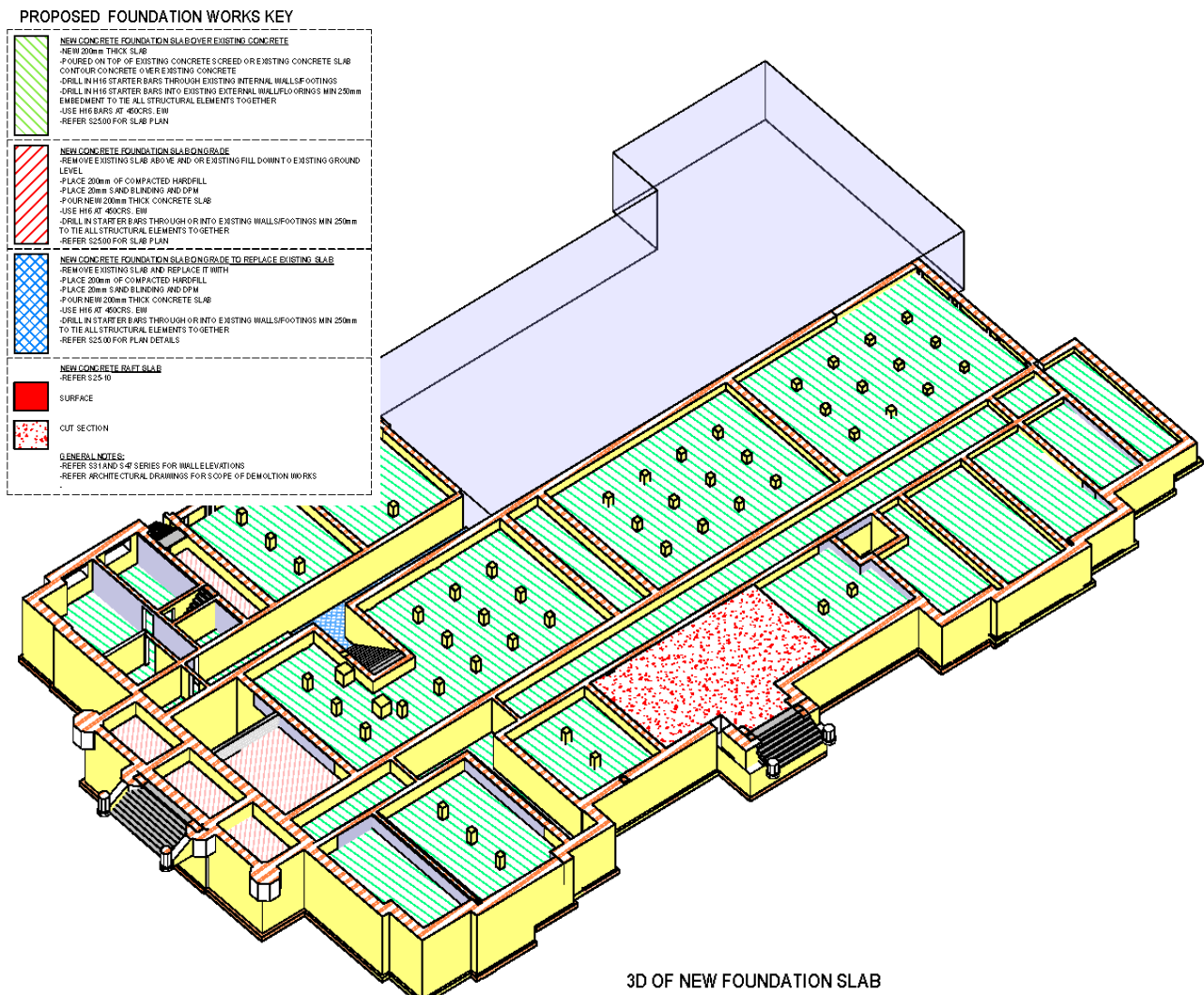


Figure 5: Diagram showing existing URM wall and timber bearer pier supports, and new reinforced concrete link slab

4.2 Walls

The in-plane and out-of-plane strength of the unreinforced block walls was calculated based on accurate in-situ material property values obtained by materials testing agency Opus. The strengths and allowable deformations were compared to the demands on the walls to verify which walls require strengthening and how much strengthening was required.

Where required, strengthening of walls in-plane included fibre-reinforced polymer (FRP) layers. The failure mode of the walls (either diagonal tension cracking, toe crushing, bed joint failure, or rocking) determined the performance requirements of the FRP. The exterior wall layers of brick and Breccia were not adequately tied together, and the floors and trusses frame into the interior skin only. New ties were required between the walls to effectively utilise the strength of both layers, particularly for out-of-plane loading. It has been

determined that the two leafs do not need to be tied together in-plane. The outermost breccia layer was capable of supporting the lateral loads from the acceleration of its own weight in-plane. The interior layer of brick supports the lateral loads in plane caused by the acceleration of the floors, roof, and the brick wall itself. This brick layer did require some strengthening to achieve this.

The URM walls out-of-plane have been assessed using the latest proposed assessment procedure for the upcoming revision to the NZSEE building assessment guidelines.

The URM walls in-plane were assessed using the “Assessment and Improvement of Unreinforced Masonry Buildings for Earthquake Resistance” by the University of Auckland, dated December 2011.



Figure 6: Photos of existing URM interior wall core samples, illustrating their solid construction with no internal cavity.

4.3 Diaphragms

The ground and first floor diaphragms were not adequately connected to the block walls with only a gravity connection present. This interface required a new connection transferring diaphragm shear forces from the top of the floor framing to the block walls.

The ground and first floor timber diaphragms were overlain with new plywood sheets to tie the structural elements together, as well as, provide a reliable load path for seismic actions. They were strengthened to 100 per cent of the seismic forces.

The out-of-plane forces from the URM walls, transferred to the diaphragms, have been calculated using the minimum of the wall destabilisation load or the parts and portions load. If the wall is destabilised before the parts and portions load is reached, then this is the highest load imparted on the wall out-of-plane. If the parts and portions load is reached before the wall destabilises, then the highest load the wall will see is the parts and portions load.

It is understood that the timber framed ground floor is susceptible to vertical movement and vibrations particularly in the main court rooms. Further investigation revealed several areas where the floor boards and gravity framing were not connected due to settlement and warping. The floor system was made true and level, and the subfloor was adequately connected to the framing, which resulted in a stiffer floor system, not suffering from vibration and creaking. It is also noted that the timber bearers at the ground floor were not tied to the isolated URM piers. The introduction of a plywood diaphragm helps restrain the bearers against the risk of losing their seating.

The existing roof diaphragm above the low and high courts was assessed to be inadequate to resist the seismic lateral loads generated from the wall mass and services. A new steel bracing diaphragm was installed for this purpose. Elsewhere a plywood diaphragm was installed to the underside of the roof trusses similar to that proposed at the ground and first floors.



Figure 7: Photo of existing timber bearer on URM supporting pier. No tie or direct fixing is evident.

4.4 The Main Tower

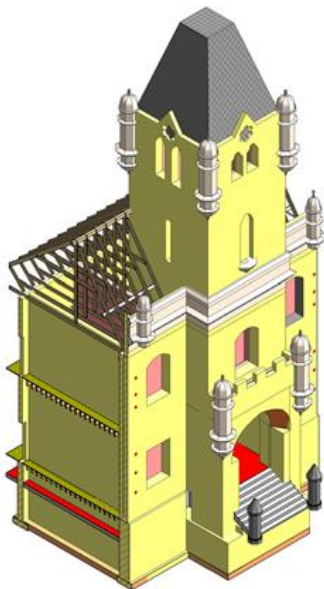


Figure 8: Photo and 3D REVIT illustration of tower structure

The tower at the northern end of the building has been assessed as being a high-risk element and prone to collapse in a seismic event. The tower had previously been strengthened using structural steel bracing members epoxy bolted to the inside walls. This bracing was considered to be inadequate for the seismic demands required to be resisted as part of the proposed strengthen works, and was removed, and the tower walls were strengthened with reinforced concrete to 100 per cent seismic loads. The new walls were both internal and external to the masonry walls, constructed both as shotcrete and as poured concrete. A large reinforced concrete raft slab was introduced to carry overturning and bending loads at the foundation level.

Geotechnical investigation determined that the soil bearing pressure caused by overturning of the tower will cause excessive vertical settlement, which in turn will cause unallowable separation of the gravity structure from the tower wall. Ground improvements below the tower were proposed by GeoSolve and were designed and specified by GeoSolve. The proposed scheme involved unreinforced jet piles, extending to a layer of soil with good bearing qualities, increasing the available bearing capacity under the tower.

5 SUMMARY

This heritage project breathes significant life into the Dunedin Law Courts, originally built between 1900-1902. The building is one of the older assets of the Ministry of Justice and, as a result, it presented a number of compromises for modern use. The client, design and construction team collaborated strongly to research the building fabric, coordinate all of the engineering and architectural requirements and work closely together to effect the seismic strengthening and refurbishment. The result is a significant refurbishment and structural strengthening of this formerly underutilised heritage building to significantly raise the seismic strength, retain the heritage aspects and to optimise its use as a court and administration function.



Figure 11: Photo showing original Dunedin Law Courts.

6 REFERENCES

Geosolve. 2014. *Geotechnical Report*, 22 December 2014