STRUCTURAL REPORT

Structural Feasibility & Recommendations

Administration Building - Hennessy College, Young

Catholic Education Archdiocese of Canberra & Goulburn (CECG)

CONFIDENTIAL

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VERIFICATION

REVISION	DATE ISSUED	PREPARED BY	VERIFIED BY	AUTHORISED BY	COMMENT
1.0	06/09/2023	G. Stojanoski	N. Dickson	A. Hayman	Issued

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1 EXECUTIVE SUMMARY

1.1 PURPOSE

This report has been produced following the acceptance of Norman Disney & Young's proposal, dated 11th August 2023, by the Catholic Education Archdiocese of Canberra & Goulburn (CECG).

The purpose of this report is to provide high level structural engineering recommendations based on the proposed architectural design and concepts for the refurbishment of the existing Administration building and adjoining new building extension.

This report shall not be relied upon as providing any warranty or guarantee of the existing building, including it's services or equipment.

This report is also not intended to be interpreted as a peer review of the original structural engineer's design, nor is it aimed to confirm whether the existing building was originally designed in accordance with relevant Australian Standards.

1.2 AUTHORITY

Authority to undertake this report was provided by the Catholic Education Archdiocese of Canberra & Goulburn (CECG) on 15th August 2023.

2 INTRODUCTION

2.1 DESCRIPTION OF THE EXISTING BUILDING

The administration building is located on Ripon Street in Young, NSW, and is described as a two storey above ground masonry/timber structure with a pitched steel sheet roof. From the dates shown on the two building plaques located at the main entry, the building was originally constructed in November 1891, and major refurbishments works completed in May 2000. The refurbishments completed to the internal spaces of the building mainly consist of long-term maintenance works and minor alterations such as new door openings and amendments to the original room configurations.

From information provided by SQC Group and CECG to NDY, the building has been continuously occupied with change in use occurring since the original construction date. NDY understands the building has previously been used as communal housing (nun dormitory) and is currently the main office for the school's staff including the administration team.

External photos of the front and rear of the existing building are included in Figure 1 and Figure 2 respectively.

FIGURE 1 - FRONT OF THE EXISTING ADMINISTRATION BUILDING

FIGURE 2 - REAR OF THE EXISITNG ADMINISTRATION BUILDING

2.2 EXISTING/PROPOSED DRAWINGS, DOCUMENTATION AND REPORTS

At the time this report was issued, the original design drawings (architectural and engineering) for the administration building were not made available to NDY. Considering the original construction date of the building, the original drawings and records may likely have been lost or destroyed.

Other technical documents such as current geotechnical reports for the site were also not available.

NDY understands that SQC Group has completed a detailed site investigation of the existing building and has produced the concept architectural drawings based on site measurements and visual observations.

The following drawings and documents have been provided to NDY by SQG Group and CECG. A description and summary of each file is provided below:

SQC Architectural Drawings: **230324-Hennessy College Administration Building - Final Concept Design.pdf**, detailed drawing information:

SHEET NO.	SHEET NAME	REVISION
A000	COVER SHEET	C
A110	DEMOLITION PLAN - GROUND FLOOR	C
A111	DEMOLITION PLAN - FIRST FLOOR	C
A130	GROUND FLOOR PLAN	C
A135	FIRST FLOOR PLAN	C
A136	ROOF PLAN	C
A205	ELEVATIONS 1	C
A206	ELEVATIONS 2	C
A300	SECTIONS	C
A800	ISOMETRIC VIEW	C
A801	ISOMETRIC VIEW	C

2.3 INSPECTION NOTES

On Friday 18th August 2023, Goce Stojanoski from NDY attended site with Daniel Trevino from SQC Group. Graham Beaver and Nadine Woods from CECG were also present.

The weather on the day of the inspection was overcast with light rain falling throughout the day.

The inspection occurred between 11am to 1pm and access was available to all the main internal spaces on the Ground Floor and Level 1. All internal rooms and spaces within the existing building were operational and occupied by staff members.

Access to the external perimeter of the building and adjacent grounds was also available, including the outdoor balconies and covered foyer zones.

As the building was operational and occupied by staff, most structural elements were concealed or covered by finishes and surfaces and could not be visually sighted. Access to the Ground sub-floor space and ceiling space was not possible, and no access panels or doors leading into the sub-floor/ceiling spaces were identified during the inspection. Limited visual inspection of the ground sub-floor was only possible through the small vent panels located in the external perimeter brick walls.

2.4 SUMMARY OF EXISTING CONDITIONS

Considering the original administration building was constructed in the 1890's, the overall condition would be generally considered as fair to good.

As access to the ground floor sub-space was not possible during the inspection, the existing foundations below the external brick walls could only be visually inspected at limited locations around the external perimeter. The existing foundations consist of large rectangular granite blocks and appear to be in good condition as showing in Figure 1.

FIGURE 3 - SITE PHOTO OF THE EXISTING EXERNAL PERIMETER BUILDING FOUNDATIONS

Due to the limited visibility of exposed structural elements and historic maintenance work (such as painting of walls), it is expected that some cracking in the existing brick walls due to movement in the foundations has likely occurred and has been repaired and/or concealed. Movement in building structures is common and expected due to several factors including long-term soil consolidation and changes in the moisture content of the soil supporting the building foundations.

The historic crack patterns that were observed in the brick walls during the inspection are generally as expected for structures like the administration building.

FIGURE 4 - HISTORIC REPAIRS OF CRACKING IN THE EXISTING BRICK WALLS

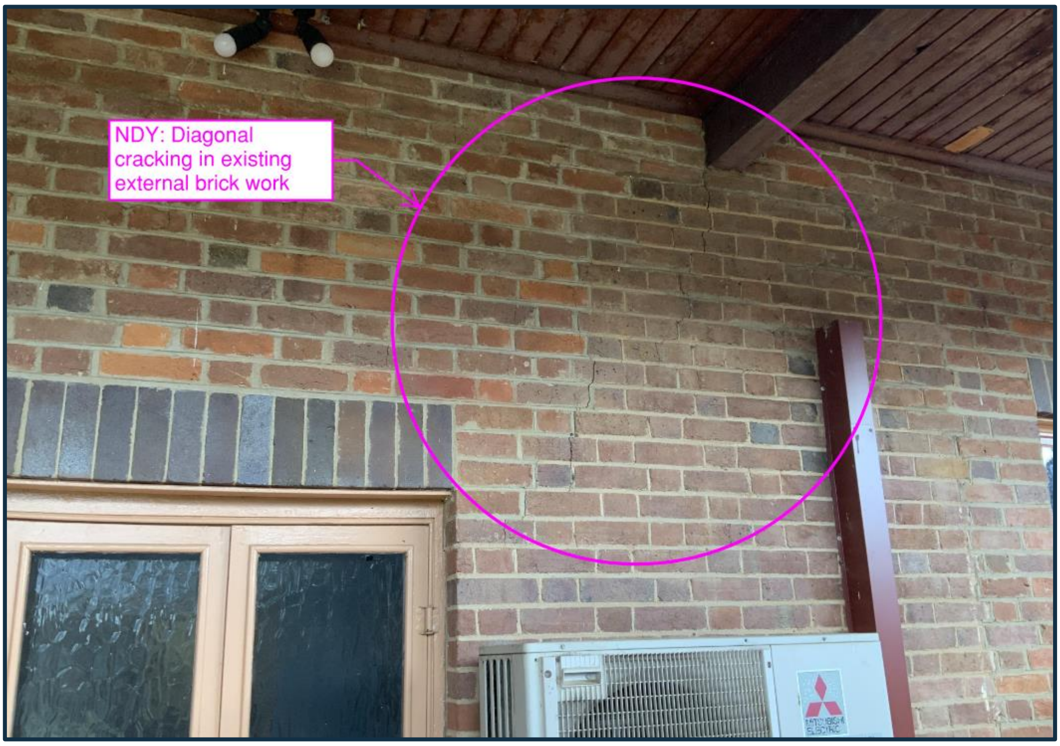

FIGURE 5 - VISIBLE DIAGONAL CRACKING IN AN EXTERNAL PERIMETER BRICK WALL

During the site inspection, signs of localised movement and cracking was observed in some of the existing brick balustrades located on the balcony perimeters as shown in Figure 6. These cracks were the most significant damage that wes visually observed during the inspection.

FIGURE 6 - LARGE VERTICAL CRACKING IN THE EXISTING GROUND FLOOR BRICK BALUSTRADE

Evidence of rising damp was observed in an external perimeter wall as shown in Figure 7.

FIGURE 7 - RISING DAMP OBSERVED IN AN EXTERNAL BRICK WALL

Some external brick walls showed signs of deterioration and erosion of existing mortar joints as shown in Figure 8, however the condition of the brick mortar joints that could be visually inspected throughout the building is generally considered good.

FIGURE 8 - LOCALLY ERODED BRICK MORTAR JOINTS IN AN EXTERNAL BRICK WALL

The exposed internal timber floorboards on the Ground Floor and Level 1 could only be visually inspected from the top surface of the internal spaces, and the general condition of these elements appeared to be fair. Some 'soft' and springy spots in the existing Level 1 timber floor was observed, suggesting the condition of some existing joists and bearers is likely to be poor.

The external timber floorboards on the Ground Floor and Level 1 balcony areas have been damaged due to long-term exposure to weather and rain. Rainwater during the inspection was observed to pond and drain across the top surface of the timber floorboards towards the strip drain as shown in Figure 9.

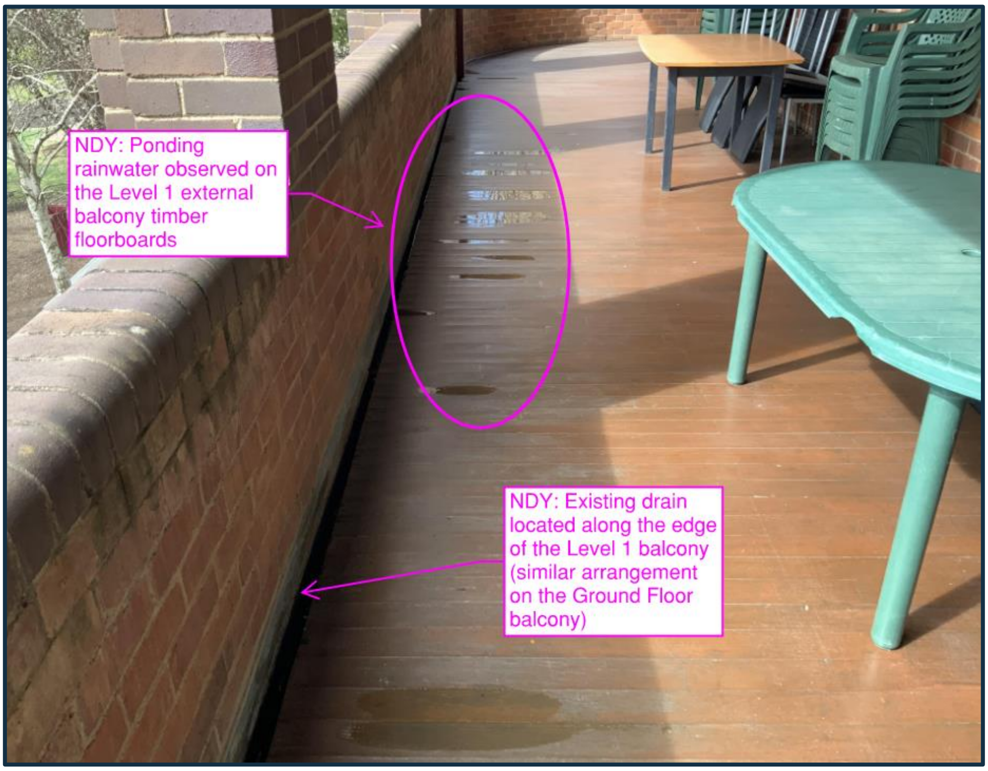

FIGURE 9 - SITE PHOTO OF THE LEVEL 1 EXTERNAL BALCONY WITH PONDING RAINWATER OBSERVED

Extensive swelling and cupping in the timber floorboards was noted on both floors with signs of rot and heavy staining observed in several locations on the soffit of the Level 1 balcony.

As the external floorboards have been exposed to long-term moisture, it is possible and likely that extensive water damage has occurred to the concealed structural timber members in these areas. Figure 10 shows a site photo of extensive mould and rot damage that was observed on the ceiling of the external balcony.

FIGURE 10 - EVIDENCE OF ROT AND MOULD ON BOTH BALCONY CEILINGS

The steel sheet roof could only be visually inspected from a distance (standing on Ripon Street, at the front of the building) and is considered to be in fair to poor condition. The large portion of the roof sheets appear to have paint flaking and peeling away as shown in Figure 11. The roof at the rear of the building could not be visually inspected, however staining and water damage on the underside of the Level 1 balcony ceiling was noted. An existing brick parapet has been constructed around the building perimeter at roof level. It is possible that a box gutter or similar drainage system has been installed around the parapet. Staining and mould around the perimeter of the Level 1 balcony ceiling may indicate previous overflow or leakage into the roof space and water damage to the timber roof structure is therefore likely.

FIGURE 11 - SITE PHOTO OF THE CONDITION OF THE EXISTING ROOF SHEETS

3 ENGINEERING RECOMMENTATIONS FOR THE PROPOSED WORKS

3.1 OVERVIEW OF PROPOSED REFURBISHMENT WORKS, OPPORTUNITIES AND RISKS

The proposed refurbishment works to the existing building is as depicted in the preliminary architectural drawing set produced by SQC Group and provided to NDY. Once all major works are complete, the reconfigured existing administration building will be referred to as Block F.

The major proposed works and associated engineering recommendations are summarised as;

Item 1. The existing internal Ground Floor and Level 1 rooms are to be reconfigured to create much larger single open spaces. Increasing the internal open spaces will require demolition of a mixture of existing load-bearing and non-load-bearing internal and perimeter brick walls as indicated in the SQG demolition drawings, refer to Figure 12 and Figure 13 below;

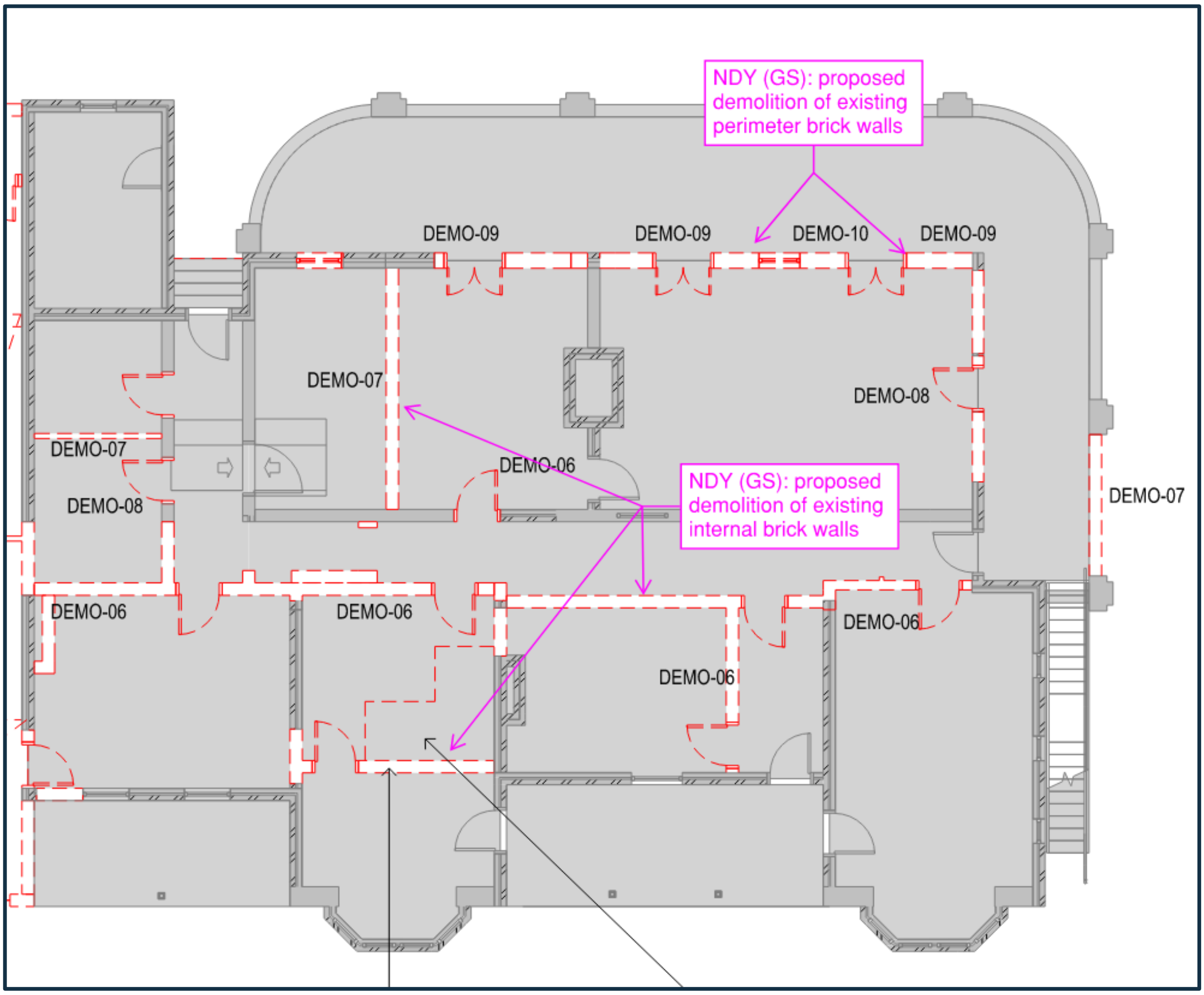

FIGURE 12 - PROPOSED DEMOLITION OF EXISTING GROUND FLOOR BRICK WALLS

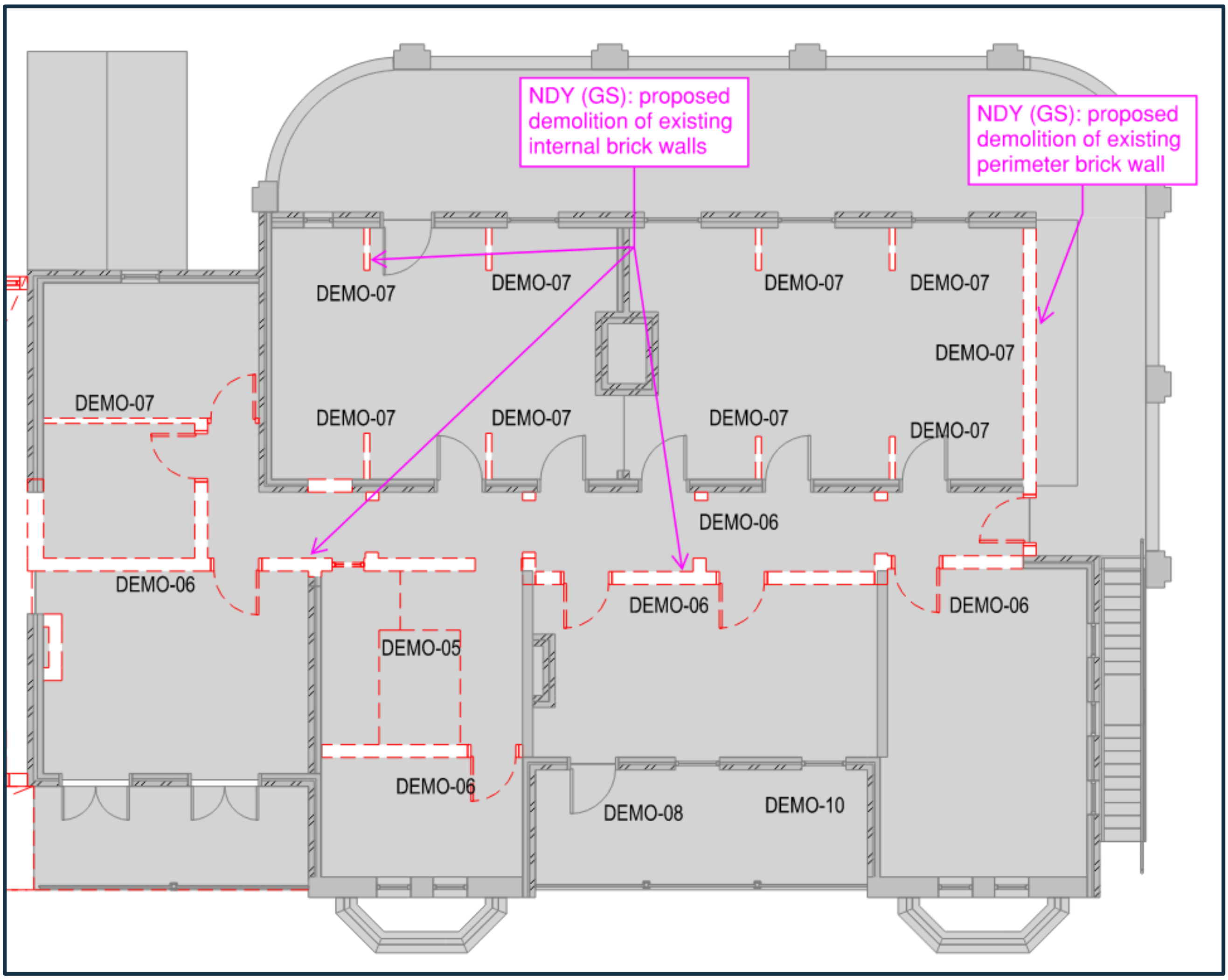

Figure 13 - PROPOSED DEMOLITION OF EXISTING LEVEL 1 BRICK WALLS AND INTERNAL PARTITION WALLS

The construction methodology in the late 1800's for building structures like the administration building typically use thick brick walls as load bearing elements. Timber bearers and joints were typical adopted for flooring elements with the finished floor consisting of solid timber boards.

The proposed demolition of the load bearing brick walls will require new structural elements to support the existing floors and roof. Possible new structural elements are columns and beams located at Ground Floor, Level 1 and underside of the existing roof.

A high-level structural mark up of a possible layout is included in Figure 14 and Figure 15. Note: These markups are provided only for visualisation and not to be considered as a developed design.

The new structural columns on the Ground Floor could be steel members and will require new concrete foundations to be constructed into the soil below the existing sub-floor space. A geotechnical report will need to be prepared that includes the design parameters required for foundations.

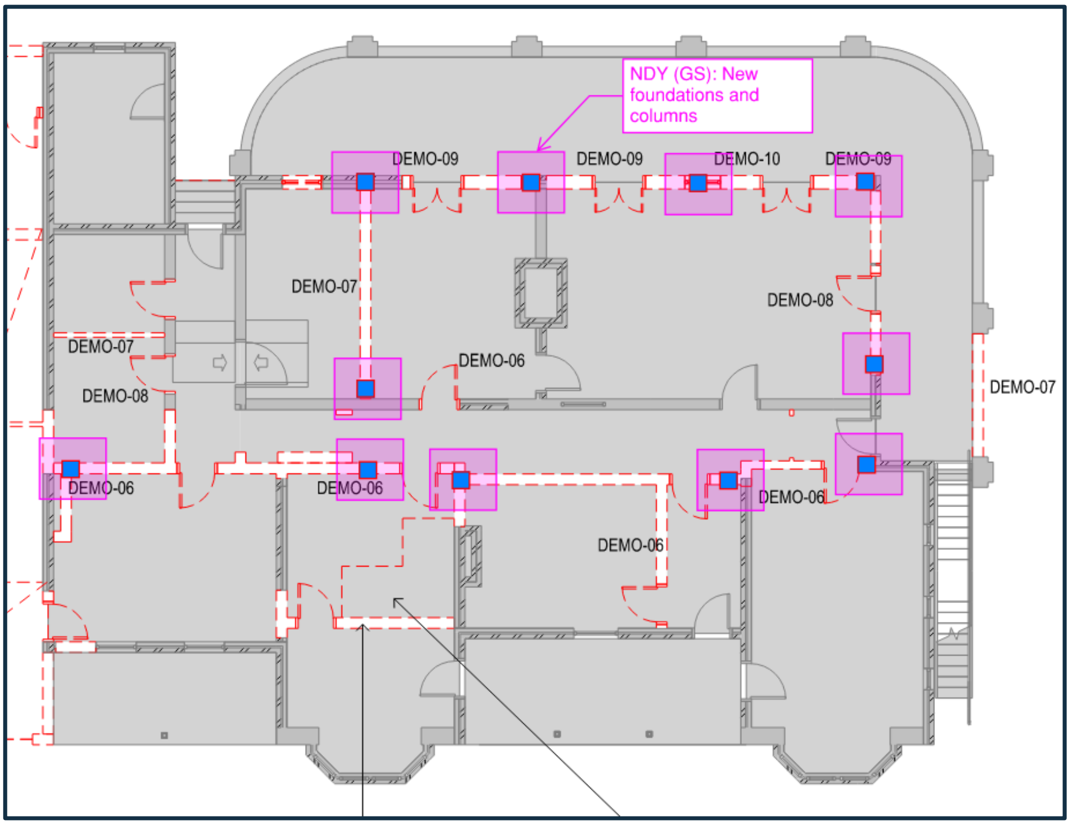

FIGURE 14 - POSSIBLE LAYOUT OF NEW FOUNDATIONS AND COLUMNS ON THE GROUND FLOOR

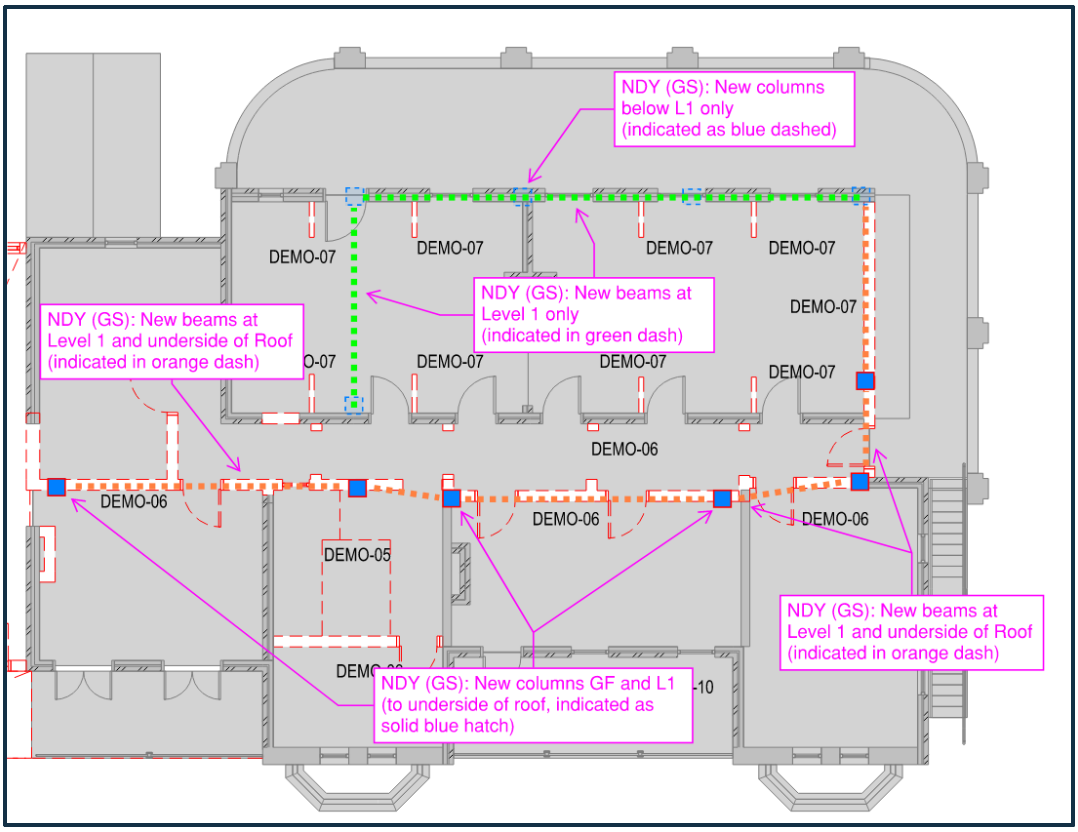

FIGURE 15 – POSSIBLE LAYOUT OF NEW COLUMNS AND BEAMS ON LEVEL 1 AND UNDERSIDE OF ROOF

Opportunities

- Considering steel or timber columns and beams for the new structural elements will allow flexible integration with the existing timber floor members (bearers and joists). New steel and timber elements can be fabricated off-site and installed as individual pieces suiting the buildability of the proposed works.
- Completing a geotechnical investigation and report at the very stage of the proposed works will reduce the risk of the unknown soil properties and soil capacity. The geotechnical engineer undertaking this work can also complete an investigation of the zone adjacent to the existing administration building where the proposed extension is located.
- The existing bricks and structural timber members that are to be demolished and found to be in good condition could be reused in other parts of the building works. Reusing existing materials can present potential cost savings to the project and contribute to preserving the heritage aspects of the building.
- Required maintenance to existing brick work such as repointing of mortar joints and crack repairs can be undertaken with the proposed refurbishment.

Risks

- Removing existing load bearing brick walls will require new structure to support the elements being retained, including parts of the Ground Floor and Level 1 timber floor members and the timber roof trusses. The detailed condition of the existing structural elements cannot be assessed unless finishes are removed, and the elements exposed. This detailed inspection process will require local demolition at strategic locations throughout the building, and spaces currently occupied by staff may need to be vacated.
- If any existing structural timber members are found to be damaged (e.g. due to moisture or insects), new timber elements will need to be designed and constructed to suit site conditions. The extent or quantity of damaged or unsuitable existing elements will not be known until partial demolition of the existing finishes is occurs and a detailed structural inspection can be completed.
- As there is currently no soil information or geotechnical report available for the site, the type of foundations suitable for the new works cannot be investigated. Demolishing long lengths of existing brick walls and constructing new structural columns to suit the proposed large open spaces will alter the current building loads from 'strip' or spread loads to more concentrated point loads. The resulting concentrated forces will apply a higher pressure into the existing soil.
- Concrete pad footings are generally considered to be the most suitable type of foundation elements to directly support the new structural columns. Pad footings are generally located close to the ground surface level and can be constructed in spaces with limited accessibility using smaller earth moving equipment. If the existing soil 1-2m below the natural ground level is found to have poor load bearing properties, the new foundations may need to extend down to soil layers with increased bearing capacity. Installing new foundations down to several meters below the existing ground surface level may be difficult due to the limited accessibility that is required for these works (large and heavy plant equipment).
- The final location, size and type of foundations may cause local undermining of the existing footings/foundations that are to be retained. Allowance for underpinning works is recommended as part of the refurbishment works.
- Brick walls and masonry elements inherently have brittle properties and are vulnerable to cracking and damage even when subjected to very small movement. The proposed demolition of some walls on the ground floor will produce vertical transfer arrangements resulting in some of the existing Level 1 walls being supported by new structural elements (beams). The new beams will need to be designed to limit the differential vertical deflections, however it is likely some of the existing brick walls will be subjected to some vertical deflections and therefore cracking and damage may be expected. Allowance for repairs and make good is therefore recommended.

Item 2. Proposed re-levelling of the existing internal Ground level timber floor to achieve a consistent finished floor level throughout the entire internal Ground floor. This will include raising the existing floor level of the rear portion of the internal ground floor space by approximately 150-200mm to match the existing level of the existing timber floor towards the front of the building. These proposed works are indicated in Figure 16 and Figure 17 (final level indicated as RL 432.240 on the SQC Group proposed plan).

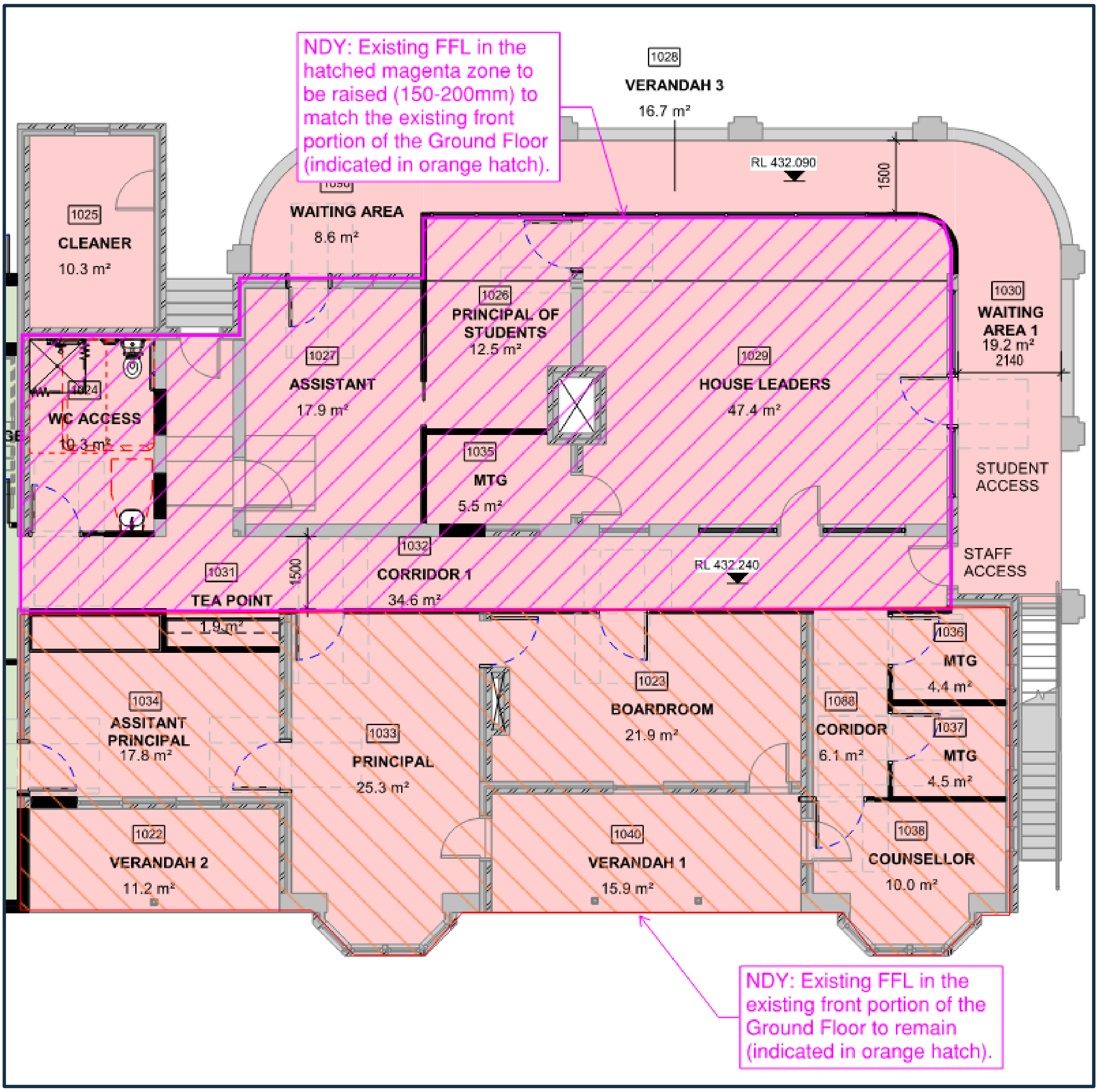

FIGURE 16 - PLAN VIEW MARK UP: GROUND FLOOR PROPOSED FINAL FLOOR LEVELS

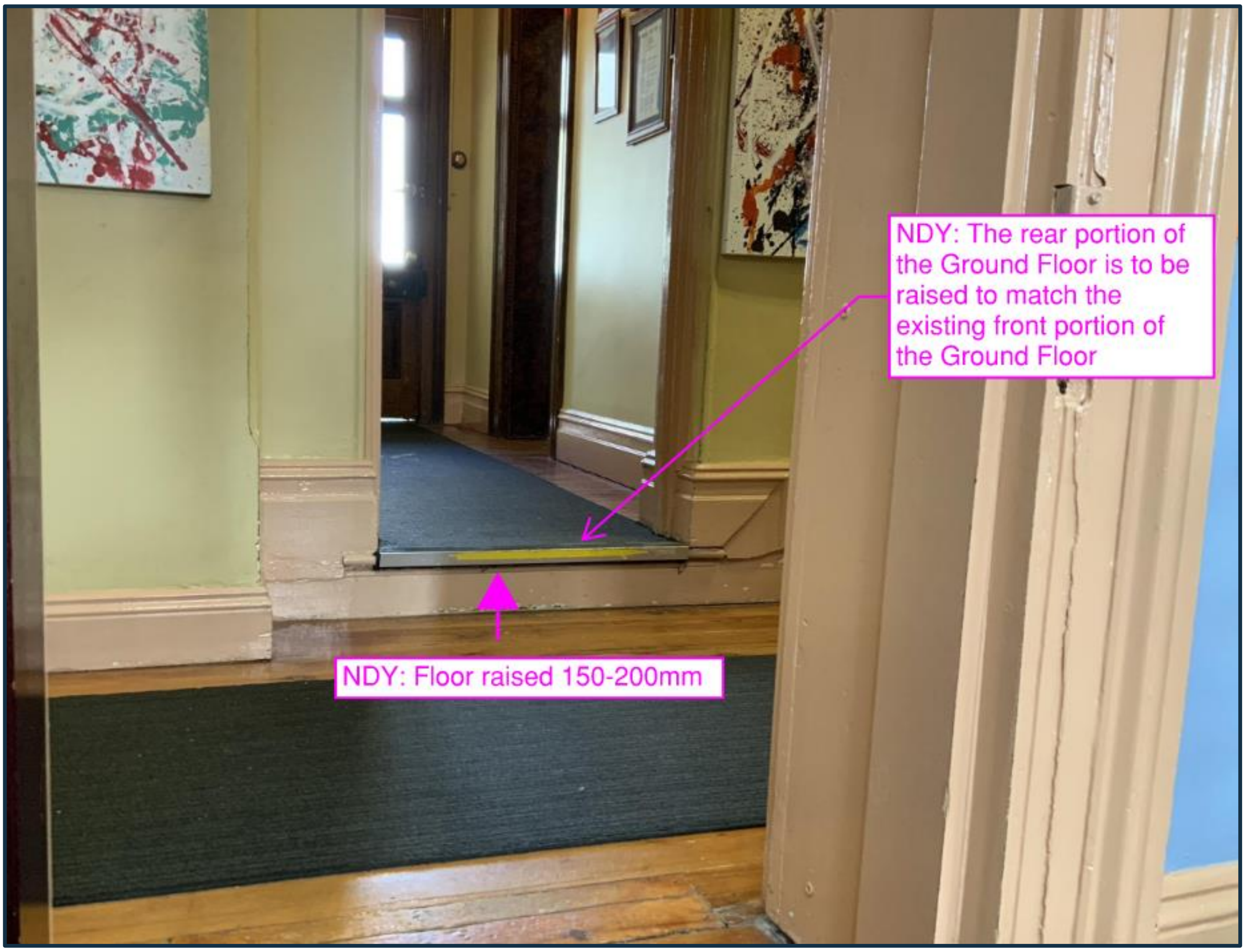

FIGURE 17 - INTERNAL SITE PHOTO SHOWING THE PROPOSED CHANGE IN LEVELS

Opportunities

- Having a consistent finished floor level provides improved accessibility throughout the Ground Floor of the building.
- Subject to the condition of the existing structural timber floor members, achieving the final floor level could potentially be achieved by retaining the existing timber members (bearers and joists) and constructing just a new layer of timber joists over the existing joists.
- The existing structural timber members and floorboards that are to be demolished or disturbed (and found to be in good condition) could be reused in other parts of the building works. Reusing existing materials can present potential cost savings to the project and contribute to preserving the heritage aspects of the building.
- Existing repair works that could be required to concealed structural timber elements can occur as part of the main refurbishments works.

Risks

- Raising the rear portion of the existing Ground floor will need to be coordinated with the works outlined in Item 1 - proposed demolition and constructing new structural elements. To provide access for the new works, parts of the existing timber floor may need to be removed and reinstated. This work may cause unnecessary disturbance and damage to the elements that are to be retained in the final state.

- Raising the existing floor level will in turn reduce the height of the existing door openings. Architectural coordination is required to details these requirements, refer to Item 5.

Item 3. Increase the internal area of the Ground Floor space towards the rear of the building by enclosing the existing external balcony.

Opportunities

- Repairs to the existing external timber floorboards can be completed as part of the refurbishment works. New methods and products can be considered as a solution to the existing water proofing issues and moisture damage observed at the existing balcony zones during the inspection.

Risks

- During the site inspection, the condition of the timber floorboards and ceilings in the external balcony areas suggest it is very likely that the existing structural timber and brick work in these zones will require repair or complete replacement. It is recommended that an allowance is made for the structural works related to these areas.
- The large cracking observed in the brick balustrades on the Ground Floor and level 1 indicates movement in the foundations and elements directly supporting these balustrades has occurred. Provision for repair and strengthening works should be considered as part of the refurbishment.

Item 4. Close up selected existing door and window openings in existing brick walls.

Opportunities

- From visual inspections, the existing internal brick walls are generally considered in good condition and these proposed works are not expected to structurally cause major impacts to the existing building or elements.
- Existing bricks that are to be demolished may be used for the infill of existing doors or openings. Utilizing the existing materials may positively impact the project cost.

Risks

- A more detailed inspection of the local existing brick work is recommended, including removing existing covers or paint. There are no major structural risks considered with the infill of existing doors or small openings – the works are to be completed by a qualified and experienced trades person.
- The condition, extent and configuration of the footings or supports at the base of the the existing door openings is currently not known. The new infills are assumed to be constructed using bricks and therefore these elements will need to be founded on a suitable support. New supports may need to be constructed to suit the proposed infill zones. A detailed inspection of each specific zone is required to provide further comments and recommendations.

Item 5. Create new door and window openings through existing brick walls. These works include raising the existing header levels of selected doors and windows throughout the building to achieve a consistent top level.

Opportunities

- During the site inspection, some inconsistency was observed between the header levels of the existing windows and doors throughout the administration building. Amending these elements and installing new lintel members can achieve a consistent arrangement. These works can be completed throughout the building during the refurbishment.

Risks

- A detailed understanding of the existing condition of the existing brick walls and mortar joints where these works are proposed is currently not known. A detailed inspection of the local existing brick work is recommended, including removing existing finishes and paint.

Item 6. Subdivide existing rooms to create smaller office and meeting rooms. Introduce new glazing elements to the rear of the building – refer to Figure 18 below.

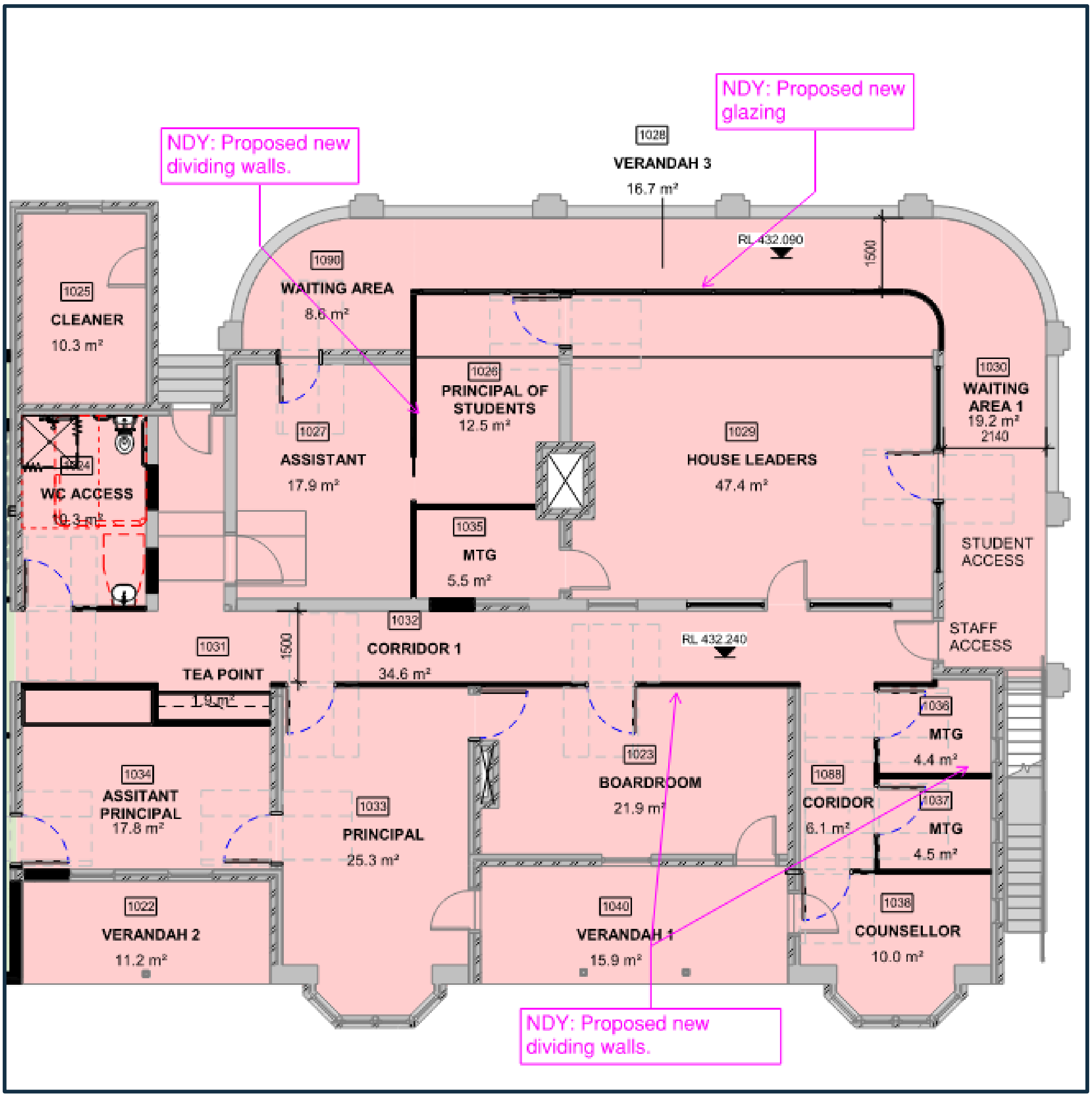

FIGURE 18 - PROPOSED NEW DIVIDING WALLS AND NEW GLAZING

Opportunities

- It is assumed the proposed dividing walls indicated in Figure 18 are to be light weight (timber or steel stud). These types of walls generally do not require specific or significant structural supporting elements and can be directly installed to a timber floor. If localised structural supports are required, these works can be designed and constructed during the refurbishment.

Risks

- The existing floor-to-floor height of the Ground Floor may result in heavy glazing units that are proposed along the boundary with Verandah 3. The existing floor may require some strengthening or new structural elements to achieve adequate stiffness in the floor and reduce the risk of differential vertical movement (that may cause damage to the glazing).
- This area is currently part of the exposed balcony and damage to the existing timber floorboards in this area was observed during the site inspection. Repairs or complete replacement of the existing timber floor members is expected.

Item 7. Demolish the existing internal timber stairs between the Ground Floor and Level 1 and construct new stairs within the proposed new extension adjacent to the existing building.

Opportunities

- The general structural condition of the existing timber stairs is considered fair to poor. During the inspection, there was noticeable localised vertical movement and creaking when moving through this space. A detailed visual inspection of the top and underside of the structural stair members was not possible during the inspection, however structural repairs to the existing stairs would be expected following a more detailed investigation. The proposed refurbishment works indicate the existing stairs are to be replaced with an entirely new stair. This is considered a favourable structural direction as potential extensive repairs to the existing stair will be avoided.

Risks

- As the existing stairs are to be demolished, there are no structural risks associated with this item.

Item 8. Reconfigure and refurbish the existing bathrooms (on both floors)

Opportunities

- The proposed refurbishment of the existing bathrooms will allow modern construction methodology and materials to be adopted in the existing building.

Risks

- The weight of the proposed bathroom finishes and fixtures can not overstress the existing structural elements. Any major increase in loading will need to be assessed and existing floor zones strengthened if required.
- Constructing new local set downs within the proposed bathroom design needs careful consideration as any alteration to the finished floor levels will impact the existing structural floor members. For example, a 20-50mm set down will likely require the existing timber bearers and/or joists to be vertically lowered. A detailed investigation of the visible existing structure in these zones is required to provide further comments on this item.
- Potentially altering the existing hydraulic components and configuration/layout will require coordination with the existing structural elements. There may be constraints on relocated some bathroom elements (toilets) as clashing with main structural floor members (bearers) may occur.
- As the existing sub-floor below the Ground Floor was not visually inspected, the layout (including entry/exit points) of new hydraulic elements within the sub-floor will require coordination with the existing structure. A detailed inspection of the sub-floor is recommended so further comments and recommendations can be provided.

4 NEW BUILDING EXTENSIONS - SITE OBSERVATIONS AND RECOMMENDATIONS

4.1 OVERVIEW OF PROPOSED NEW BUILDING (EXTENSION TO EXISTING BUILDING)

The proposed new extension to the existing administration building is shown in the preliminary architectural drawing set produced by SQC Group and provided to NDY.

The proposed new 2 storey extension is depicted in the coloured portion of the 3D architectural render shown in Figure 19. Access between the new and existing building will be provided at 2 locations on the Ground Floor and at a single location on Level 1.

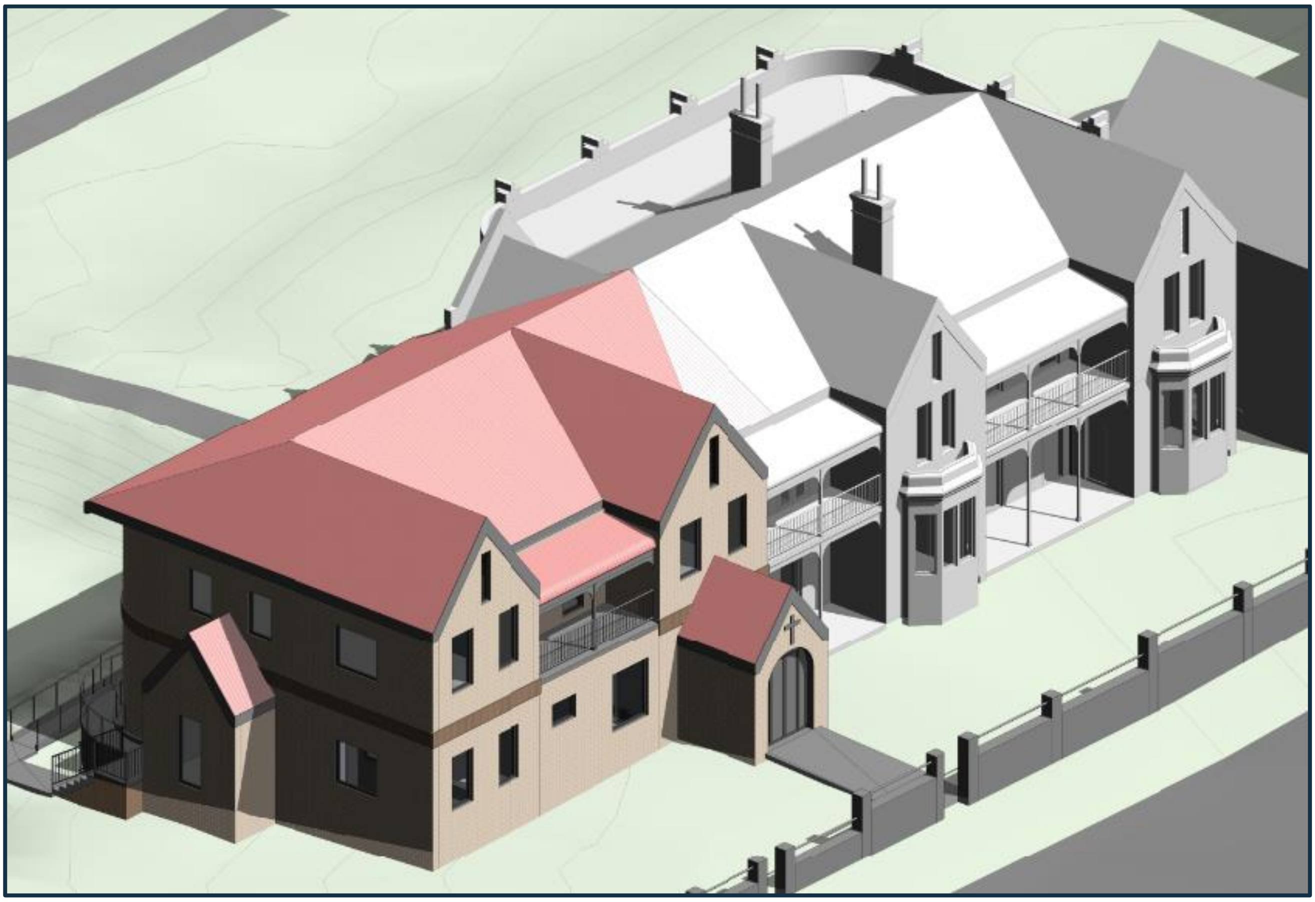

FIGURE 19 - PROPOSED NEW EXTENSION (COLOURED BUILDING PORTION)

Once complete, the new extension to the existing administration building will be referred to as Block K.

The proposed Ground Floor plan of the new extension is shown Figure 20.

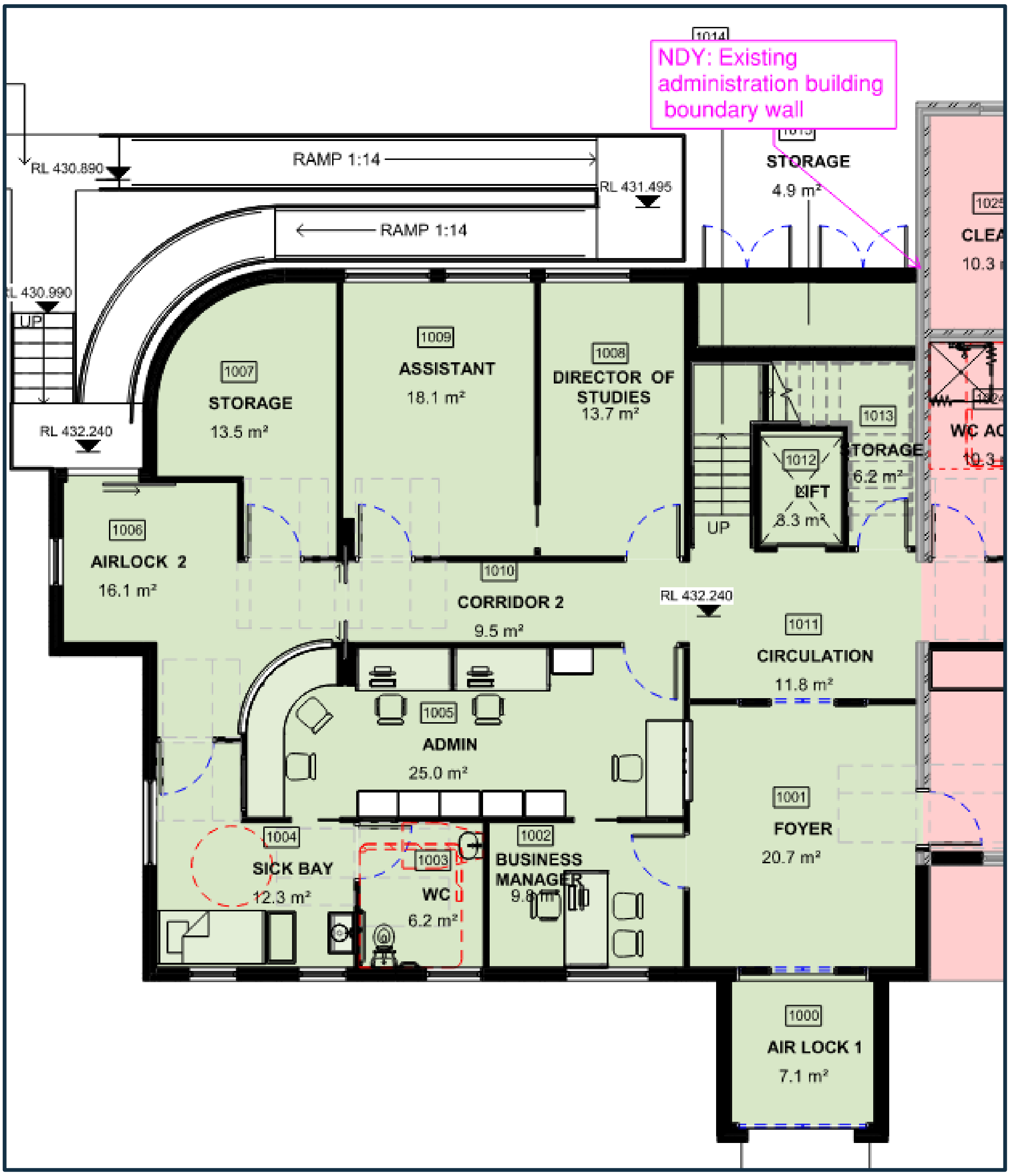

FIGURE 20 - PROPOSED GROUND FLOOR PLAN OF THE NEW EXTENSION

The proposed First Floor plan of the new extension is shown Figure 21.

FIGURE 21 - PROPOSED LEVEL 1 PLAN OF THE NEW EXTENSION

The major proposed works and associated engineering recommendations are summarised as;

Opportunities

- Modern building materials and methodology can be adopted for the new extension while maintaining an architectural and aesthetic relationship with the existing building.
- The extension allows for improved movement and circulation to be incorporated in the final design. The existing administration building has an existing perimeter brick wall that is suited to forming a connection to the new extension.
- Modern structural engineering design and performance can be incorporated in the new extension, including the behaviour of the super-structure under gravity and lateral loading. The proposed extension includes a lift and stair core that can utilised as the primary structural bracing elements.

Risks

- The demolition of the existing building where the proposed new extension is to be located is shown in Figure 22. The proposed arrangement will expose the existing foundations below the boundary brick wall of the administration building. The extension will require new foundations and footings to be constructed which will potentially undermine the existing footings. An allowance for underpinning of existing footings and foundations should be made in the new works.

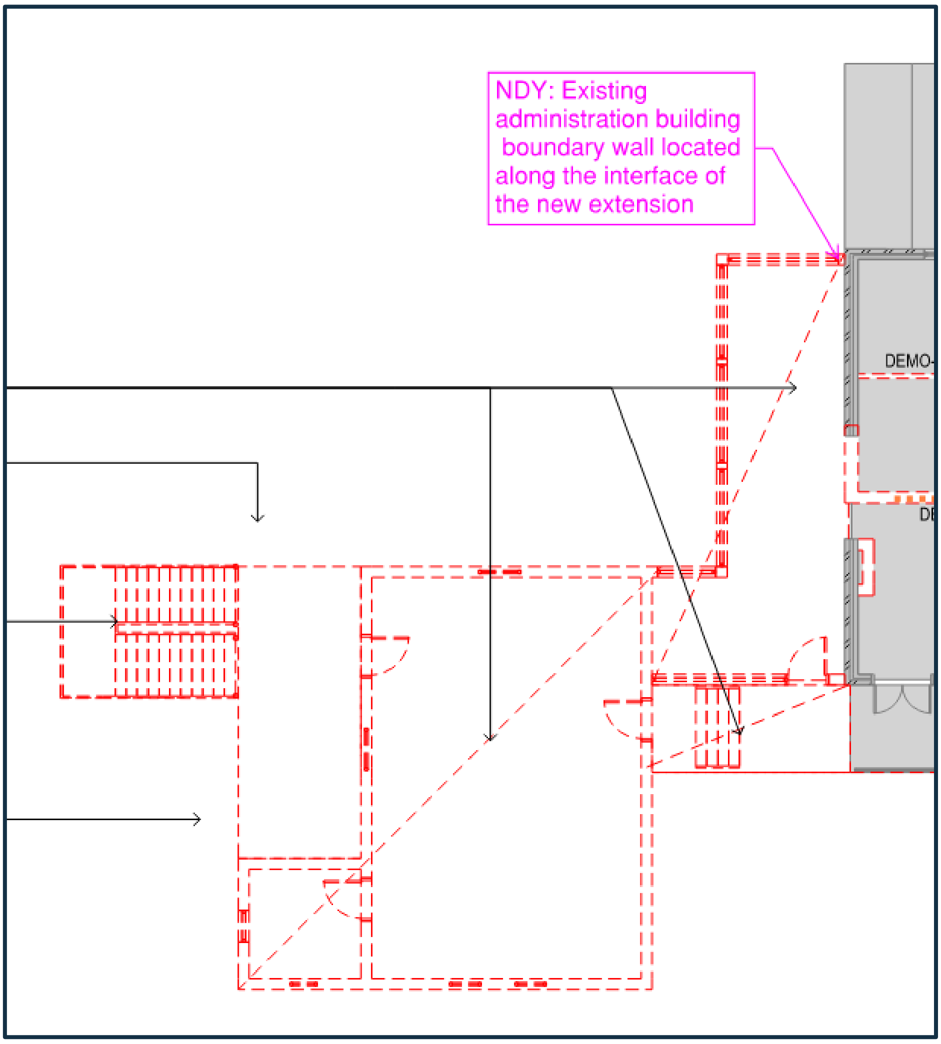

FIGURE 22 - EXISTING BOUNDARY BRICK WALL TO BE RETAINED

- If modern materials such as reinforced concrete are to be adopted for the super structure of the new extension, the overall weight of the building may increase. If higher loading needs to be transferred into the ground, the required foundations may need to be constructed into deeper soil layers. Without a current geotechnical report for the site and unknown soil capacity, the general depth of the new footings cannot be developed. It is recommended that a geotechnical engineer is engaged at an early stage of the project.
- The new extension will extend over external areas of the current site that are outside the footprint of the existing building (that is to be demolished). Existing in ground services need to be located and documented at an early stage in the design to ensure foundations can be constructed (or avoided) as required for the new extension.

- During the site visit, an existing concrete dome located at the rear of the building was visually inspected as shown in Figure 23. The dome appears to be sealed for a significant period and the original purpose of this structure is not known. Considering the age of the administration building, it might be possible that an underground well or water storage space has been constructed below the visible dome lid. It is recommended that a detailed investigation of this element is completed, including internal inspections.
- The existing concrete dome will need to be demolished to accommodate the new extension. The geotechnical investigation should specifically address the soil adjacent to the dome.
- An allowance to infill an inground void should be considered as part of the project scope.

FIGURE 23 - CONCRETE DOME AT THE NATURAL GOUND LEVEL (REAR OF BUILDING)

- During the inspection, it was noted that existing above ground powerlines are located along the front of the existing administration building on Ripon Street. Construction work and sequencing that requires crane setup and lifting from Ripon Street into the site needs to consider this existing infrastructure.

5 OTHER CONSIDERATIONS

5.1 STRENGTHENING FOR EARTHQUAKE LOADING

Modern structures are required to be designed and constructed to confirm to the requirements set out in the current NCC and Australian Standards. The current seismic design and performance requirements have evolved through specialist research and development of technical (and practical) knowledge following significant seismic events in the past 30-40 years. The theoretical performance of existing historic buildings can therefore not be directly assessed using the criteria that applies when designing and building new structures.

Extensive engineering studies of the actual performance and behaviour of low-rise historic solid brick building structures subjected to seismic loading have been completed following the recent events including the Newcastle and Christchurch earthquakes. From these studies, it has been found that strengthening specific existing structural elements and components greatly improves the performance of these structures under seismic loads.

At the recent *Australian Earthquake Engineering Society 2019 Conference*, a technical paper was presented, titled: *Seismic Risk Management of NSW Education's Buildings Including Heritage Buildings.*

The information contained in this document is directly applicable to the proposed works for the existing administration building. A copy of this document has been included in Appendix A of this report, with the main structural strengthening recommendations summarised below;

- Bracing of existing parapets
- Bracing/stiffening of existing load bearing walls
- Stiffening of existing diaphragms
- Tying side of wall to frame/walls
- Strengthening of existing chimneys
- Tying the top of walls to frames/ceilings
- Tying existing gables

The items noted above are not intended as an exhaustive list for the existing administration building, but are included to provide general awareness of key elements and works that can be addressed as part of the major refurbishment to the existing administration building. From actual seismic events, it has been shown that risk of vulnerable key structural building elements in heritage buildings can be mitigated by adopting specific strengthening and construction methodologies that focus resources on key structural and non-structural elements.

NDY recommends key seismic strengthening works are considered as part of the overall project.

6 APPENDIX A

Seismic risk management of NSW Education's buildings including heritage buildings

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Abstract

A building's high-level elements, such as masonry chimneys, parapets and gable walls, are considered to have a greater risk of damage and collapse during an earthquake event, with the potential to cause injury, or loss of life. To minimise risk to students and the public during an earthquake, NSW Department of Education (DoE) initiated a seismic risk management program for school buildings, including heritage listed buildings, located in higher seismic risk areas. A desktop study was done to screen school buildings for seismic risks, based on their location, age, construction types and high-risk elements. DoE supplied a list of their buildings in the higher seismic risk areas, including heritage listed buildings. Site visits were made to identify buildings with high risk elements followed by structural documentation to stabilise these elements. Gable and parapet walls were tied back to the roof structure. Masonry chimneys were stabilised by inserting a galvanised steel tube in the flue, grouting the annular space with cement grout, re-pointing weak mortar joints and/or using remedial ties to connect all brick skins together. As part of this work, chimneys were also fixed/braced to the internal roof structure and ceiling/roof diaphragms strengthened by adding ceiling/roof bracing.

Keywords: Unreinforced masonry, heritage school buildings, high seismic risk, chimneys, parapets, gable walls, flue stiffener, bracing.

Seismic risk management of NSW Education's buildings including heritage masonry buildings

Introduction

New South Wales Department of Education (DoE) is running a program to manage risk to education buildings, especially school accommodation for primary and secondary schools. The risk management approach involves seismic risk assessment, assessment of corrosion of wall ties in highly corrosive marine environments. The risk of peeling of the external skin and its probability of falling outwards is very high in an earthquake event, or even in high wind suction on the exposed wall with corroded wall ties. Risks due to non-engineered assets are also part of the compliance division of DoE.

Before the 1989 Newcastle earthquake, seismic risk in Australia was considered very low, and no specific design was required for low-rise buildings. The 1989 Newcastle earthquake, which was of moderate magnitude but caused a relatively large damage bill and broke this long-held myth [1]. However, the seismic risk is still relatively moderate compared with countries located on the ring of fire, e.g. New Zealand, Indonesia, Philippines, Japan, West Coast of America.

NSW Public Works undertook repair/remediation work of government buildings after the 1989 Newcastle earthquake [1,11]. The total damage bill exceeded $2billion. Public Works Advisory (PWA) was engaged by the compliance and maintenance division of DoE to undertake a desktop study to identify seismic risks to school buildings.

In the "Atlas of Seismic Hazards Maps of Australia", published by Geoscience Australia, several hot spots with higher hazard factors were delineated. The revised map showed two hot spots around Goulburn and Newcastle. Since damaged schools in Newcastle were repaired and strengthened after earthquake, school buildings falling under Goulburn hot spots were identified for further assessment. The seismicity, or historical records of earthquakes in this area, were also reviewed [5]. A pilot study by Public Works Advisory, called "Earthquake resistance review of existing school buildings", was also reviewed [7].

Seismic Vulnerabilities

Before the 1989 Newcastle earthquake, there was no requirement to design buildings for earthquake loading. Most buildings were designed for wind loads as the governing global design load and heavy masonry construction was suitable for wind loads. However, earthquake shaking is due to inertia, and the heavier the structure the more earthquake force will be imposed on it during an earthquake. The unreinforced masonry construction is non-ductile and may suffer major damage and/or collapse during an earthquake event of moderate magnitude [1].

Following the 1989 Newcastle earthquake, NSW Public Works (now PWA) inspected over 1000 state government buildings within 35 km of Newcastle and managed repairs to 651 buildings. Of these buildings inspected, 24 suffered major damage, 104 moderate damage and 523 minor damage. 400 buildings belonged to DoE, with 55 to the emergency services and 4 to the Department of Health. This list does not include damage to commercial, residential, educational and religious (churches) buildings.

The earthquake damage showed weakness in structures which had not been designed for earthquake, were of heavy masonry construction and it highlighted maintenance issues and poor construction practices. The extent of damage depended on the following factors:

- Foundation conditions – significantly higher damage to buildings on soft soil/alluvium. The amplification of earthquake shaking on alluvial soil foundations is now well known.
- Type of construction - ductile versus non-ductile construction. Ductile construction can absorb large amount of energy by undergoing plastic deformation.
- Regular vs irregular construction, both in plan and elevation.
- Building features – high level freestanding elements, e.g. masonry chimneys, parapets, gable walls, bell towers and decorations/appendages, have a higher risk of collapsing during the shaking of a moderate earthquake.
- Age of buildings – older masonry buildings with weaker mortar joints and corroded wall ties. It is worth noting that the earliest residential buildings (pre-1910), which didn’t have cavity walls, survived the 1989 Newcastle earthquake better than the cavity wall constructions built in a latter period [1,7, 11].
- Maintenance and quality of workmanship - lack of maintenance and poor workmanship lead to higher damage.

The failures of the heavy old masonry have been observed during moderate earthquakes in seismic regions all around the world. [1,2,3,4].Seismic vulnerabilities of the old heavy masonry constructions are:

- Out-of-plane actions on the walls,
- untied roof/floor to wall connections,
- lack of rigid floor and roof diaphragms,
- large voids in diaphragms,
- free standing appendages, parapets, chimneys and gable walls

Following the earthquake in Newcastle [1,11], some structural strengthening was carried out during repair work to earthquake-damaged buildings to give them greater resilience to future earthquakes. Structural strengthening was recommended for the damaged buildings. Approved strengthening methods included:

- Bracing/tying of parapets.
- Bracing/stiffening of walls.
- Stiffening of diaphragms.
- Tying side of wall to frame/walls
- Strengthening chimneys.
- Tying the top of walls to frames/ceilings.
- Tying gables and
- Other.

Desktop study

A desktop study of schools in the Goulburn area was done using information available from the DoE. This was supplemented by data capture plans, plan-room plans and site visits.

The objective was to:

- identify building blocks with vulnerable elements.
- use a staged approach – high risk to life safety studied first. Complete upgrade studied during second stage/during major upgrade/retrofit.
- recommend remediation works to reduce risk of collapse of these high-risk elements, to reduce life safety risk. These works will not necessarily prevent damage to the building.

The desktop study identified 15 schools located in the hot-spot area around Goulburn with heavy masonry construction, that may have vulnerable elements.

After further site inspections of these schools, only seven schools had vulnerable elements. Also, all these schools were heritage listed on the DoE register and on the local LEP. The seven schools were: Yass Public School, Goulburn PS, Goulburn North PS, Goulburn HS, Dalton PS, Crookwell PS and Breadalbane PS. The other eight school buildings did not have any vulnerable elements.

Seismic assessment and strengthening.

There are two Australian Standards that apply to earthquakes in Australia, namely:

AS1170.4-2007 “Structural design actions Part 4: Earthquake actions in Australia”, and

AS3826-1998 “Strengthening existing buildings for earthquake”.

AS1170.4-2007 is referenced by the Building Code of Australia (Part B1) and is mandatory for the design of new buildings.

AS3826-1998 “Strengthening existing buildings for earthquake” sets out minimum requirements for the assessment and analysis of earthquake resistance of existing buildings and their strengthening. This standard is not intended to prevent damage to the existing building but to minimise the risk of loss of life and injury from structural collapse and not to impose severe economic impact. (AS3826-1998 was withdrawn in June 2019)

In the case of existing buildings, including heritage buildings, it is recognised that it is not always economical, or practical, to comply with AS1170.4-2007 and AS 3826-1998 ‘Strengthening Existing Buildings for Earthquakes’ requirements. Strictly speaking the need to comply AS1170.4 is not mandatory for existing buildings until substantial alterations/additions works are planned for the building, that would require compliance with the NCC [13].

The owner of building has a legal obligation to ensure the protection and conservation of the heritage building and provide an acceptable safety level for people, both inside and outside the building. In the absence of clear legislative direction, it is effectively left to the discretion of the building’s owner to choose to what extent to strengthen the building will result in different levels of safety, impact on heritage fabric, disruption to building occupants, and cost.

Based on these factors through consultation and involvement of the structural engineer, heritage architect and building owner the scope and degree of stabilization works were determined. Only vulnerable parts of the building were recommended for strengthening. Chimneys, gable walls and parapets should be strengthening to withstand two-thirds of the design earthquake load determined in accordance with AS1170.4

Case study – Yass Public school

Yass Public Schools was chosen for this case study, as it is listed on the DoE & local LEP heritage register and has all the vulnerable parts, for example, Block "G" (Library/classroom block) has 7 chimneys, eight gable walls, 11 gablet walls and one parapet. Chimneys extend 5.5m above the building's eaves level.

Refer to Figures 1 and 2, which show the front photo and elevation.

Figure 1 – Yass Public School – North-east elevation. Library and Classrooms Block "G". Inset photo shows year of construction 1877.

Figure 2 – Yass Public School – drawing of north-east elevation

Figure 3 – South-East Elevation – showing two tall chimneys, two gable walls and two gablets

Figure 4 – South-West elevation from 1940 drawings for amenities extension.

The building was built in 1877. The building is U-shaped in plan. The central part is the library, and the two sides are classrooms. The library's roof structure comprises scissor shaped timber roof trusses, under-purlins and timber rafters. The roof structure of the building's side wings comprises king post trusses, under-purlins and rafters. The rafters are lined with timber boards and a slate roofing. A suspended ceiling had been added to the side wings in the past.

The chimneys, gables walls and parapets were assessed to comply with requirement of AS 3826-1998 [10] which was current at that time. The unreinforced masonry parapets, gable walls and chimneys which have a ratio of unrestrained height above the uppermost connection to thickness (H/T) greater than 3:1 are considered unstable in an earthquake event. The scope of strengthening works comprise of those identified unstable parts and does not include earthquake assessment and strengthening of the of existing buildings structure as a whole for resistance to earthquake loads.

The force generated on the building parts was calculated using equation 8.2(1). as per Section 8 "Design of Parts and Components" of AS1170.4-2007

$$F_c = a_{floor}[I_c a_c/R_c]W_c \leq 0.5W_c$$

Two-thirds of force 'F_c' was used to design strengthening of chimneys, gable walls parapets and roof/ceiling diaphragm. The additional connections for these parts were designed for horizontal force of 10% of the seismic weight of the gable walls and chimneys ($0.1W_c$).

The chimneys were designed as a cantilever above ceiling/roof level and strengthening with steel stiffener installed in flue. The gable walls were strengthening with horizontal steel beams and designed for spanning vertically between roof, ceiling and steel beams.

The scope of seismic strengthening works for unstable parts comprised the following:

- Chimney were strengthening by inserting a galvanised steel tube stiffener in the flue and fill the annular space with cement grout. The stiffener was extended below ceiling about 2.0 meter and connected to ceiling/roof structure.
- Chimneys brick work was strengthening by inserting stainless steel 'Helibar' into bed joints around flue at specified vertical spacing. Weak mortar joints in chimneys were re-pointed as required.
- Gable walls were laterally restrained to existing ceiling and roof structure by masonry anchors. Also gable walls were strengthened to spanning vertically against face seismic load by steel beams at specified vertical spacing. The beams were fixed to gable walls by masonry anchors and connected to roof structure.
- The roof and ceiling structure acted as diaphragms were strengthen and stiffened by installing steel strap and rod bracing to provide lateral support to chimneys and gable walls to transfer loads to cross walls.
- Additional connections of the roof and ceiling diaphragm to masonry walls were provided by masonry anchors.

Refer to figures 5-10 for the design details for construction.

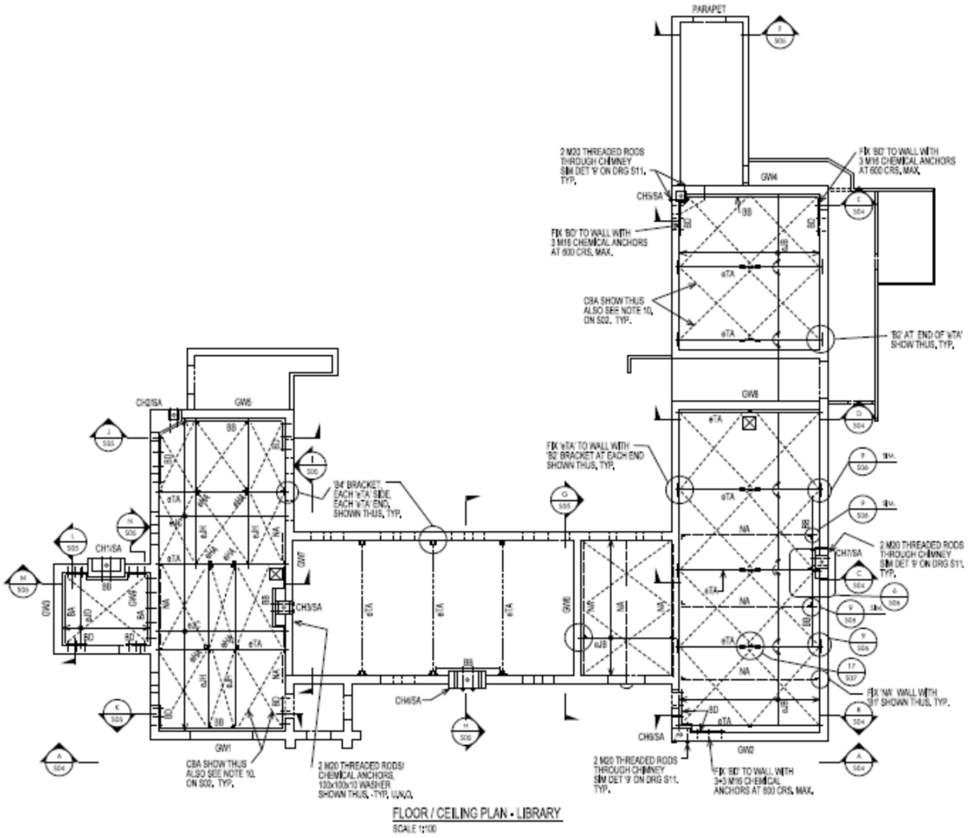

Figure 5 – Ceiling level bracing plan – Strengthening ceiling diaphragm.

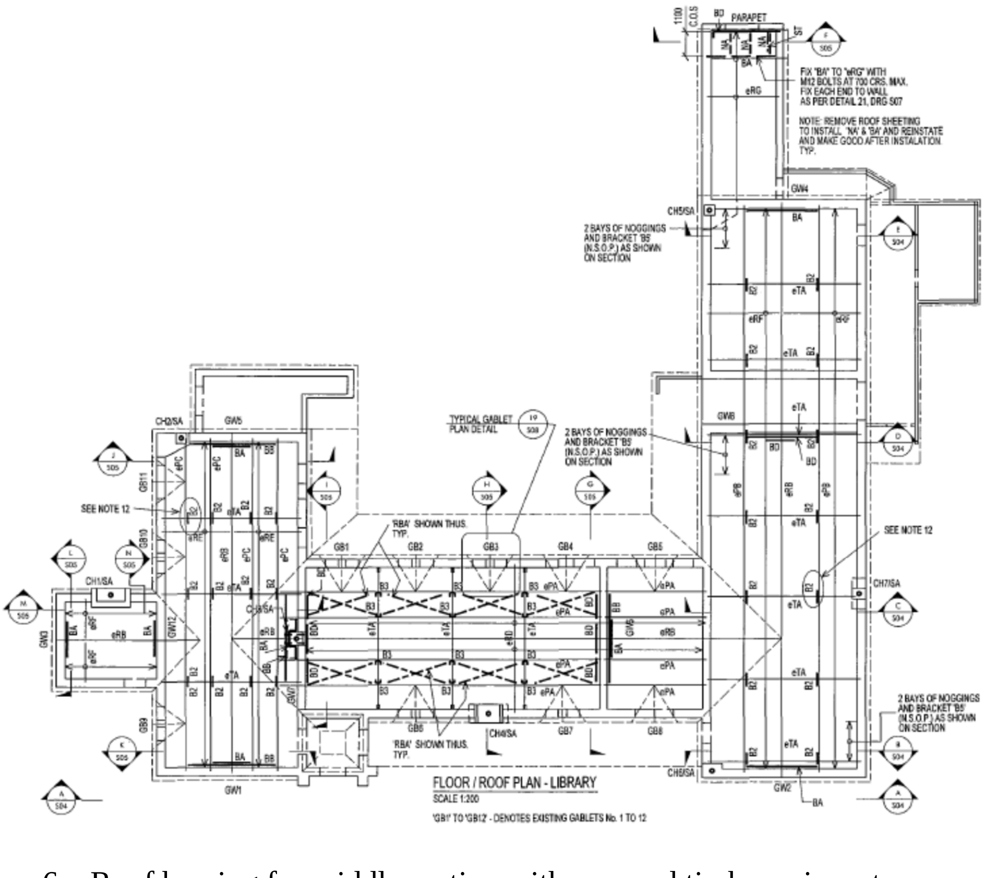

Figure 6 – Roof bracing for middle section with exposed timber scissor trusses

Figure 7 – Shows steel channel beam between roof trusses for chimney.

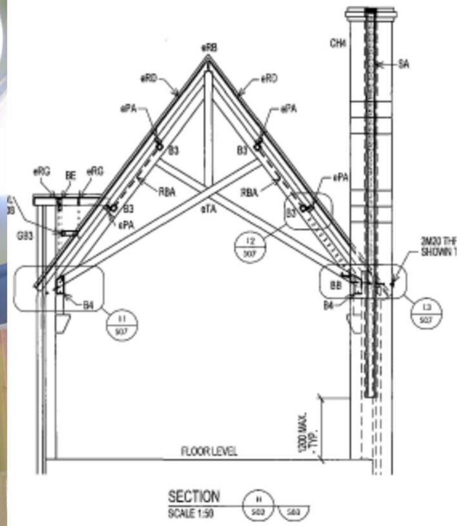

Figure 8 – CAD drawing of cross-section.

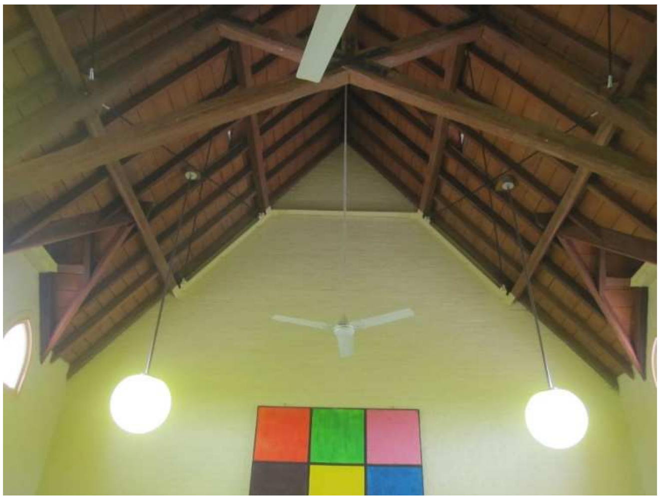

Figure 9 – Shows the steel angle and roof bracing connection to the gable wall.

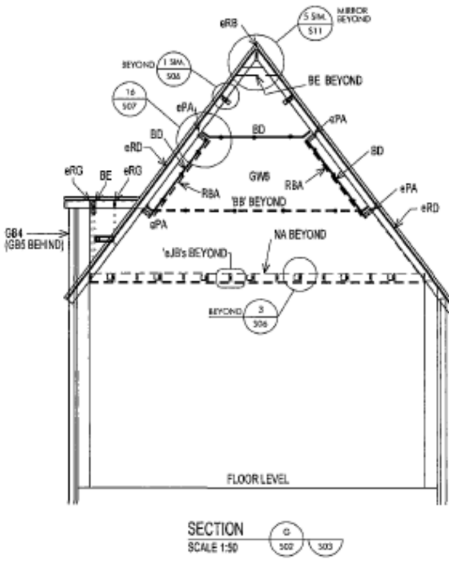

Figure 10 – CAD drawing of gable wall elevation and steel beam BB is behind this wall at lower under-purlins level (shown dotted)

CONCLUSIONS

The different extents of strengthening against earthquake actions will result in different levels of safety, impact on heritage fabric, disruption to building occupants, and cost. The acceptable level of safety and strengthening for such buildings should be based on risk assessment and determined through consultation and involvement of the structural engineer, heritage architect and building owner.

The case study has demonstrated that the client agencies acting proactively can significantly reduce the risk of collapse of most vulnerable parts in their building stock of a low cost and minimum disruption to the school. The seismic strengthening of masonry chimneys, gable walls and parapets can be carried out without any adversary impact on the heritage fabric and is acceptable from heritage point of view.

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