Cranbrook

Cranbrook school development

Structural Scheme design report

0001 REPT

Rev A | 6 April 2018

Job number 256385-10

Arup
Arup Pty Ltd ABN 18 000 966 165

Arup
level 10, 201 Kent Street
Sydney
NSW 2000
Australia
www.arup.com

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Job title		Cranbrook school development		**Job number** 256385-10
Document title		Structural Scheme design report		**File reference**
Document ref		0001 REPT		
Revision	**Date**	**Filename**	Design Report.docx	
Draft 1	16 Jun 2017	**Description**	First draft	
			Prepared by	Checked by	Approved by
		Name	Jane Nixon		
		Signature			
Issue	29 Sep 2017	**Filename**	STR scheme design report and brief_Rev01.docx	
		Description	For Development Application	
			Prepared by	Checked by	Approved by
		Name	Jane Nixon	Jane Nixon	
		Signature			
Rev A	6 Apr 2018	**Filename**	STR scheme design report and brief_Rev0A.docx	
		Description	For revised SSDA application	
			Prepared by	Checked by	Approved by
		Name	Jane Nixon	Jane Nixon	Mike King
		Signature			
		Filename		
		Description		
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ✓

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Appendix A

Centenary Building Retention and lateral deflection

1 Introduction

This documents summaries the structural engineering performance criteria and strategy for the Hordern Oval Precinct redevelopment at Cranbrook School, Bellevue Hill.

The proposed works involve demolishing existing building on site for construction of two buildings:

- New Centenary Building Teaching Facility; A 4 story building at the south end of the site. Approximately 7000 square meters, consisting of teaching and learning environment which also includes teaching terraces, a drama theatre, a dining commons, a place of worship and an assembly hall/ basketball court on the lowest level.
- New Aquatic, Fitness Centre and car park (AFC). It is proposed to excavate the existing oval to discretely accommodate a sub-surface car park which will provide an additional 124 car parking spaces. A double story space will also be provided under the existing oval will contain aquatic and fitness. Approximately total 5000 square meters. The turfed surface of Hordern Oval is to be reinstated over both the new car park and the new aquatic recreation centre with a new groundsman's facility to be constructed to replace the existing series of ahoc sheds along the eastern side of the oval.

2 Ground conditions and foundations

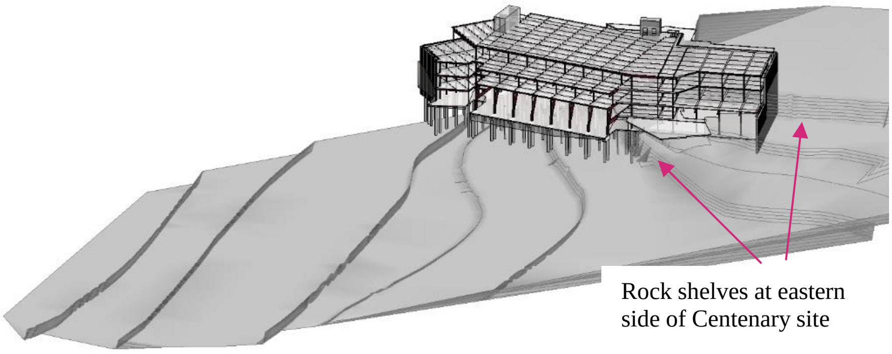
2.1 Overview

The site typically consists of approximately 1m of uncontrolled fill on natural medium to dense marine sands. However northern end of the site, as the oval goes towards Rose Bay, the fill depth increases to 3m. That is, it appears that fill was used to form the flat oval across the site which originally naturally sloped down from south to north.

Rock levels vary across the site:

- Centenary building; rock is expected to be weathered sandstone of low strength layer over medium strength sandstone. Rock levels vary, with rock at about 4m below original ground level at the western end of the building and increasing to 20m below original ground at the eastern end. This is caused by two rock shelves across the building foot print, each stepping down approximately 10m.
- AFC building, rock is expected to be weathered sandstone of medium strength sandstone. Rock levels vary with rock at about 4.5m below original ground level at the south end of the oval and increasing to 17m below ground at the north end of the oval. The rock surface is generally smoothly sloping "down the hill" but is made up a series of four smaller rock shelves, each stepping down approximately 3-4m.

Rock levels interpreted form existing bore hole data and inspections on site. Refer to Douglas Partners report “84944.00.R.001.Rev0 Cranbrook Geotech” dated February 2016.



Interpreted rock surface profile under Centenary building showing series of rock falling shelfs from south to north across the site

2.1.1 Ground water

Ground water during geotechnical investigations very between RL 6.7m and 12.8m, ie below the current lowest levels for the Centenary (Lv 00, RL 18.25) and AFC building (B2 at RL 8.6). Ground water is likely to flow along the rock surface from south to north across the site and towards the harbour.

Structure has not been designed as water retaining. Drainage is to be provided at the base of walls with spoon drain and cavity system to collect and drain the water from behind the walls.

Ongoing water monitoring is required to confirm expected water levels and flow across the site.

2.2 Centenary building

2.2.1 Foundations

Part of the Centenary Building excavation will be carried out into rock as the building footprint cuts 10m into the higher level rock shelf. In this area columns will be founded on reinforced concrete pad foundations directly to the rock. As rock levels drop away on the east, and to maintain a uniform foundation material, foundations will then be provided by piles into rock.

Part of Lv 00 will be slab on grade where excavation is in rock. Adjacent areas not in rock excavation will be suspended structure spanning between piles.

2.2.2 Retention

The new developed cuts into the side of the existing hill and requires a 3-4 story high retention along the south side of the building. The intent is to use a secant pile wall along the southern perimeter to restrain the soil and sands as well as the surcharge load of existing building and roads behind the new development.

Where rock shelf is higher and in areas adjacent to the existing Heritage buildings the intent is that the secant wall will be restrained laterally by a permanent anchor retention system. Such a system will provide lateral support to the shoring system in both temporary and permanent situations.

When rock shelf steps down to level RL 10 and building is close to the boundary, temporary anchors into sand will be used during excavation with lateral load transferred into the permanent building structure when complete. A series of shear walls will be provided in the building to resist the resulting retention lateral load permanently.

Retention system will need to be developed considering resulting settlement behind the retention wall from lateral displacement of the wall. Refer to Appendix A for Memo discussion on design options and resulting horizontal and vertical movement considerations for both the new structure and existing structures south of the development.

The majority of the retention material is sands expect for the western corner of the building were excavation will be in rock. Rock excavation in Class III or higher quality sandstone will stand vertically with local rock bolting of adverse failure planes in the permanent and temporary condition, with weaker rock requiring permanent retention. Class IV may stand vertically in the temporary condition subject to geotechnical review, joint orientation, and loading condition.

2.3 AFC building

2.3.1 Foundations

At the south end of the site, basement levels are near the expected rock level and hence will be founded on rock. To then provide a consistent foundation system for the building the intent is to then provide pile foundations to rock across the building.

B2 and B1 level of the arch building is expected to be in dense sands or close to rock level. Hence intent is to have slab on grade forming the lowest basement levels sitting on the natural material. Sections of suspended slabs may be required around pool areas over pool services and mechanical trenching.

2.3.2 Retention

A single to double story retention wall will be provided around the perimeter of the site under the oval to form the excavation and basement. Retaining wall will be a secant or contiguous wall with temporary anchors. Wall will then be tied into the permanent structural to provide the lateral resistance to the retention loads.

3 Structural systems

3.1 Centenary Building

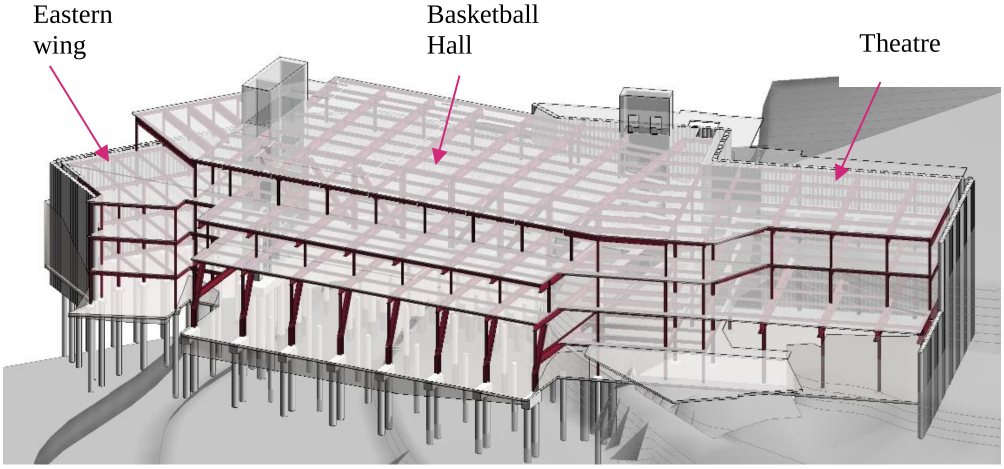
The Centenary Building consists of a 4 story building formed by steel frame and with composite beams and reinforced concrete slab to form the floors. This is then stabilised by a series of reinforced concrete cores and walls placed within the building.

Steel framing is provided on a 6m grid creating spans of 8-15m to maximise column free areas, flexibility of space and floor use. Secondary beams will be provided between primary grid to create a 3m span support for the bondek concrete floor system.

The building can be broken up into a series of spaces;

- The centre of the building has a double height basketball court at the lowest level, with two stories of classrooms and function space over. A steel transfer truss formed from welded columns though the level 2 and 3 structure creates the 32m x 42m clear span required over the courts and seating.
- The western side of the building has a double height theatre space with two stories of classrooms over. A series of steel transfer beams will be provided in the steel framing grid at level 2 to provide a 18m x 28m clear span double story space over the theatre.
- The eastern wing consists back of house space and meeting rooms with structure provided on a 8m x3m gird to directly support bondek floor system.

Level 4 or roof of the building provides a trafficable green roof and terrace area tying into the existing building to the south of the site.



Centenary Building framing and rock contour

Chapel and single story structure to tie in lift core and access to the Centenary Building will also be provided at level 4. The chapel structure will be a timber framed building and roof.

3.2 AFC building

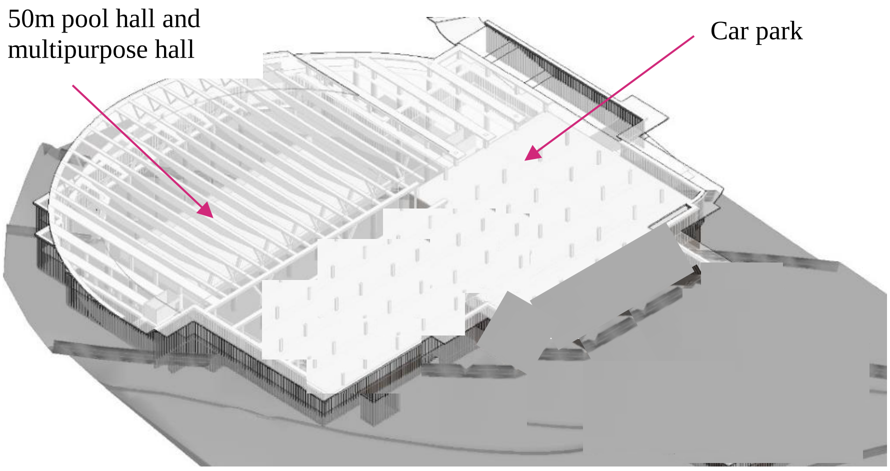
The AFC building consists of a two story basement building constructed under the existing oval. A secant pile retention wall will be provided around the perimeter to allow excavation and construction of the basement structure. This will be covered by concrete roof to form surface for the new oval over.

Structure is formed by post-tensioned floors with reinforcement concrete walls and stair core to provide the lateral stability.

The building can be broken up into a series of spaces;

- 50m pool hall. Double height space provided over the pool hall. Scheme is to use a series of posttensioned narrow beams (2100D x750W) at 4.1m centres to create a ribbed slab with a 34m span over the pool and 22m span over the multipurpose hall, supporting the oval above. Rooms around the pool hall and B2 level will consist of building and pool plant, formed by a traditional post tensioned band beam and slab on an 8-10 m grid.
- Car park if formed by traditional post tensioned band beam and slab on a 8.5 x 8.2 m grid.

Design of the pool and tanks structure is by the Aquatics Engineer.



AFC building and rock contour

4 Design loads

4.1 Self weight

Structural self-weights are to be calculated on the basis of the following densities:

Reinforced concrete: 24.5 kN/m3

Steel: 78.5 kN/m3

4.2 Overall building loading

Loads will be determined in accordance with;

Design Live loads to AS/NZS 1170.1

Design Wind Loads to AS/NZS 1170.2

Importance level (BCA table B1.2a)	= 3
Annual probably of exceedance	= 1:1000
Regional wind speeds	V1000 (ULS) = 46m/s
	V20 (SLS) = 37m/s
Terrain category	2.5

Design Earthquake Loads to AS/NZS 1170.4

Annual probability of exceedance	1:1000
Site sub soil class	Be- Rock (Centenary Building)
	Ce – Shallow soil (AFC)
Site Hazard Factor	0.08
Earthquake design category	II

Notional lateral loading of 1.5% gravity loading will be provided as a minimum stability requirement in accordance with AS/NZS 1170.0

4.3 Imposed movements

Consideration of the stresses induced by imposed movements such as differential foundation settlement and differential elastic and time-dependant shortening between the new and existing structures will be considered.

4.4 Vertical Design loads

4.4.1 WMB

Vertical design loads in accordance with AS1170

Location	SDL	Live Load
Level 4 Green roof	6kPa (300mm thick soil) 0.5kPa (ceiling and services)	5kPa
Level 3 Class rooms	*Internal:* 1kPa (floor build up and partitions 0.5kPa (ceiling and services) *External* 3kPa (floor build up) 0.5kPa (ceiling and services)	3kPa (internal) 5kPa (external)
Level 2 and level 3 Kitchen and pre-function	*Internal* 0.5kPa (build up/partitions) 0.5kPa (ceiling and services) *External* 3kPa (floor build up) 0.5kPa (ceiling and services)	5kPa 5kPa
Lv01	*Seating areas* 0.65kPa +6.1 kPa for precast seating *Foyer areas* 2.5kPa	5kPa
Lv 00 Basketball hall	0.5kPa raised floor/ finish	5kPa
Lv 00 - change rooms	2.5kPa	3kPa
Lv 00 – plant and store	2.5kPa	5kPa
Lv -01	Access corridor 0.25kPa for finishes	3kPa

4.4.2 AFC building

Vertical design loads in accordance with AS1170

Location	SDL	Live Load
Oval/Green roof **	10kPa to 15.4kPa (500mm min to 700mm max thickness of build up) 0.5kPa (ceiling and services)	5kPa (beams and columns– larger supporting area) 20kPa (slabs – for local stacked material during construction- 1m max height)
Car park	0.25kPa (services)	3kPa (typically) *Loading doc and load requirements TBC*
B1 foyer	2kPa Finishes 0.5kPa hanging services	5kPa
B1 bike store/kitchen	1.5kPa finishes 0.25 ceiling/services	4kPa
B1 plant/storage	3.5kPa SLD (plinths and finishes)	5kPa
B2-B1 Seating	0.5kPa finish 6.1kPa (SW precast)	5kPa
B2 pool plant	3.5kPa (finishes and plinths)	7.5kPa
B2 adjacent to pool/storage	2.5kPa SDL (topping and tiles)	5kPa
B2 change rooms/office etc	3.5kPa SLD (topping and tiles + partitions)	3kPa
B2 multipurpose	0.5kPa raised floor/finish 1 kPa partitions	5kPa

** *It is assumed that vehicles for future maintenance will be managed to limit loading of the roof slab to within these design loads. Emergency vehicles will not be driven across the oval and hence slab does not need to be design for such vehicles*

5 Serviceability

5.1 Design life

The structure is intended to be designed for a nominal 50 year design life. The BCA and Standards Australia material standards will be used as the basis for the durability specification for the structure.

Reference should be made to the relevant material standard regarding maintenance assumptions that form the basis of the design code.

5.2 Floor vibration

Floors in the Centenary Building building will be designed considering use of space across teaching spaces and performance spaces.

The vibration of the floor slabs in response to human footfall is controlled by checking frequency and acceleration response. Similar to Office space the teaching spaces in the Centenary Building will be designed to achieve:

- Floor designed for peak response factor of 6 assuming 3% damping
- Transfer truss targeting frequency above 6 Hz

5.3 Deflection limits

Total defection for large span members, transfer structures and elements supporting green roof systems will be managed through precambering of structural elements

The deflection criteria specified in AS 3600 and AS 4100 and as specified below are appropriate for this building.

Type of member	**Deflection to be considered**	**Deflection limitation (△Lef)**	**Comments**
PT Band beams and slabs	The total vertical deflection	1/250, (30mm max) spans 1/125 (15mm max) cantilevers	
Members supporting masonry partitions	The deflection which occurs after the addition or attachment of the partitions	1/500 where provision is made to minimise the effect of movement, otherwise 1/1000	
Centenary Building primary framing composite beam floor system	Incremental defections	Span/500 (30mm max) spans	25-30mm precamber to manage total defections

Centenary Building transfer structure	Incremental defections	Span/1000	50-70mm precamber to manage total defections
Large span AFC roof structure	Incremental defections	Span/500 (50mm max) spans	25-30mm precamber to manage total defections 30mm
Mullions and wind columns	Deflection under wind load	1/240	-
Storey drift under wind	H/500	-	-
Overall sway under lateral loads	H/500	-	-
Differential settlement between foundations	L/1000	-	-

5.4 Durability

Concrete

The requirements of AS 3600 will be applied to all reinforced and post-tensioned concrete. For the foundations, the concrete mix and cover to reinforcement selected will be appropriate for the ground conditions.

Steel

The corrosion protection system for structural steelwork will be dependent on the location of the steel elements within the building. Systems will be selected in accordance with AS/NZS 2312 as a minimum specification.

Location	Exposure classification
Internal (air-conditioned spaces)	A2 (AS 3600) Category C2: Low (AS 2312)
External	B1 (AS 3600) Category C3: Medium (AS 2312)
Pool Environment	B2 (AS 3600) Category C4: High (AS 2312)

5.5 Fire Resistance levels for structural elements

Fire resistance levels for structural elements shall be determined in accordance with the BCA and fire engineered outcomes. Typically expect 120/120/120 for building elements and no fire rating require for roof and elements supporting the roof.

Concrete covers are to be in accordance with AS 3600 Section 5.

Structural steel work supporting floors will need Fire protection. As the intent is to have the majority of steel exposed then would expect this to be paint applied system:

- Internal steelwork, water or solvent based system can be used
- External steelwork with either 1hour or 2hour fire rating require an epoxy intumescent coating eg Interchar 212

6 Design Codes and References

The design and documentation of the building and associated works shall comply with all relevant Australian Standards and the Building Code of Australia (BCA).

Standard Specifications or Codes of the British Standards Institute (BS) or the American Society for Testing and Materials (ASTM) or other are referenced only when a relevant Standards Australia publication does not exist.

Current editions of all codes and standards shall apply.

6.1 BCA Structural Provisions

The building is classified as followings in accordance with part B1 of the BCA

BCA Table	Classification
Table B1.2a – Importance Level of Building	3 – Buildings and facilities with a primary school, a secondary school or day care facilities greater than 250.

6.2 Codes and standards

The following codes and standards will form basis of structural design

AS/NZS 1170.0 Structural design actions – general principles

AS/NZS 1170.1 Structural design actions – Permanent, imposed, and other actions

AS/NZS 1170.2 Structural design actions - Wind actions

AS 1170.4 Structural design actions – Earthquake actions in Australia

AS 1720.1 Timber Structures Code - Design Methods

AS 2121 Cold Formed Steel Structures Code

AS 2159 Piling code

AS/NZS 2312 Guide to the protection of structural steel against atmospheric corrosion

AS 2327.1 Composite structures - Simply supported beams

AS 3600 Concrete Structures Code

AS 3700 Masonry Code

AS 4100 Steel Structures Code

AS 5100.6 Bridge design – Steel and composite construction

BS 5950-8 Structural use of steelwork in building – Code of practice for fire resistant design

Eurocode 4 Design of composite steel and concrete structures

BCA Building Code of Australia

AISC; Design Guide 11 – Floor Vibrations Due to Human Activity

SCI design guide: Design of Floors For Vibration

CCIP016 A design Guide for Footfall Induced Vibration Structures

Appendix A

Centenary Building Retention and lateral deflection

Memorandum

ARUP

To	Mark Flanagan, Cranbrook School John Whatmore, Gary Henighen, Architectus Mike Currie, Craig Keen, David Stralow, Buildcorp	Date 29 September 2017
Copies	Mike King, Arup	Reference number 256385-10
From	Jane Nixon, Arup Adrian Callus, Arup	File reference Memo 01 rev 01 –WMH retain
Subject	WMH – Retention and lateral defection	

This is a memo outlining the design options and considerations for the design of the retention wall along the south of the WMH

A key design criteria for the retention and lateral system for the new WMH is management of lateral movement of the proposed retention system and impact of resulting immediate surface settlement of the retained ground. This a key issue along the junction with the Perkins building and Rosebay Avenue due to buried services.

From existing information available to us, the Perkins building is a two story high masonry building assumed to be supported on shallow foundations, founded within natural sand. Any settlement of the founding sands for the building is likely to result in cracking and damage of the Perkins building.

As well as limiting the deflection and movement of the retention system, consideration should be given to under pinning Perkins building below exiting footing depth below to limit damage to the existing building.

It is understood that there are number of buried services long Rosebay Avenue. Of particular importance is a water main adjacent to the site boundary. Sydney water will expect resulting settlements from the new building to be limited to ensure that their asset is not damaged.

This memo outlines initial investigations, considerations, potential systems, and initial sizing for comparison. However further detailed analysis is required to fully investigate potential movements, interactions of systems and settlements.

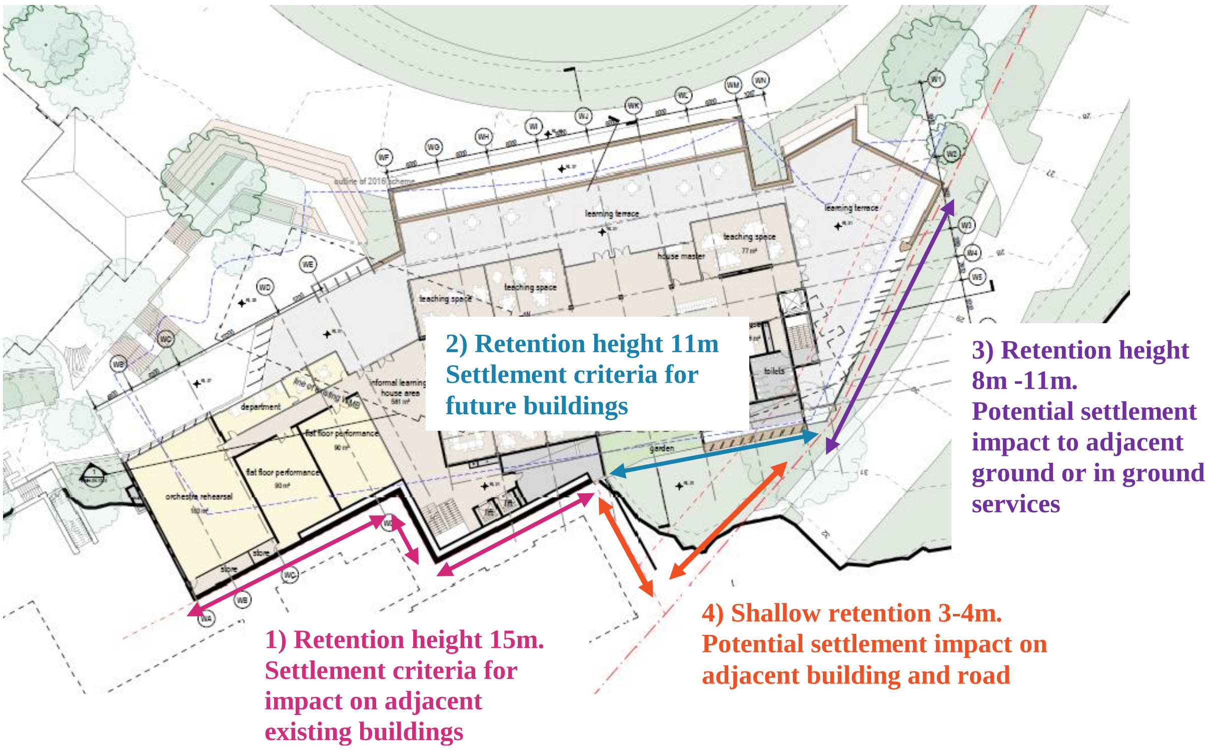
The second half of the memo then describes how this resulting movements could be described as qualitative damage to the walls and structure in the Perkins building. As similar investigation would need to be carried out around the full perimeter of the new retaining wall and boundaries scenarios.

Memorandum

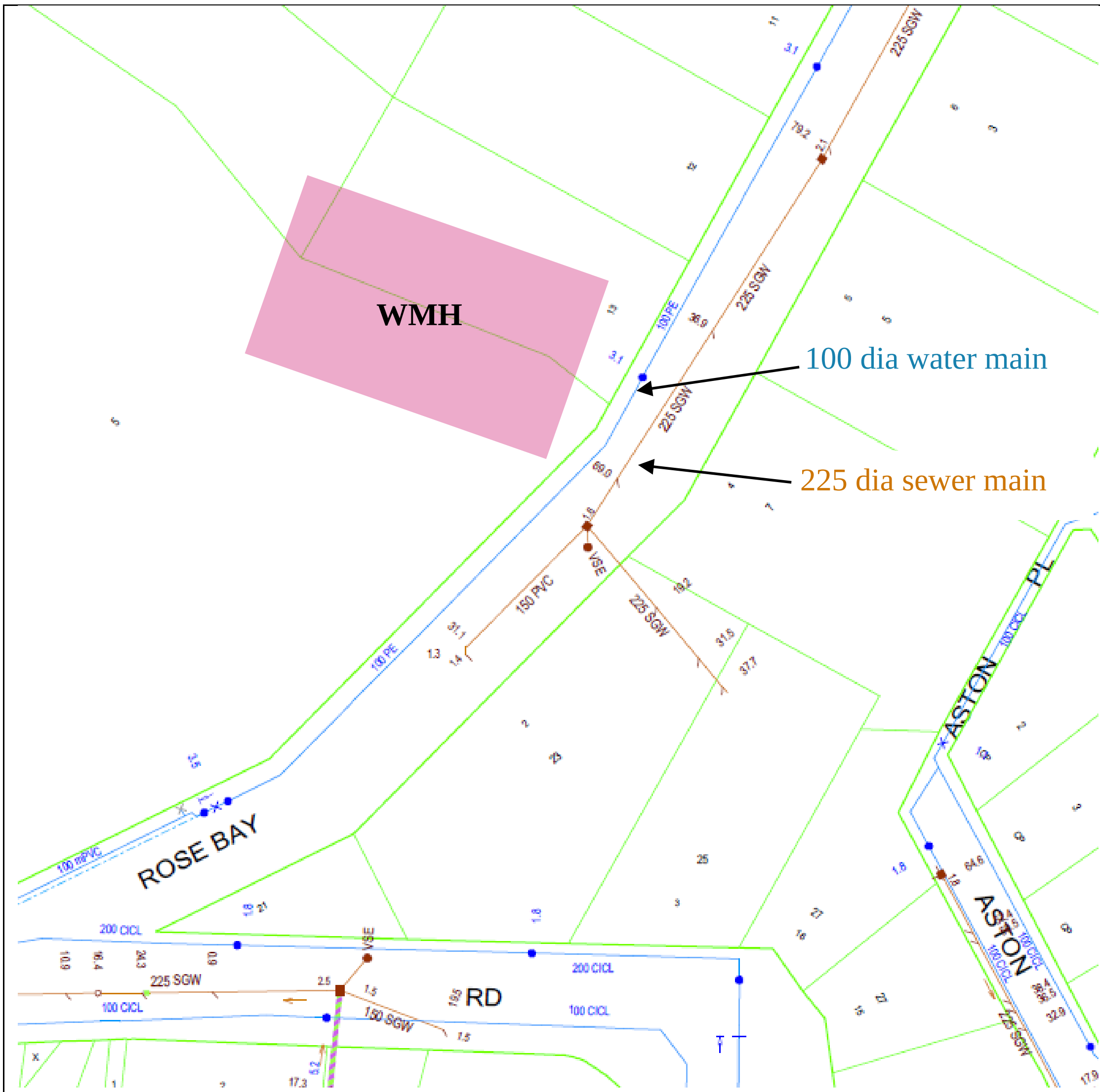
1 The Site

Along the southern retention wall the following four scenarios have been considered:

1. Retention and Settlement impact on existing buildings. That is existing building behind the new retaining wall will see short term movements during excavation and construction as well as long term creep/movement of the building
2. Retention and Settlement impact future buildings. Typically only need to consider long term creep/movements of the system, however interaction with adjacent scenarios (1) and (3) would also need to be considered
3. Retention and Settlement impact on adjacent road and/or adjacent buried services. It is understood there is a water main in the adjacent street. Settlement will need to be limited to ensure water main is not damaged.
4. Retention and Settlement from landscaping works. From architecturals it is noted that south east corner behind the building will be landscaped at RL 31 to allow access to level 3. The reduction in levels in this area will require battering or retention to manage impact on existing building and boundary.



Memorandum



Extract from dial before you dig map "MAP_6363368912790191"

View up Roase Bay Avenue

2 Expected ground movements

2.1 Published guidance

The UK CIRIA guide C670 provides published data on recorded cases studies on expected settlements behind embedded retention systems in sands.

Figure below provides expected ground service settlement due to excavation – based on a 12m soil retention height could have up to 36mm vertical settlement behind the wall or 20mm vertical settlement at Perkins (3m behind the wall).

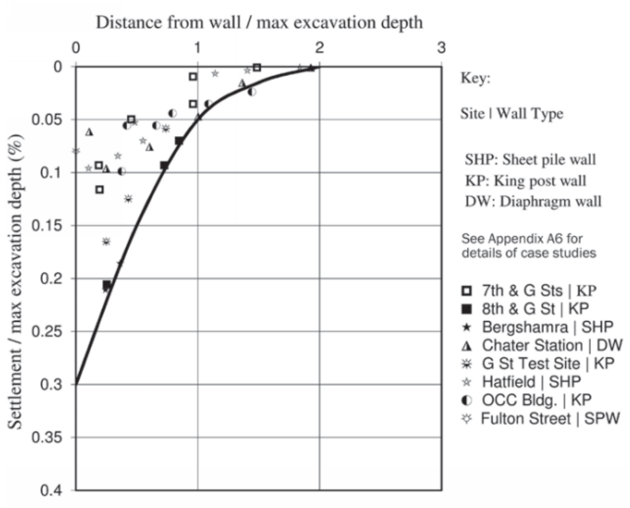
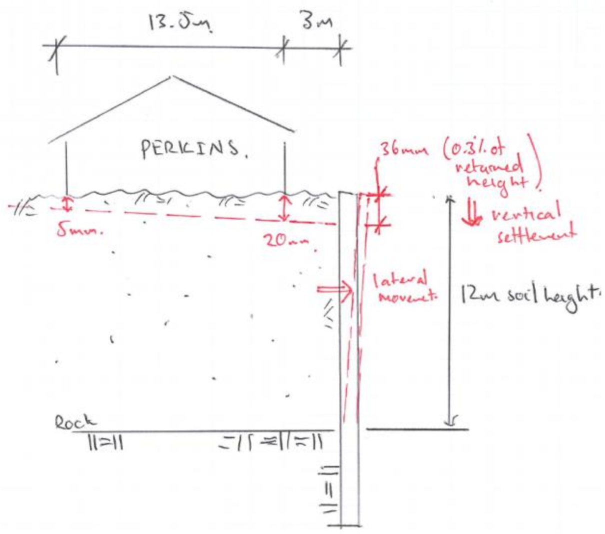


Figure 6.16 Ground surface settlement due to excavation in front of wall in sand

From " Guidance on embedded retaining wall design", C760, CIRIA, 2017

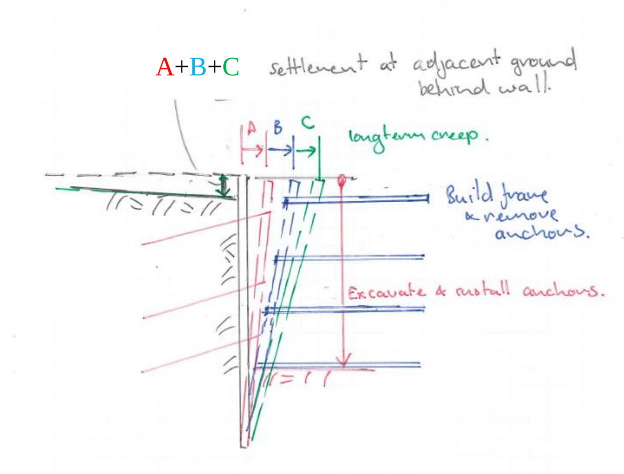


CIRIA guide applied to Perkins

Memorandum

2.2 Behaviour of designed system considering construction sequence

The lateral movement of the building will occur over a series of stages;



Possible lateral movements:

A) During excavation and installation of anchors: design targeting 10-15mm but note case studies above suggest up to 20-36mm

B) Short term lateral movement of building frame during de-stressing of temporary anchor and transfer of lateral load to the building frame or buttress system(20-30mm)

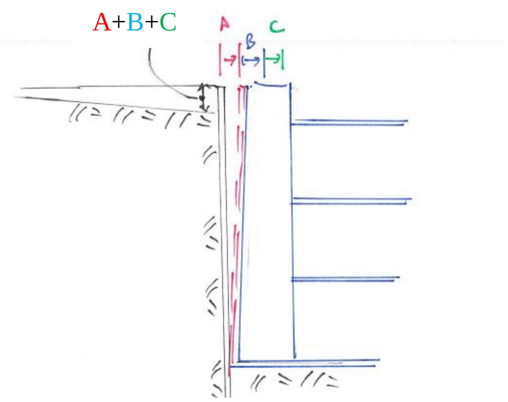
C) Additional long term lateral movement (20-30mm) due to creep of the building lateral frame or buttress system

That is could be up to 50-100mm horizontal movement, resulting in a 50-100mm vertical surface settlement of ground behind the wall.

Lateral deflection is effect by the foundation stiffness as well as building frame stiffness, hence a combined analysis model is required to estimate movements. Also considering the non-linear behaviour of the sand will require an iterative design to estimate movements.

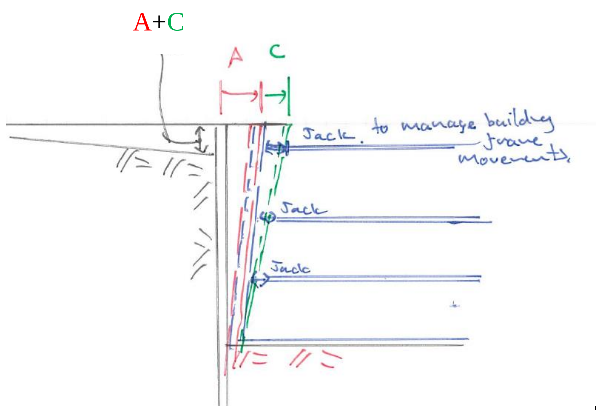
Memorandum

2.3 Lateral restraint systems.

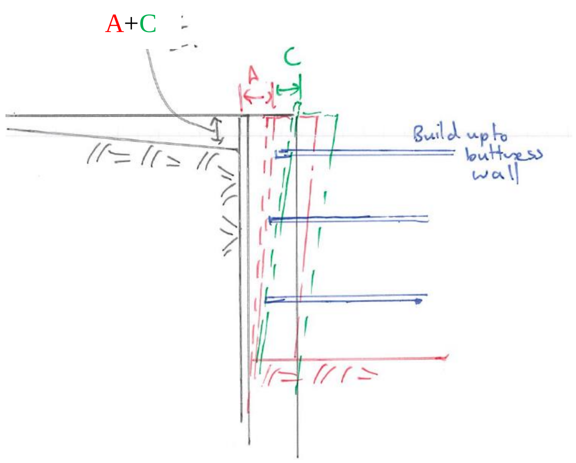
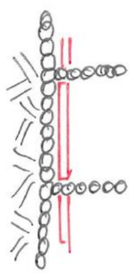
<table>
<tr><th colspan="2">Strategies to manage lateral defections</th></tr>
<tr><td>
</td><td>Stiff buttress system to minimise lateral displacements

Design retention and temporary anchors to limit defection during excavation (A)

Then construct a shear wall as part of the permanent structure and with adequate stiffness so that (B) and (C) deflections are within acceptable limits.

Note (B) and (C) deflections will be also influenced by building frame and foundation stiffness</td></tr>
<tr><td>
</td><td>Laterally jack the building with hydraulic bottle jacks, or similar, to preload the building frame before de-stressing anchors.

This will mean retention system will not experience the (B) displacement.

Surface settlement will only be a result of excavation displacement (A) and long term displacement (C)</td></tr>
<tr><td>
</td><td>
PLAN

Build permanent retention and buttress system during excavation.

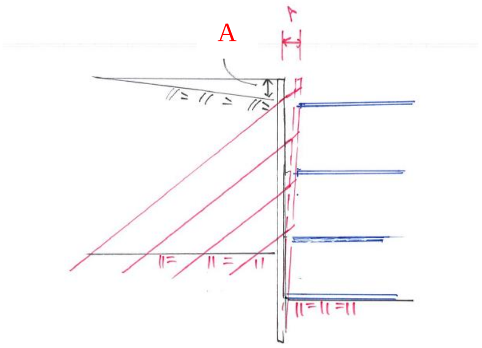
That is use a secant pile wall system to build the orthogonal buttress with the retention wall. Removes the needs for temporary anchors.

Majority of the displacement will occur during excavation, ie (A)

Surface settlement will only be a result of excavation displacement (A) and long term displacement (C).

Disadvantage – larger buttress system required. Interlocking piles is not as efficient as a monolithic wall. Significant movement required to “engage” the buttress.</td></tr>
</table>

Memorandum



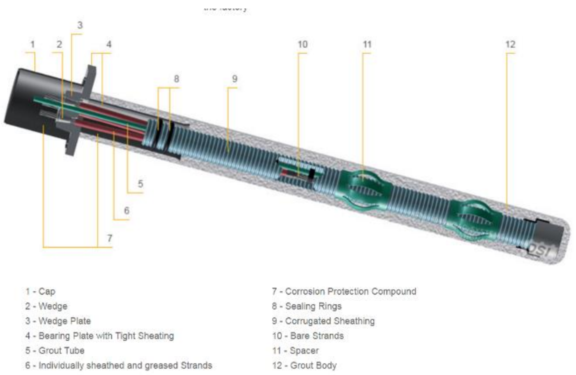


Diagram of such a permanent anchor system

(eg DYWIDAG or VSL)

Example of access able anchor head

Permanent retention anchors.

Only have (A) deflection, however system could potentially creep over time so would recommend allowance for a similar additional defection long term

As anchors are permanent would require a double corrosion protection system. Consisting of galvanised HDPE sheathed wire strand, this is then provided within corrugated plastic sleeve provided over the full length of the anchor and fully grouted. Anchor head will need to be protected with an adequate cover and fully encapsulated in grease.

Design life for anchors would need to be confirmed. Building is expected to have a 50 year design life. It is noted while the design life of a building can be extended through inspection and review of building performance, this cannot be done as easily for the anchors. Hence additional anchors will need to be considered as redundancy for design life extension of the retention.

It is noted that reasonable access to the anchor heads will need to be provided thought the life of the building for maintenance and re-stressing of anchors should relaxation occur.

Memorandum

2.4 Systems applied to WMH

2.4.1 Perkins – 15m retention height

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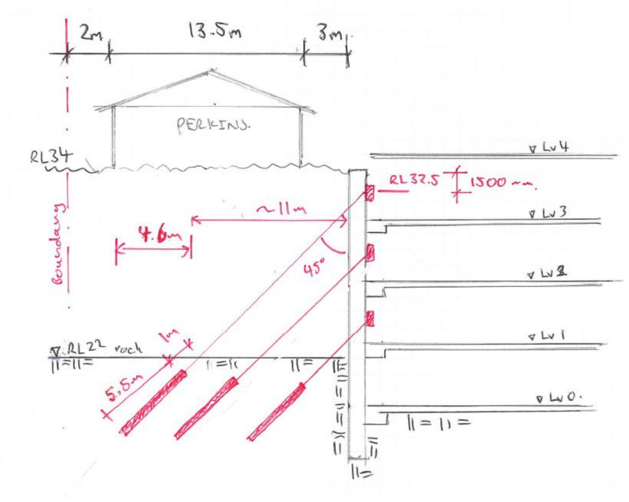

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Permanent anchor system

Based on 900 dia pile wall with 3 rows of anchors over the height of the excavation. At 6m c/c, initial calculations indicate anchors need about 900kN (SLS) anchor

This would result in 9x 15.2 strand anchors,250dia with a bonded length of 5500m (into class III rock) at 6m c/c.

Hence anchors would extent about 16m from rear of wall. In this area boundary is 18.5m min so appears anchors could just fit within the boundary

Expected lateral movement: 10mm (short term) + 10mm long term

TOTAL = 20mm horizontally

Potentially 20mm vertical surface settlement behind the wall

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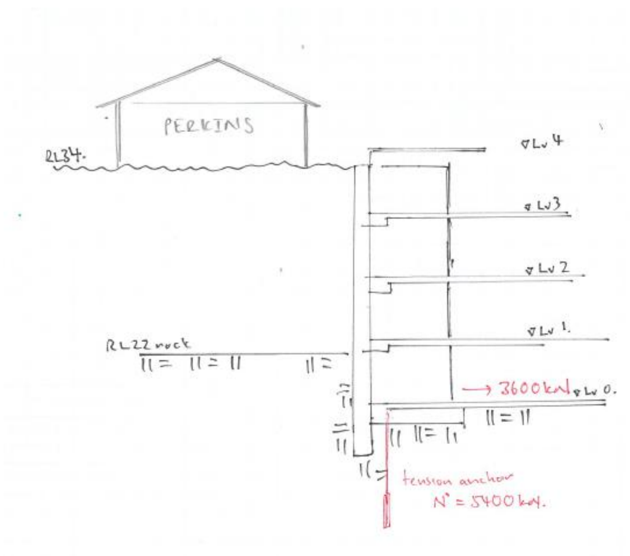

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Stiff buttress system.

Temporary retention is formed with 900 dia pile with 3 rows of temporary anchors (at 2m c/c). Permanent lateral restrain is provided by 5000mm x 450mm blade wall at 6m c/c

Such a system will result in tension loads on foundations and require tension anchors into the ground. On each 6m gird require 2x[10x15.2 strands] each with a 300mm dia socket 9000mm into class III rock. This would require a double corrosion protection system.

A) Excavation displacement = 10mm

B) Framing lateral displacement = 15mm

C) Long term displacement = 15mm

TOTAL = 40mm horizontally

Potentially 40mm vertical surface settlement behind the wall

</td>
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</table>

2.4.2 Basketball – 11m retention height

As this area is closer to the boundary and rock is typically at lower level (RL 9-8) a permanent anchor system will not fit within the boundary. Also area does not have adjacent existing buildings or in ground services so suggest short term displacement is less critical

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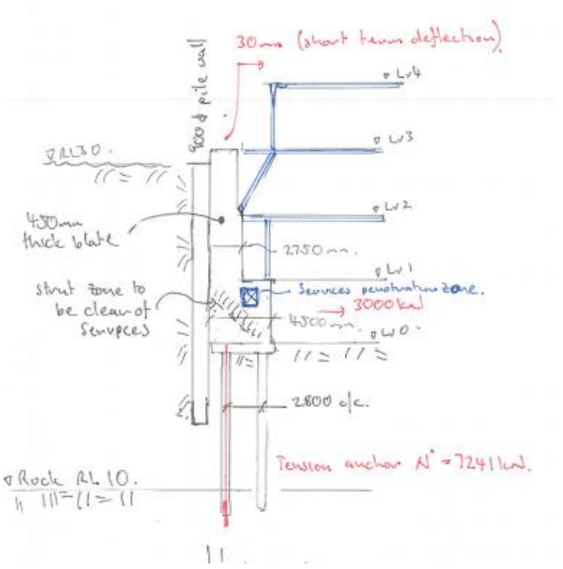

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<td>
Stiff buttress system.

Temporary retention is formed 900 dia pile with 4 rows of temporary anchors (at 2m c/c). Permanent lateral restraint is provided by stepped blade wall at 6m c/c

Such a system will result in tension loads on foundations and require tension anchors into the ground On each 6m gird require 2x[13x15.2 strands] each with a 500mm dia socket 7,000mm into class III rock. This would require a double corrosion protection system.

Rock is 10m below foundation level, hence tension anchors would need to be about 17m long (at each 6m grid)

A) Excavation displacement = 15mm

B) Framing lateral displacement = 25mm

C) Long term displacement = 25mm

TOTAL = 65mm horizontally

Potentially 65mm vertical surface settlement behind the wall

With 25mm long term horizontal movement (and vertical surface settlement). This is a result of H/500 for lateral defection of the new building
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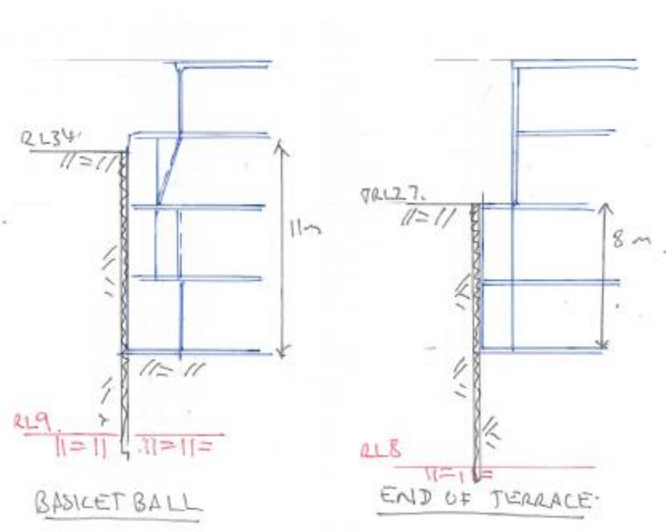
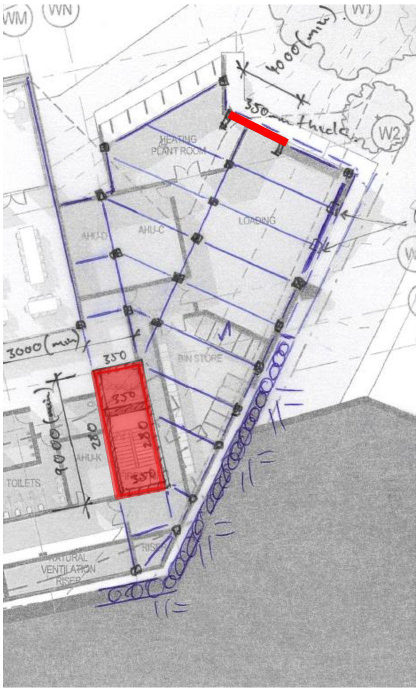
Memorandum

2.4.3 Boundary - 11-8m retention height

This will need to be designed to ensure settlement does not affect adjacent in ground services.





Stiff buttress system. – provide by stair and lift core within the building as well as a 4m long wall (350 thickness) at the eastern end of the building

A) Excavation displacement = 10mm

B) Framing lateral displacement = 15mm

C) Long term displacement = 15 mm

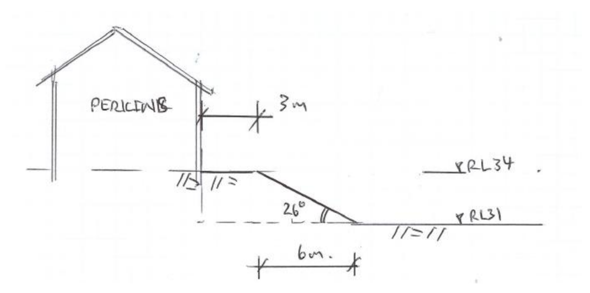
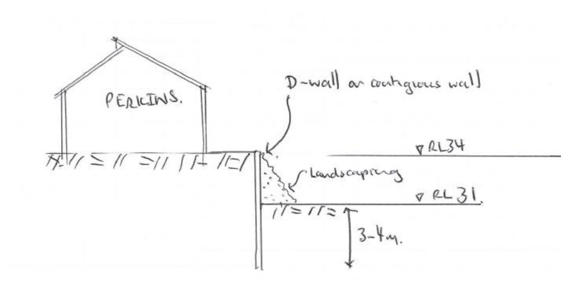
TOTAL = 45mm horizontally

Potentially 45mm vertical surface settlement behind the wall

Memorandum

2.4.4 Landscaping retention (3-4m height)

Considering the zone required for battering it would be assumed that a retention wall would be provided along Perkins and the boundary to provide the RL 31 landscaping levels behind WMH

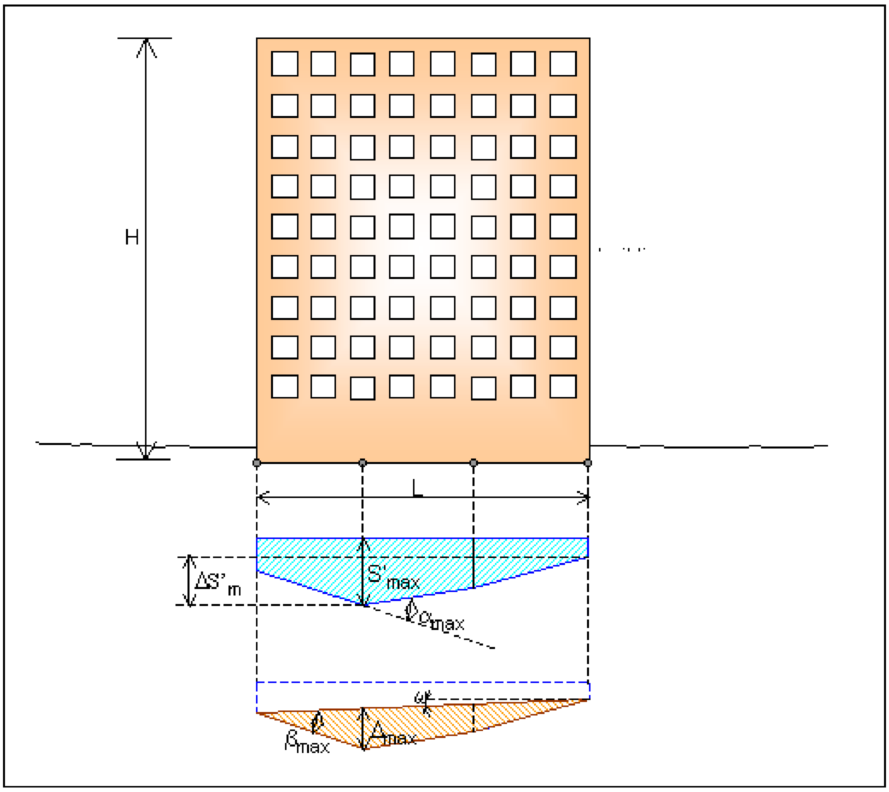
	**Battering** As in sands would require a 26deg batter or 2 (H):1(V) permanent batter , Hence for a 3m height will need a 6m wide batter
	**Retention wall** D-wall or contiguous wall, embedded H into the ground

3 Potential Damage assessment

3.1 Definition of potential damage

In order to define the potential damage induced in an existing structure, design standards provide guidance on acceptable values for the most common deformation parameters of a building subjected to differential settlement.

For structures with isolated foundations the damage is caused mainly by the differential settlement between the columns, with the most important parameters are the maximum angular distortion (βmax) and the maximum settlement (Smax).



Most important factors for the definition of damages for building

For preliminary evaluation of the effects of differential settlement on buildings it is reasonable to assume that for values 1/β < 1/300 there will not be any cracking in concrete walls while for 1/ β > 1/150 there should be damage for concrete bearing structures and such a local deviation of exceeding this should be avoid. Eurocode 7 suggests more conservative limit values: 1/500 for frame structures with concrete reinforced walls and 1/200 only for concrete frame structures

The Australian standard into residential slabs and footing (AS 2870) also provides guidance suggesting maximum differential footing deflection of L/800, 15mm max for articulated full masonry and L/2000, 10mm max for full masonry.

For designs within this limit it would be expected the footing and resulting wall cracking performance would achieve a Category 0 or 1crack performance.

TABLE 4.1

MAXIMUM DESIGN DIFFERENTIAL FOOTING DEFLECTION (Δ) FOR DESIGN OF FOOTINGS AND RAFTS

Type of construction	Maximum differential deflection, as a function of span, mm	Maximum differential deflection, mm
Clad frame	L/300	40
Articulated masonry veneer	L/400	30
Masonry veneer	L/600	20
Articulated full masonry	L/800	15
Full masonry	L/2000	10

Suggested design criteria from AS 2870. This achieve performance of Negligible, very slight cracking in walls

3.2 Damage classification

The classification for damage in the structure as a result of foundation movement is proposed by AS2870 as well as C760 CIRIA guidance. The classification of damage is split into 6 categories a resulting crack width and provides a qualitative description of possible damage.

Table 6.4 Classification of visible damage to walls (after Burland et al, 1977, Boscardin and Cording, 1989, and Burland, 2001)

Category of damage	Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain, ε_{lim} (%)
0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible	<0.1	0.0 to 0.05
1 Very slight	**Fine cracks that can easily be treated during normal decoration.** Perhaps isolated slight fracture in building. Cracks in external brickwork visible on inspection	<1	0.05 to 0.075
2 Slight	**Cracks easily filled. Redecoration probably required.** Several slight fractures showing inside of building. Cracks are visible externally and **some repointing may be required externally** to ensure weathertightness. Doors and windows may stick slightly.	<5	0.075 to 0.15
3 Moderate	**The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable lining. Repointing of external brickwork and possibly a small amount of brickwork to be replaced.** Doors and windows sticking. Service pipes may fracture. Weathertightness often impaired.	5 to 15 or a number of cracks >3	0.15 to 0.3
4 Severe	**Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows.** Windows and frames distorted, floor sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Services pipes disrupted.	15 to 25, but also depends on number of cracks	>0.3
5 Very severe	**This requires a major repair, involving partial or complete rebuilding.** Beams lose bearings, walls lean badly and require shoring. Windows broken with distortion. Danger of instability.	Usually >25, but depends on numbers of cracks	

Notes

1 In assessing the degree of damage, account must be taken of its location in the building or structure.

2 Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.

From “ Guidance on embedded retaining wall design”, C760, CIRIA, 2017
Similar table is provided in AS 2870 (Appendix C, table C1)

3.3 Applied to Perkins building

Unfortunately limited structural information is currently available for the Perkins building. From current investigations on site Perkins is a two story high masonry building supported on shallow masonry foundations. The building was constructed and opened in 1919. Investigations on site at the north east corner of the building suggest that foundations consist of masonry strip footings on natural sands, 3m below the current ground levels

Summarising the different scenarios and possible displacement;

- In line with AS 2870 to achieve a Damage Category of 0 or 1 footing differential settlement should be limited to; L/2000, 10mm max
- From Section 2.1: Based on the assumption of the retention wall is 3m from the Perkins building, publish guidance suggest a differential settlement of 15mm or 1/900 over the width of the building
- From Section 2.4.1:
  - Permanent retention systems would have an expected lateral movement and resulting settlement behind the wall of 20mm or 1/675 over the width of the Perkins building.
  - A stiff buttress system could have a total lateral movement and resulting settlement behind the wall of 40mm or 1/337 over the width of the Perkins building

Based on the above, it is expected that due to the lateral movement behind the shoring wall and the resulting differential settlement under Perkins will be limited to 15-20mm, resulting in increased superficial and aesthetic damage as defined by Category 2 (slight), and without major structural impact to the building.

It is expected that greater lateral movement and subsequent differential settlement would cause significant damage as defined by Category 3 or worse.

3.4 Recommendations and considerations.

Preliminary estimates for settlement adjacent to the Perkins building suggest that if settlement is limited to 20mm then the potential impact to Perkins will be within Damage Category 2 can be achieved, resulting in superficial and aesthetic damage. However, it is considered that this will result in minor to no structural impact to the building.

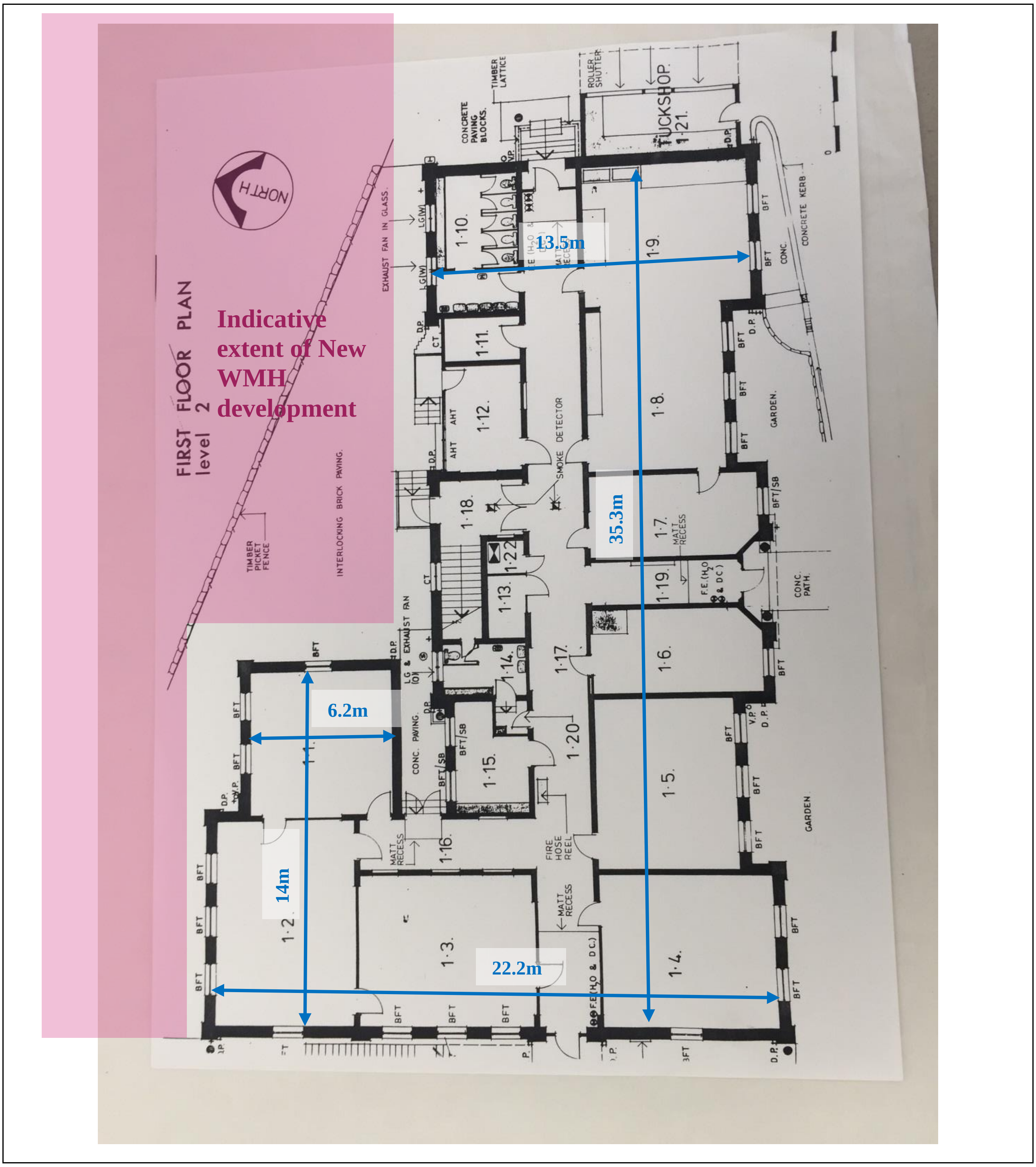
It is noted that our preliminary calculations have been estimated on published empirical relationships commonly used in industry and does not take into account a number of factors present on site such as:

- Based on assumption of retention system performance. Further design work required to confirm the performance of the preferred system.
- Work above has looked at Perkins in isolation further investigation is required to consider interaction with adjacent systems and junction between different systems.
- Impact of construction sequence and location of wall adjacent to existing structure. Work is currently being carried out by ECI contactor into possible construction sequence which could have significant impact on wall performance, estimated displacements and resulting settlement
- Effect of possible poor ground conditions under Perkins that could be disturbed during construction of the wall and new retention system.

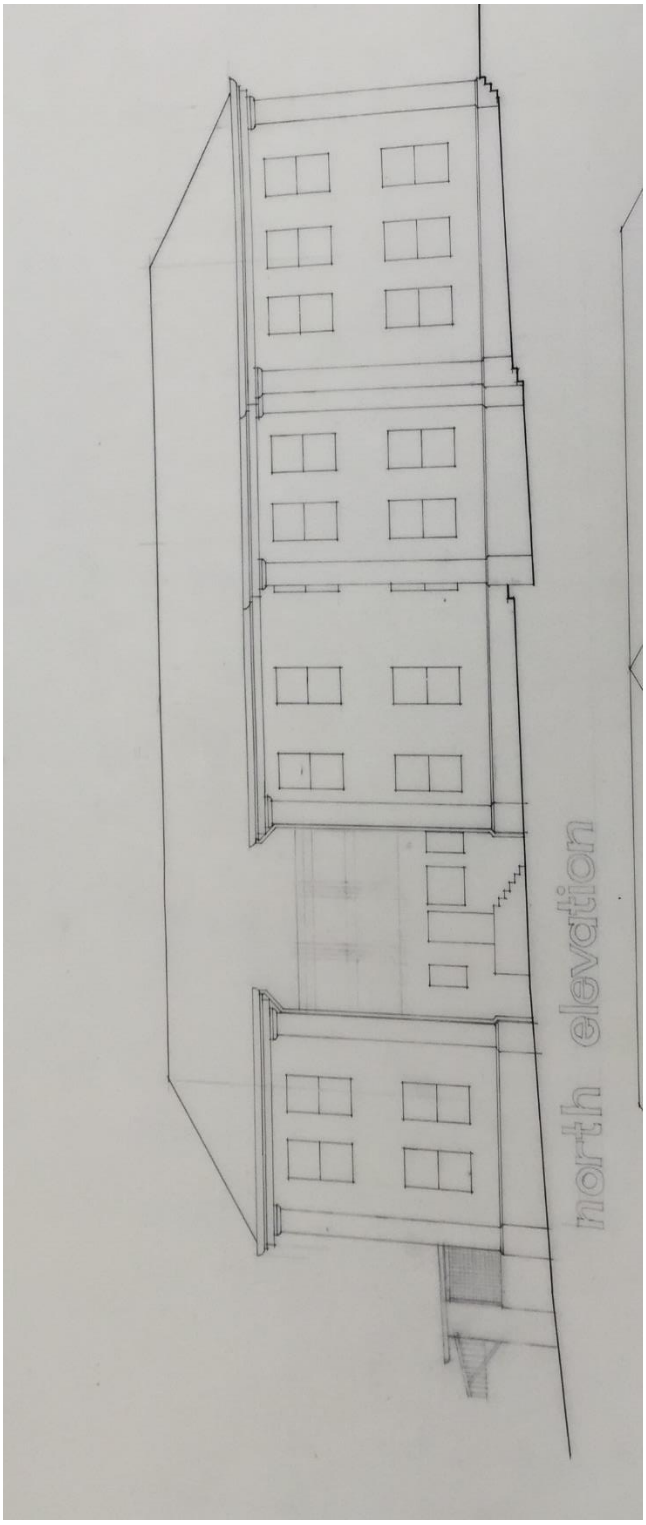
Memorandum

4 Perkins Building existing drawings

Unfortunately limited information is currently available for the Perkins building. Below provides a plan and elevation of the existing building



Memorandum

GA drawing from existing architectural drawings
 North elevation - May 1978 architectural drawings