TUNSTALL SMITH KING

Consulting Structural & Civil Engineers

Lincoln Science & Innovation Park Phase 2.

Structural Engineering Feasibility Report

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Contents

1.0 Introduction

1.1 Tunstall Smith King Ltd has been appointed by Lincoln Science and Innovation Park Limited to provide structural engineering consultancy services for the development of a new café facility.

1.2 This report looks into the works required on site. This involves the review of the existing ground conditions and optioneering of structural forms.

1.3 This document provides a description of the proposed structural engineering works and general design criteria associated with the project. It also advises on the possible risks that may be encountered during design and construction. This document is to be read in conjunction with all other relevant information produced by the rest of the design team.

1.4 The report has assumed a basic layout for the proposals based on a gross area of 200m^2. No information in the form of Architectural sets of drawings showing the proposed site, buildings and proposed works have been provided to inform this report.

Figure 1 - Site Location Plan

2.0 Site Description and Constraints

2.1 The approximate site boundary is outlined in red on Figure 1. The proposed development site occupies an loosely rectangular area of land and is located to the North-West of Poplar Avenue, Lincoln and centred at OSNGR 496420E 371160N. The site is currently used as a car park. To the North of the site Commercial buildings with brownfield land exist. To the East the University of Lincoln student accommodation and education buildings are present. To the West a vacant piece of land comprising concrete exists and to the South vacant land and educational buildings of the wider Lincoln Science and Innovation Park are present.

2.2 The Site is currently vacant and in use as a car park with an access gate in the north-west corner of the site off Edge West Road. The ground surfacing primarily comprised mixed gravel across the site, with a small area of asphalt hardstanding in the north-west corner associated with the gated access. The eastern area of the site was partially covered in young grass and shrubbery growth, with a semi-mature tree located on the eastern boundary.

2.3 The site topography has a gentle, gradual slope from west to east by approximately 1.0 m. The regional topography is generally flat.

2.4 Based on the EA Groundwater Protection Map, the site is not within a groundwater source protection zone.

3.0 Description of Existing Ground Conditions

A specific Geo-Environmental Phase 1 Ground Investigation report was undertaken by Delta Simons in October 2022 for Lincoln Science & Innovation Park Ltd. The report includes extracts from previous Phase 2 Ground Investigation reports undertaken in the vicinity of the site between 2003 and 2019.

3.1 Geotechnical Conditions

British Geological Survey (BGS) online viewer (mapapps2.bgs.ac.uk/geoindex) and mapping (bgs.ac.uk/maps) (1:50,000 Sheet Number 114, Lincoln) indicates that ground conditions at the Site comprise:

- Superficial deposits: Alluvium, comprising clay, silt, sand and gravel;
- Bedrock: Charmouth Mudstone Formation - Mudstone.

Based on Delta-Simons' local knowledge of the area and previous investigation on-Site, it is known that the Made Ground is present to a depth of approximately 2.0 to 3.0 m bgl associated with a former landfill. The underlying natural deposits generally comprise a thin (<400 mm) layer of **peat** followed by alluvium comprising clay and sands. Mudstone bedrock is present at approximately 11.0 m bgl.

There are numerous BGS recorded boreholes (mapapps2.bgs.ac.uk/geoindex) in the immediate vicinity of the Site.

In addition, Delta-Simons has previously undertaken intrusive investigation and assessment of the Site in August 2019 (ref. 19-0773.01), comprising five dynamic sampler boreholes (DS201 to DS205) and the ground conditions encountered comprised the following generalised sequence:

- Made Ground: encountered in all locations to a maximum depth of 3.00 m bgl. Typical composition comprised clayey sandy gravel, sandy gravelly clays and clayey gravelly sands, with gravels consisting of concrete, metal, brick, coal and ash. An obstruction was recorded within one location at a depth of 1.20 m bgl.
- The underlying superficial Alluvium deposits comprised sandy clays with rootlets and clayey sands, encountered to maximum drilled depths of between 2.0 m and 3.0 m bgl;

- Groundwater was recorded between 1.68 m and 2.03m bgl.

3.2 Geo-Environmental Conditions

Delta-Simons previously undertook a desk study and ground investigation for the Site in August 2019, comprising 5 dynamic sampler boreholes. Following soil and groundwater analysis none of the contaminants were above the applied commercial GAC. Elevated concentrations of arsenic and lead were identified within groundwater.

3.3 Buried Services

A topographical and utility survey has not been undertaken for the site. Therefore, the extent and nature of any buried services are currently unknown.

3.4 Hydrology and Hydrogeology

The nearest surface water features are a series of drainage ponds located approximately 150 m north. Beyond that an unnamed drainage channel is located approximately 170 m north. Foss Dyke Canal is located approximately 220 m to the north of the Site. The hydrology of the area has been highly modified; however, the drain and Foss Dyke Canal ultimately flow towards the River Witham. Based on data contained within the Envirocheck Report, there are two licensed abstraction records from surface water located within 500 m of the Site, the closest of which is summarised as follows:

• Located approximately 420 m north-west of Site on the Foss Dyke Canal. Abstraction type is for non-evaporative cooling in machinery and electronics. Permit start date of 1st April 2004, no end date supplied.

Given the distance from the Site and the nature of the surrounding area, the surface water features are not considered sensitive receptors in the context of the site.

3.5 UXO

The Zetica Regional Unexploded Bomb Risk Map for the area of the Site (zeticauxo.com) indicates that there is a low risk of UXO in the area of the Site.

3.6 Radon

Public Health England (ukradon.org) data indicates that the Site lies within lower probability area where between 3-5% of homes are estimated at being at or above the action level for radon.

3.7 Coal Mining

Reference to the Coal Authority on-line viewer (bgs.ac.uk/coalauthority) indicates that the Site is not with a Coal Mining Reporting Area and is not within a Development High Risk Area. Consequently, a Coal Mining Risk Assessment (CMRA) is unlikely to be required under the planning regime. The Envirocheck report does not record any opencast quarrying within 500 m of the Site.

4.0 Flood Risk Assessment

The Fosse Dyke Canal is the main river in the locality. This canal is 200m to the north of the site. This watercourse can be classed as a significant source of flood risk to the site.

The EA website indicative flood mapping confirms that the site lies within Flood Zone 3 in which there is a high probability that flooding can occur on site.

5.0 Description of Design Proposals and Structural Options

5.1 Overview

The proposed brief for the structure was to provide a structure with an internal area of 200m^2 with clear spans over the café area. It is considered desirable to have flat soffits to ease service distribution in lieu of down stands with possible service penetrations. In order to limit the building height a structural zone of 300mm is proposed. The facades of the proposed scheme feature large expanses of glazing, making external load bearing walls difficult to implement.

5.2 Structural Options for Substructure Foundations

Based on Delta-Simons' local knowledge of the area and previous investigation on-Site, it is known that the Made Ground is present to a depth of approximately 2.0 to 3.0 m bgl associated with a former landfill. The underlying natural deposits generally comprise a thin (<400 mm) layer of peat followed by alluvium comprising clay and sands. Mudstone bedrock is present at approximately 11.0 m bgl.

Due to the presence of the layer of peat and the potential for this organic material to decompose over time leading to differential settlement of the proposed structure a more informed foundation solution is required.

Since the structure is a single storey building, the loading from the structure is relatively lightweight. Ideally a reinforced concrete raft would be adopted for this type of building.

A number of ground improvement techniques are available to improve the load bearing capacity of the ground and minimise the potential for differential settlement. The following options have been explored and discounted where required;

5.2.1 Excavation of the existing ground to remove peat layer.

An option to reduce the risk of differential settlement would be to remove the layer of peat. This would involve excavating out the existing made ground to a depth of 3m and carefully remove the peat layer.

An operation of backfilling the excavation with a combination of compacting the existing made ground and stone backfill. However due to the depth of the ground water levels being at 1.6m, the removal of the existing made ground and the peat layer would become problematic without significant dewatering equipment and the disposal of the groundwater. Attempting to compact backfill through saturated sandy clays and clayey sand alluviums could potentially create running sand and a very soft and unworkable platform to build up from. For this reason, this option has been discounted.

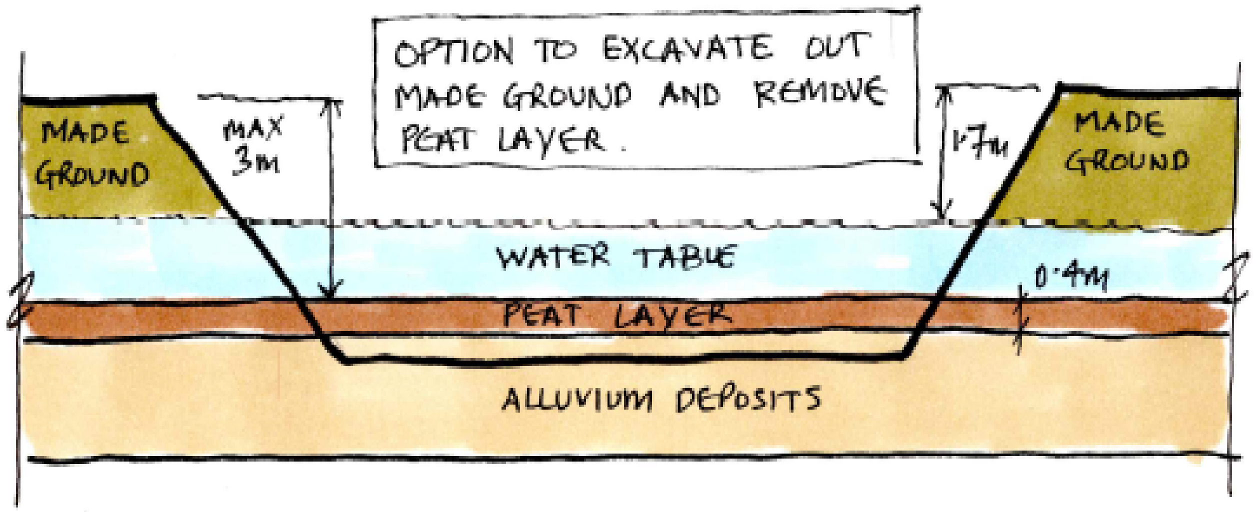

Figure 2 – Option to Remove Peat Layer

5.2.2 Ground Improvement using Resin Injection.

Due to the unworkable nature of the peat and alluvium layers due to the high ground water an alternative would be to leave the peat layer insitu and improve the physical properties of the peat by introducing a ground improvement solution.

Injectable resin is a leading Ground stabilisation method in which poor / un-compacted / loose soils underneath a structure, can be made into a stable medium with an increased bearing capacity that can be classed as better performing soil than the existing conditions. The process removes the need to excavate materials out of the ground in order to reinstate a structure. Because materials remain where they are, costs of excavation and transportation are minimal. A perfect example of an extreme cost saving is on Brownfield sites where excavation & disposal of existing materials are costly.

As the material is hydrophobic, it is does not change its properties once cured. It is chemically inert and therefore poses no threat to ground water. The resin used in these cases is injected in a low viscosity liquid form, allowing it to penetrate into areas that would be inaccessible to cement-based grouts. In addition, the low pressure injection prevents the possibility of hydro-fracture of both the soils and adjoining structures.

The only disadvantage of this method, particularly in areas where there is a high probability of flooding is that the injectable resin displaces the groundwater. Subsequently the groundwater migrates upstream or downstream and could cause changes in how the groundwater behaves in the local area with potential flooding issues to adjacent buildings.

For this reason, this method has been discounted.

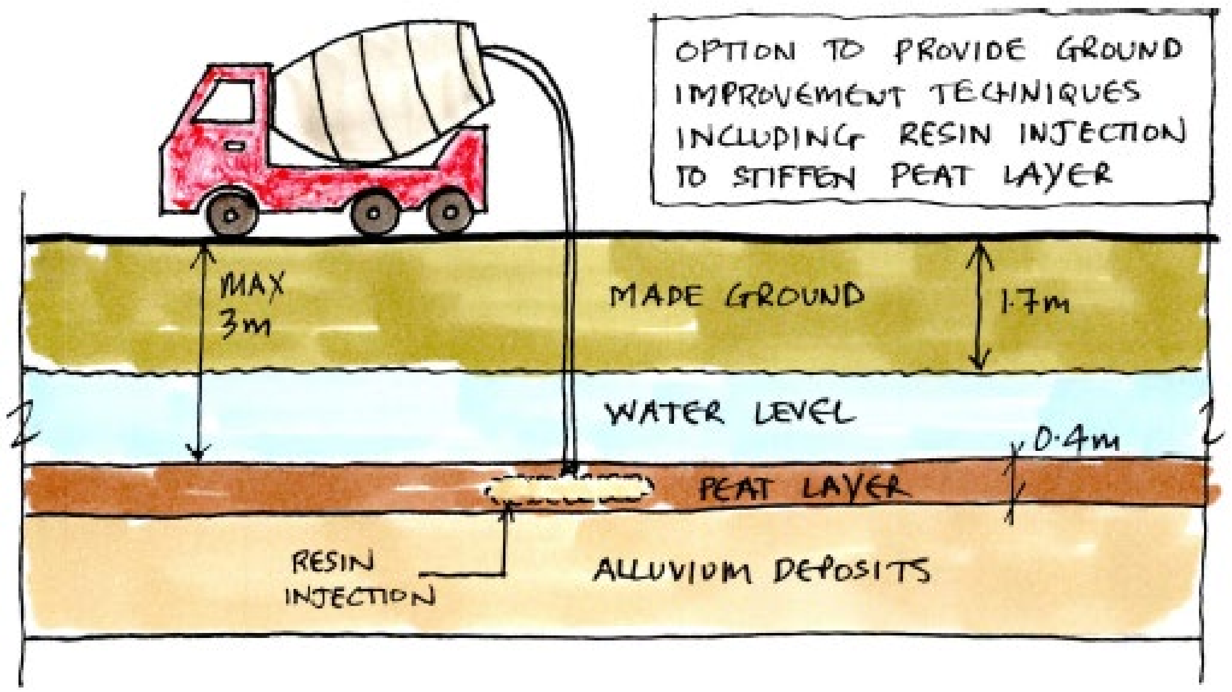

Figure 3 – Ground Improvement Techniques

5.2.3 Ground Improvement Compaction Techniques.

A more favourable alternative to injection resin ground improvement techniques is compaction of the existing made ground and introduction of Geogrids and Geotextiles.

The risk of the peat layer decomposing whilst saturated due to the ground water is minimal, since the peat has no way of drying out and compacting under the weight of the ground above. However should groundwater levels reduce and the peat has the potential to dry out over time and consolidate utilising a stiff crust at the surface which would support a lightweight single storey building could be achievable.

The process includes excavating out approximately 0.5m – 1m of existing made ground, proof rolling and compacting the insitu material, laying a geogrid and geotextile, backfilling with the excavated made ground in well compacted layers. This would provide an improved ground bearing platform and would be improved further by the introduction of a stiff reinforced concrete raft foundation.

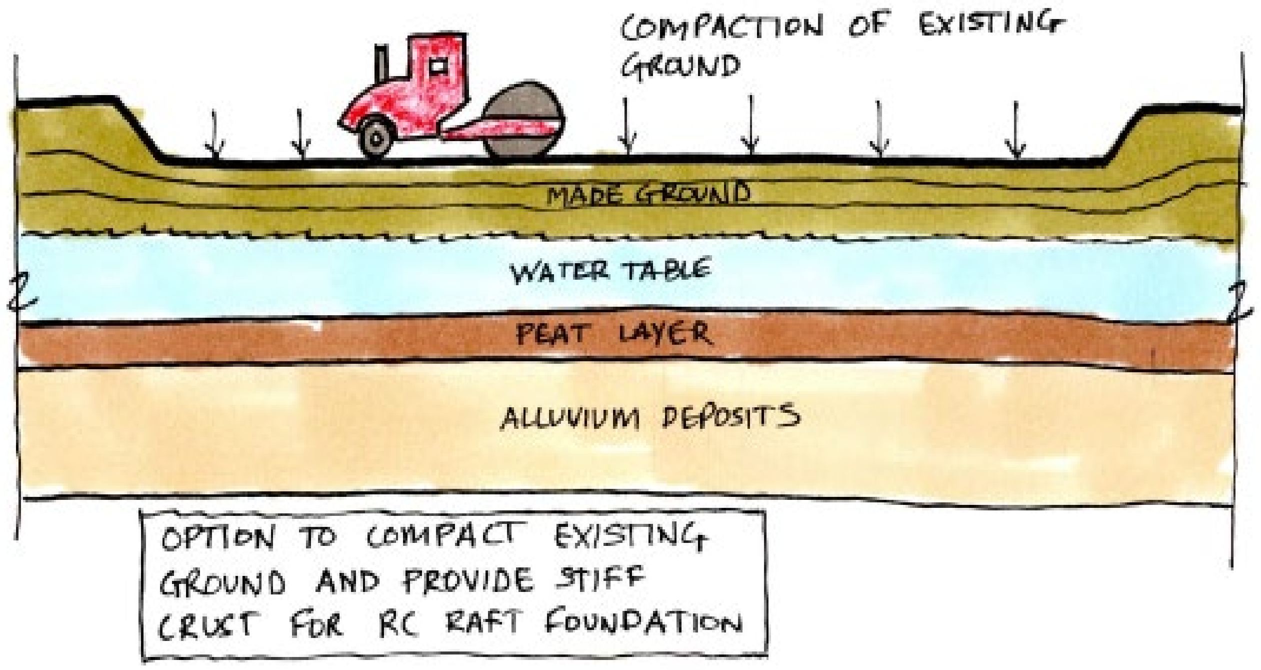

Figure 4 – Ground Improvement Compaction Techniques

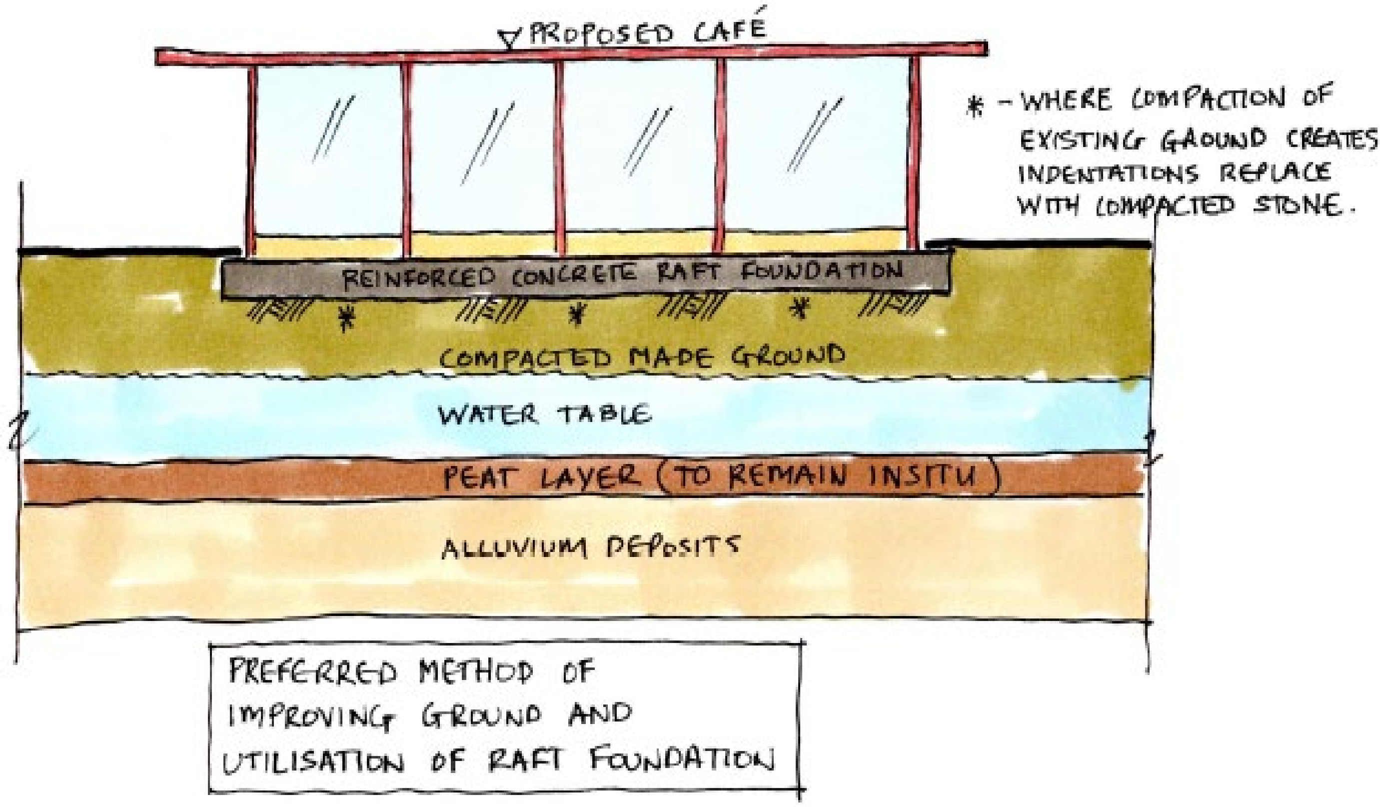

Figure 6 – Reinforced Concrete Raft Foundation & Compacted Ground

5.3 Structural Options for Superstructure

5.3.1 Cross Laminated Timber (CLT)

CLT is a structural system designed to be a more sustainable alternative to masonry, concrete or steel construction. It is made by layering together timber sections perpendicularly. These are then held together by an adhesive material.

It is a robust structural material with inherent strength, often used for floors, walls and roofs. Economy through repetition is achievable if the building is of a modular layout. Prefabrication is achievable offsite once a design is frozen. This leads to a longer lead in time relative to a steel frame however it has a much faster onsite assembly time.

Figure 7 – Cross Laminated Timber and Glulam Cafe

Advantages
- Economical for modest size building with a modular layout
- Minimises onsite construction time
- Lightweight product leading to cost savings in foundation design
- Good sustainability values for reduction of embodied energy

Disadvantages
- Limits of spans
- Long lead in time

- Difficult to integrate services
- Poor fire resistance so fire compartmentalisation detailing can be complex
- Poor acoustic performance
- Design needs to be frozen in order to fabricate meaning that there cannot be changes made late into the project
- Limited to cellular layout and not ideal for cantilevered elements
- Limited flexibility for future alterations

Scale of Construction
- Typical span range of 4.5-8.0 m
- Depths of 180mm to 300mm
- If spans need to be greater beams need to be introduced into the design (glulam or other)

Sustainability Benefits
- Low embodied energy
- Minimisation of waste due to offsite fabrication and it being a more efficient use of materials
- Sustainable sourcing
- Lightweight, therefore, less energy required in transportation and reduction in foundation sizes leads to less embodied energy in the foundations

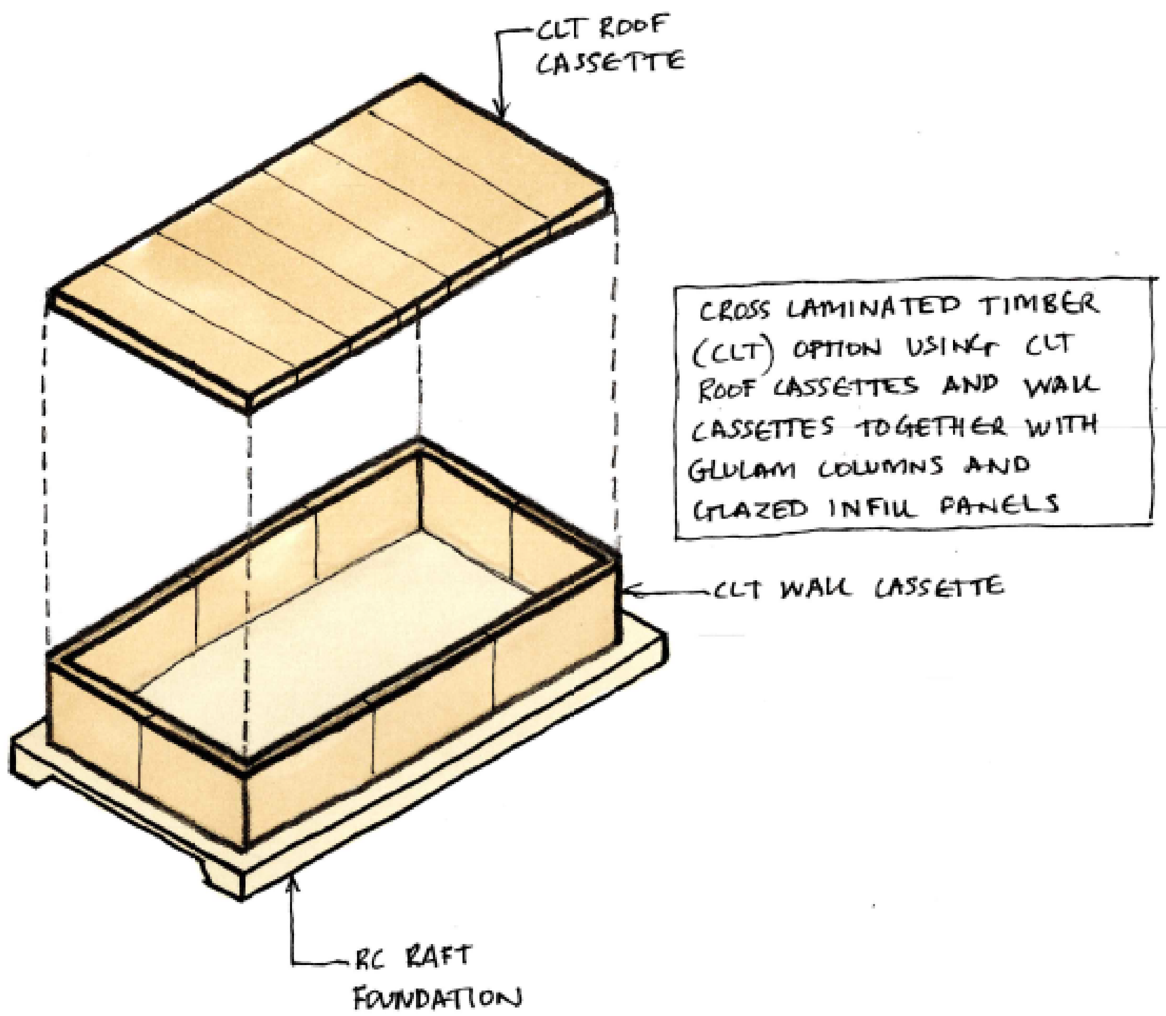

Figure 8 – Cross Laminated Timber Option

5.3.2 Modular Construction

Modular construction can be seen as another alternative construction method to the more traditional 'steel or concrete' frames. Light Gauge Steel Frame construction usually consists of wall panels fabricated from small sections of cold rolled steel C-Sections at regular centres fixed together with either plywood or cement board. This process happens in a factory meaning that it is a good quality and a high accuracy level is achievable. The cladding system can then be attached to the outside face leaving the required cavity.

Light Gauge Steel Modular Panels can be load-bearing but to achieve large roof spans steel beams are required. With these factors as well as it being a sustainable alternative to hot rolled steel and relatively cheap has led to its gain in popularity over the last few years.

Figure 9 – LGSF Modular Cafe

Advantages
- Economical in comparison with hot rolled steel
- Minimises construction program as frames are constructed off site
- Lightweight structure leading to reduced foundation costs

Disadvantages
- Long lead in time
- Difficult to integrate services
- Fire compartmentalisation detailing can be complex
- Poor acoustic performance
- Design needs to be frozen in order to fabricate meaning that there cannot be changes made late into the project

Scale of Construction

- A typical C-Section joist roof 300mm deep can span approximately 9m between supports

Sustainability Benefits:

- Low embodied energy
- Minimisation of waste due to offsite fabrication and it being a more efficient use of materials
- Sustainable sourcing
- Lightweight, therefore, less energy required in transportation and reduction in foundation sizes leads to less embodied energy in the foundations

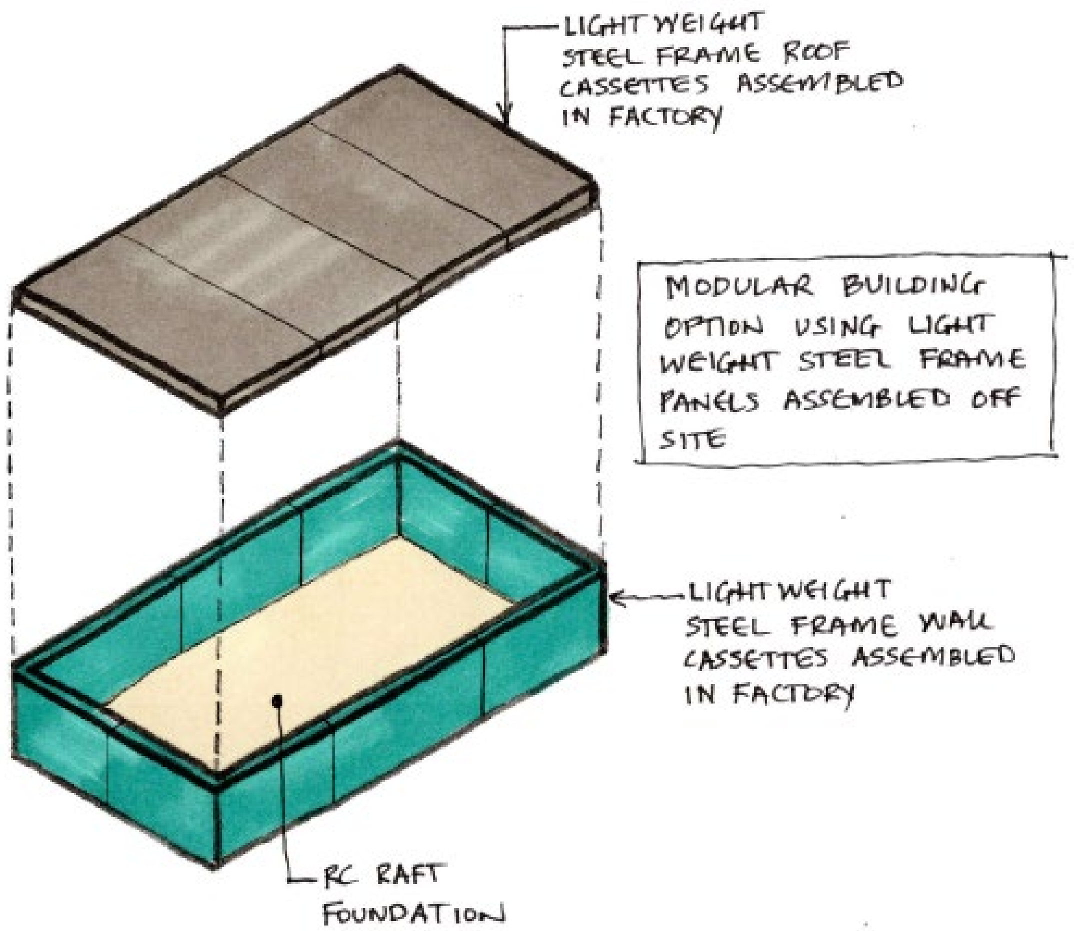

Figure 10 – Light Gauge Steel Frame Modular Construction

5.3.3 Steel Frame Construction

Steel members are fabricated offsite and delivered for assembly according to a schedule. Although lead in time is quicker for steel in comparison with timber onsite construction time is longer although still relatively quick.

Steel frames are economical for large spans and irregular layouts with the benefit of producing iconic and bespoke structures. In addition to this, service integration is possible within the depth of the steel beams by the provision of web penetrations in agreed locations. This allows M&E ductwork to travel through the beam. Lightweight cold rolled steel purlins can be utilised between the main steel beams.

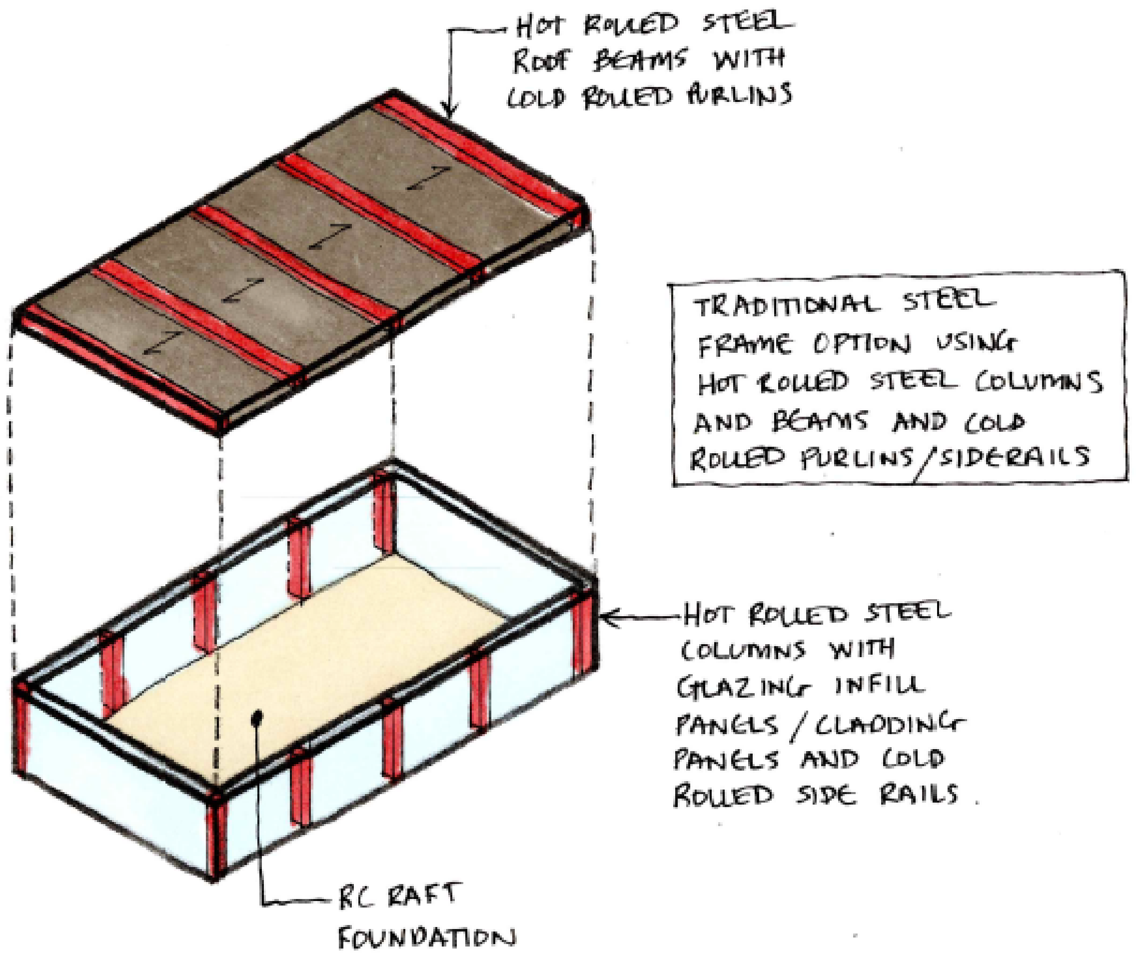

Figure 11 – Traditional Hot Rolled Steel Frame Option

Figure 12 Bespoke Steel Frame Cafe

Advantages
- Quick to construct.
- Long spans help create open flexible spaces.
- Good availability of contractors for steel and concrete construction.
- Compatible with building services.
- Good thermal mass if soffits are exposed.

Disadvantages
- Potentially more expensive than timber solutions.
- The steel frames require fire protection.

Scale of Construction
- 200mm deep purlins.
- 400-450mm deep beams at 6m centres typical for an 10m span.

5.4 Tunstall Smith King Preferred Construction Method

In terms of the ground treatment and the substructure design we would recommend that the ground improvements using compaction methods is adopted together with a stiff reinforced concrete raft foundation for the reasons noted previously.

The superstructure solution is one which the client will need to consider. All the options highlighted are robust solutions, however if the client has any aspirations relating to carbon reduction, BREEAM, design led solutions or commercially driven aspects of the scheme Tunstall Smith King can offer further advice.

6.0 Project Risks

A project risk register will be maintained throughout the project. It is a live document which will be updated as the design progresses.

Currently there are a number of risks that have been observed. Contamination of the made ground and groundwater may be observed upon completion of the Phase 2 Geo-Environmental Ground Investigation report. Although it is considered that no material will be exported off site, there may be risks associated receptors to human health during the course of the works and measures to reduce the impact on human health will need to be presented in the ground investigation report.

7.0 Design Standards and Criteria

7.1 Structural and Civil Design Standards

The design of the civil and structural elements of the development shall generally be carried out to satisfy the requirements of the British Standards and Eurocodes (and all relevant National Annexes) listed below. This is not an exhaustive list and the Contractor shall add to the list where appropriate.

- BS EN 1990: Eurocode 0: Basis of Design (EC0)
- BS EN 1991: Eurocode 1: Actions on Structures (EC1)
  - Part 1-1: General Actions – Densities, Self-Weight and Imposed Loads
  - Part 1-2: General Actions on Structure Exposed to Fire
  - Part 1-3: General Actions – Snow Loads
  - Part 1-4: General Actions – Wind Loads
  - Part 1-6: General Actions – Actions During Execution
  - Part 1-7: General Actions – Accidental Actions From Impact and Explosions
- BS EN 1991: Eurocode 2: Design of Concrete Structures (EC2)
  - Part 1-1: General Rules - Rules for Buildings
  - Part 1-2: General Rules – Structural Fire Design
- BS EN 1991: Eurocode 3: Design of Steel Structures (EC3)
  - Part 1-1: General Rules – Rules for Buildings
- BS EN 1991: Eurocode 4: Design of Composite Steel and Concrete Structures (EC4)
  - Part 1-1: General Rules – Rules for Buildings
- BS EN 1991: Eurocode 5: Design of Timber Structures (EC5)
- BS EN 1991: Eurocode 6: Design of Masonry Structures (EC6)
- BS EN 1991: Eurocode 7: Geotechnical Design (EC7)
- BS 8004 Code of Practise for Foundations (where not superseded by Eurocodes)
- BS EN 752: Drain and Sewer Systems Outside Buildings

The design of all elements shall comply with the Building Regulations. Where appropriate, the following codes and regulations will be applied in the civil and structural design. This is not an exhaustive list and the Contractor will add to this list where appropriate

- BS 6472 Evaluation of Human Exposure to Vibration in Buildings
- BS 8102 Protection of Structures Against Water from the Ground (where not superseded by Eurocodes)
- Building Regulations Approved Documents A – Structure
- Building Regulations Approved Documents B – Fire Safety
- Building Regulations Approved Documents E – Resistance to the Passage of Sound
- Building Regulations Approved Documents H – Drainage and Waste Disposal
- Building Regulations Approved Documents G – Sanitation, Hot Water Safety and Water Efficiency
- NHBC Part 4: Foundations. Chapter 4.2 Building Near Trees
- SCI Publication P354 Design of Floors for Vibration: A New Approach should be referred to when designing floors

All to include revisions and amendments to date of site start.

7.2 Design Criteria

7.2.1 Preliminary Design Loads

Refer to BS EN 1991: Eurocode 1: Actions on Structures (EC1)

Lateral Forces
Wind actions are to be calculated in accordance with EC1 part 4
Equivalent horizontal forces due to construction imperfections to be calculated in accordance with EC3
The lateral system is to be designed for the worst case of the above actions, or combination thereof, in accordance with the design standards

Table 1 - Table Showing Lateral Forces

7.2.2 Vertical Deflections

The following vertical deflection limits are to be used in the design of structural members. Where non-structural elements are affected they should also be designed to accommodate the following movements.

Element	Deflection Type	Limit
Steel and timber beams - general	Deflection due to permanent and imposed loads (subtracting camber, if any)	L/250
Steel and timber beams supporting brittle finishes	Deflections due to imposed loads	L/360
Steel and timber beams supporting non brittle finishes	Deflections due to imposed loads	L/300
Steel beams supporting masonry partitions	Deflection due to imposed loads	L/500
Secondary framing (wind posts / cladding etc.)	Deflection due to imposed load (i.e. wind)	L/360
Reinforced concrete beams and slabs	Long term deflection due to permanent and imposed loads (including long term creep effects of sustained loading)	L/250
Reinforced concrete beams and slabs	Incremental deflection due to permanent and imposed loads occurring after construction of finishes and	L/500

	partitions (including long term creep effects of sustained loading)	

Table 2 - Table Showing Vertical Deflection Limits

Where L=distance between supports for span considered. Note for cantilevers, L is equivalent to twice cantilever length.

7.2.3 Lateral Deflections

The following horizontal deflection limits are to be used in the design of structural members. Where non-structural elements are affected, these elements should be designed to accommodate the following movements.

Element	Deflection	Limit
Total Structure	Deflection under SLS conditions	H/500
Inter-storey	Deflection under SLS conditions	h/500

Table 3 - Table Showing Lateral Deflection Limits

Where H = total building height
H = storey height under consideration

7.2.4 Dynamic Response

In addition to the deflection in any long span floors, dynamic response of the steel beams and the flooring system as a whole needs to be allowed for. Long span floors should be designed in accordance with SCI publication P354 'Design of Floors for Vibrations: A New Approach'; and aim to achieve a natural frequency and response factor which minimises the perception of vibration for the end user.

The size of the structural member, and the mass of the floor is likely to be governed by this service design case in longer spans rather than an ultimate limit strength case.

7.3 Disproportionate Collapse

A single storey cafe buildings is classed as Class 2A 'lower risk group' in Building Regulation Approved Document - A part 3. This therefore means the structure will be designed to meet the requirements of this classification. For class 2A the building must be constructed in accordance with the rules given in the Approved Document 'Building Regulations A'.

7.4 Fire Rating

The fire rating is based on the requirements of Approved Document B – Fire Safety. As the structure is no higher than 18m above ground level the structural frame is to have a fire resistance of 60 minutes. Areas with special uses, such as plant rooms, may be required to have increased fire ratings.

Concrete elements will be specified with the appropriate cover to suit. Adequate protection in the form of intumescent paint or other means of fire protection will be required for structural steel elements as specified by the Architect.

The fire ratings of all areas are to be co-ordinated and confirmed by the Architect and Fire Consultant.

7.5 Design Life

The structural frame will be designed in accordance with BS EN 1991: Eurocodes 1: Actions on structures (EC1) which requires a design life of 50 years. To structural soundness must be maintained throughout the life of the building. This means that periodic inspections and maintenance will be required to ensure that the protection methods are performing adequately. The external structural elements will require more frequent inspection and maintenance than internal structures due to them experiencing more severe exposure conditions.

7.6 Materials and Workmanship

All articles, materials and goods shall be new and of good quality, suitable for the required purpose and shall conform to the appropriate British Standards, Eurocode or other applicable quality standard where such exists

We aim to specify the use of sustainable materials such as recycled aggregates wherever it is viable.

7.7 Sustainability

Sustainability is a key factor in our design approach. We proactively encourage adopting sustainable and economic solutions. Consistent considerations will be given to design efficiencies highlighting opportunities for improvement ensuring the solution is the most efficient and environmentally responsible solution.

8.0 External Works

8.1 There are a number of landscape improvements to be carried out to compliment the proposed build. These include a number of new paths walls and grassed areas. New trees are proposed to be planted on site. Care should be taken to ensure that there is no negative impact on the foundation and structure. Appropriate species should be selected (low water demand and short mature heights where possible) and there locations designed in accordance with NHBC Chapter 4.2 for buildings near trees to mitigate the risk of heave affecting the new or existing foundations.

9.0 Loadings

9.1 Material Densities In Reference to Eurocode 1 Annex A

Concrete - 24.0 kN/m^3
Steel - 80.0 kN/m^3
Brickwork/ Blockwork - 20.0 kN/m^3
Glass - 25.0 kN/m^3
Screed - 22.0 kN/m^3
Timber - 3.5 – 10.8 kN/m^3
Glulam - 3.7 – 4.4 kN/m^3

9.2 Superimposed Dead Load

Roof
Cladding - 0.75 kN/m^2
Insulation and Membrane - 0.25 kN/m^2
Timber Rafters and Boarding - 0.25 kN/m^2
Ceiling and Services - 0.25 kN/m^2

Vertical Elements

External Cladding: Assume 100mm Brick	5.50 kN/m^2
External Cladding: Window/Glazing/Curtain Wall	0.75 kN/m^2

9.3 Live Loads

Roof -	0.4 -2.0 kN/m^2
Communal Areas (Cafe) -	4.00 kN/m^2