

Assessment 1: Modern and Traditional Construction (ACBA5000)

**Case Study on the GSK Carbon Neutral Laboratory for Sustainable Chemistry,
University of Nottingham**

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1. Introduction

This is a two-part study to discuss the foundation and superstructure of the Glaxo Smith Klyn Carbon Neutral Laboratory for Sustainable Chemistry which forms part of Nottingham University (Laboratory). (BMTRADA,2019)

The Laboratory was designed to minimise impact on the environment in its construction and operation. The approach is different in many ways to a normal commercial build, demanding 'out of the box' thinking be applied to its design, buildability and sustainability.

The design delivers power savings and uses less energy than a traditional building design. This enables the carbon emitted during the construction phase to be "paid back" over a 25-year period. The foundation and superstructure are unusual and much of the building is made up of modules manufactured off-site. Construction of the laboratory began in early 2013 and it was expected to be completed during 2014.



Figure 1



Figure 2

During construction, on 12th September 2014, a fire broke out. The fire spread rapidly and the building was destroyed. Initial reaction from the media questioned the safety of the timber build but later investigation determined the fast-burn was mainly due to the incomplete state of build. The opening of the Laboratory eventually took place on 27 September 2017. (Wikipedia,2023)

2. Task 1. Foundation

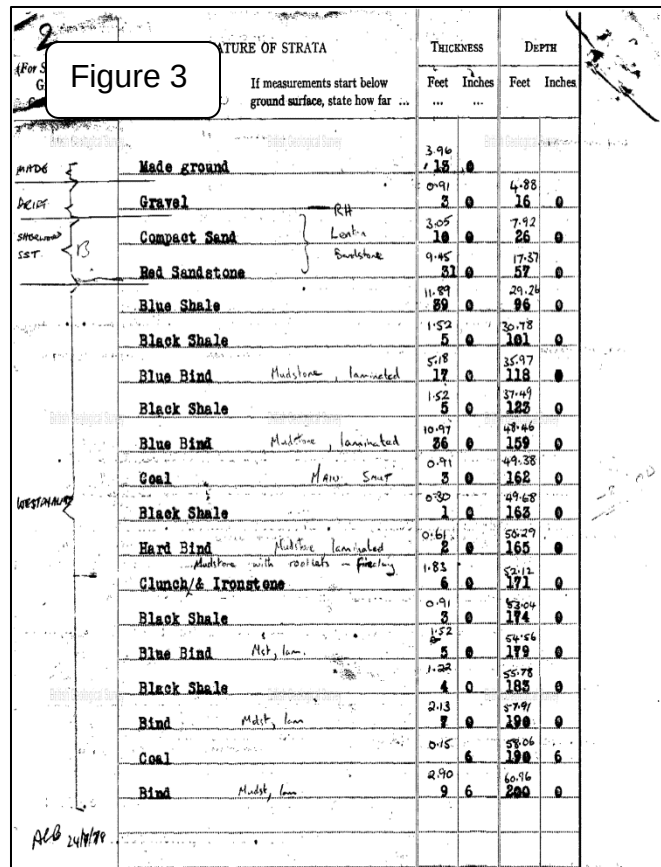
2.1. Details of the Building and Site.

	Detail	Reference
Description	Research and learning facility, occupying 4500m ² over two floors. Laboratory space for 100 researchers, dedicated instrument rooms, teaching laboratory and space for outreach activities. With the objective of minimising carbon pollution, the laboratory is created as an exemplar of sustainability in its design, construction and materials used.	(BMTRADA,2019) & (Wikipedia,2023)
Location	6 Triumph Rd, Lenton, Nottingham NG7 2GT. Coordinates 52° 57' 1" N, 1° 10' 58" W. Nearby land use – North, West and South is academic and commercial, East is mainly residential. Topography 20m above ordnance survey datum.	Google Mapping (Earth,2023) & British Geological Society (BGS,2023)
Site History	A brownfield site, land previously utilised for a bicycle factory.	Nottingham Council Planning (Portal,2023)
Environmental	The high probability of ground contamination (asbestos in particular) required the entire build site to be capped. Aquifer, flooding & groundwater vulnerability, coal mining and radon risks were all mitigated during planning stages.	(Portal,2023) & (BGS,2023)

2.2. Ground Conditions

Planning stages of the Laboratory would have seen significant effort in determining ground conditions. These would have included physical inspections using bore hole and trial pit excavations. These reports are not available to the general public, however located just a few meters to the south west of the site, there was a borehole drilled in 1955. The borehole offers a comprehensive view of the site conditions to a depth of 60.69m. (BGS,2023)

The load bearing capacity of the various soil strata is critical when considering foundation options. The borehole test report SK53NW25 (Figure 3) shows the first four metres of depth to be 'made ground' which has unpredictable engineering qualities and at 4 to 8m gravel and compact sand. The British Standards Institute documents BSI8004 and BSI5930 (BSI,2023) show compact sand and gravel to have a worst-case load bearing capacity of 200kN/m². The sandstone found at 8m depth offers excellent load bearing capacity of between 500 and 4000kN/m².



Strata	Thickness(m)	Depth(m)
Made Ground	3.96	0
Gravel and Compact Sand	3.96	7.92
Red Sandstone	9.45	17.37
Blue & Black Shale	13.41	30.78
Blue Bind (Mudstone & Laminated Rocks)	5.18	35.79

2.3. Foundation Options. The methods applied within modern construction may be classified as Strip, Raft and Pile, although there are many variations and combinations of each. (Chudley&Greeno,2013) & (Barrys,2010).

	Description	Advantages	Disadvantages
Strip	Strip foundations involve the removal of ground to a set depth and width. Concrete is then poured into the strip/trench (sometimes reinforced) and levelled.	Low-cost foundation. Relatively simple, widely used with great familiarity throughout the industry. A relatively low carbon footprint.	Only used for lighter structures on firm, good load bearing strata, and to a depth of no more than 1.5-2 m, thereafter it becomes un-economical.
Raft	Raft foundations are often used where the ground has poor load-bearing capacity. Spreads load over a greater surface area. Normally reinforced with steel.	Medium cost option, relatively simple for lighter to medium loaded buildings on poor load bearing strata. Useful where individual column loads may be heavy.	Only used on lighter to medium loaded buildings. Requires increased skills. Larger material volumes increase the builds carbon footprint.
Pile	Classified as a deep foundation used from two to tens of metres. A pile is a vertical structural element that transfers building loads through weak soil to a better load bearing strata.	Used on large, heavy buildings, and where the ground has poor load-bearing capabilities. The many variants offer flexibility to meet different circumstances.	More complex, increased materials and time-consuming. Requires specialist skills and equipment, inevitably more expensive. The highest carbon footprint.

2.4. Foundation Discussion

The foundation is the base on which the laboratory will rest and its purpose is to safely transfer the dead, imposed and wind load of the building to a suitable subsoil. There is not enough data available from this case study to determine the total load of the Laboratory and due to its unusual design, there are complex and varying column loads for consideration.

Recent calculations for a traditional build two story commercial building arrived at a total building load of approximately 100kN/m^2 (BenJefferies,2022). The Laboratory load will be greater but in the absence of more specific data, to enable discussion this figure is referenced as the discussion load value.

A strip foundation can immediately be eliminated from consideration, the Laboratory building load or indeed the load of any substantial two-story commercial building is too great for the unpredictable engineering qualities of the 'made ground', additionally strip foundation becomes uneconomical at depths below 2m.

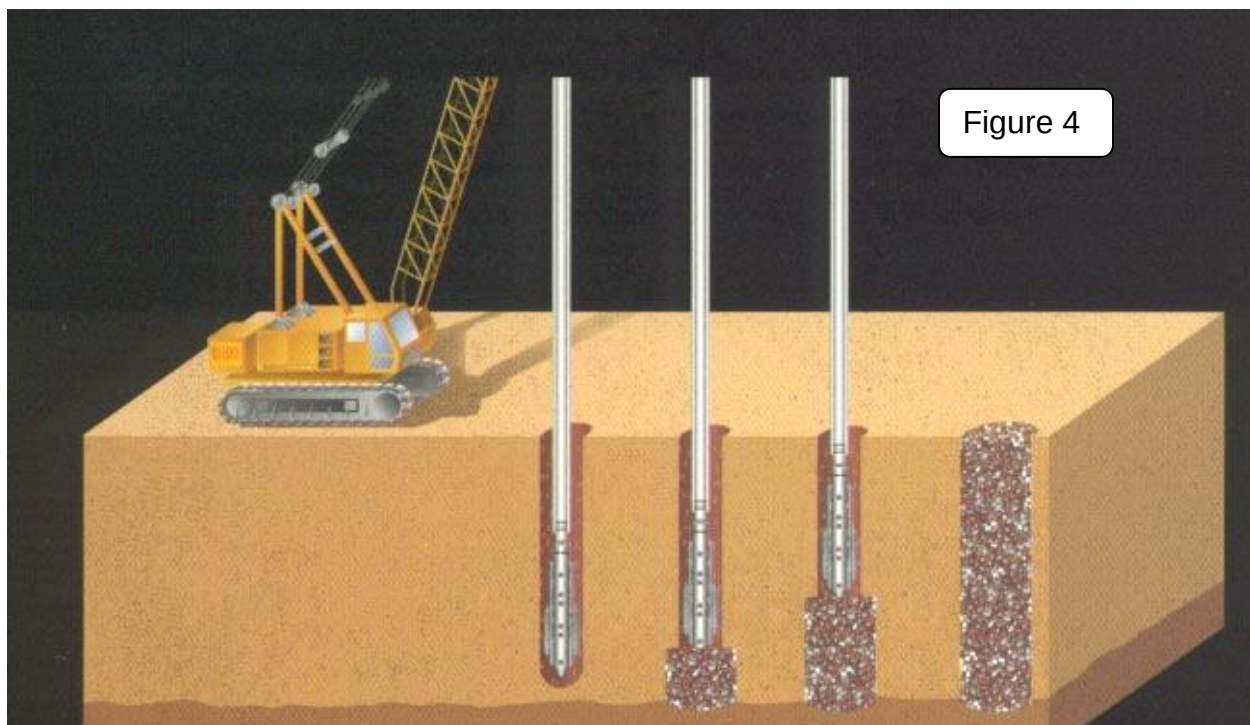
A raft foundation could be utilised, floated at the layer of compact gravel and sand that is present at approximately 5m. Taking into account the depth of excavation works required and the potential increase of concrete required to raise the building, then this becomes less desirable from both an economic and sustainability perspective. Alternatively, a finished level below ground level could have been designed-in but it is important that this building blends in with the existing environment so terraforming the land into a crater is not ideal. Instead, a more natural and less environmentally disruptive approach was favoured in terms of aesthetic, cost, timeframe and suitability to purpose. Additionally, from an engineering viewpoint a doubling of the discussion load value is uncomfortably close to the load bearing capacity of the strata's above 8m.

The engineering qualities of the strata below 8m (minimum 500kN/m^2) implies a significant buffer/margin from the discussion load value. It is fair to say that the ground inspections actually carried out will have determined that foundations must rest upon the sandstone strata at 8m. (BSI,2023)

In end bearing piles, the load of the building is transferred through the pile onto the bottom end where it rests on the surface, which is the intersection of a weak and strong layer. The load therefore bypasses the weak layer and is safely transferred to the strong layer. Friction piles transfer the load of the building to the soil across the full height of the pile, by friction, through the entire surface area of the pile.

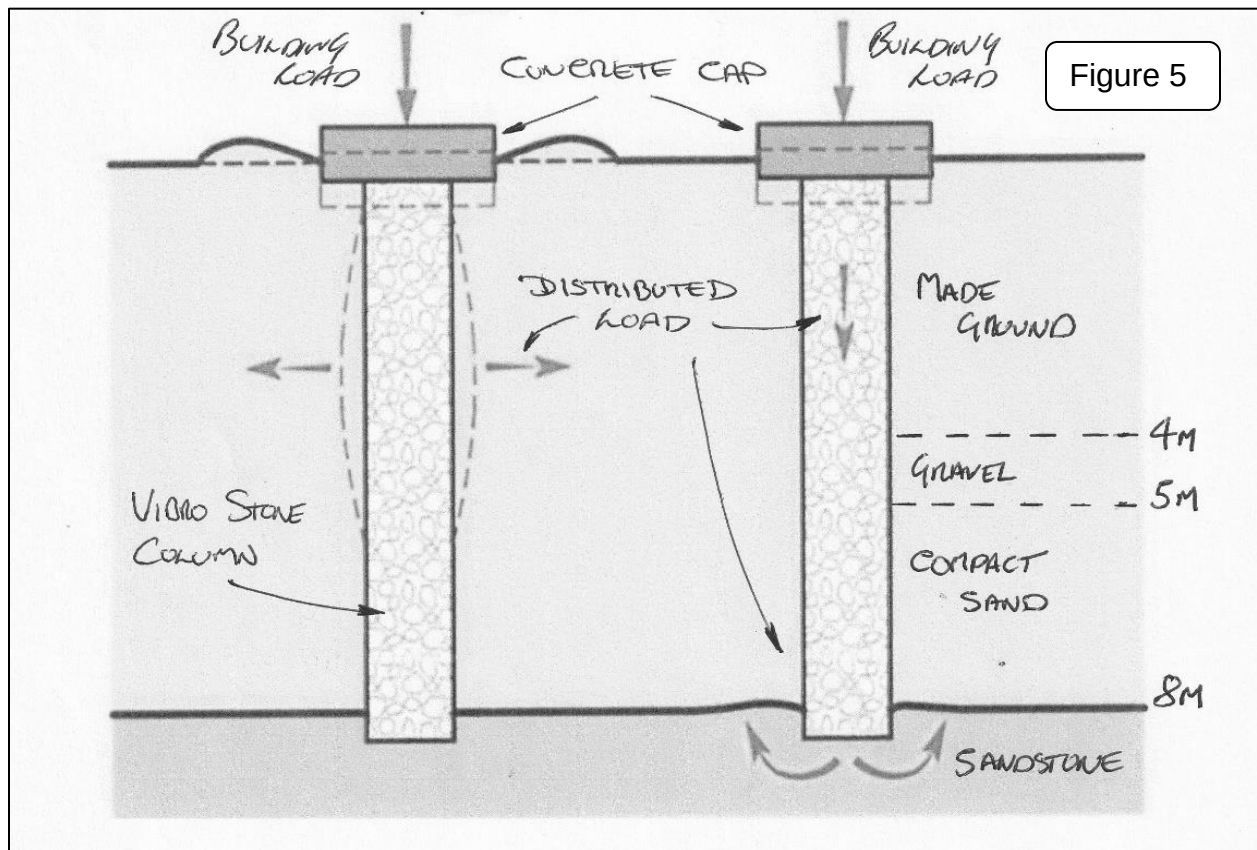
The Laboratory design originally called for Continuous Flight Augering (CFA), this is a fast and economic technique to create a deep concrete foundation. A CFA drill is used to excavate a hole, no casing is required and concrete is injected through a hollow shaft under pressure as the auger is extracted. Thus, creating a combined load end-bearing and friction effect.

However, saving carbon was clearly an imperative for the construction team, thinking outside of the box the constructors changed to the similar but even more environmentally friendly method of Vibro-stone columns. Replacing concrete piles with aggregate, reduced embodied carbon from 90 tonnes to just 6 tonnes. A press article by Construction News reports on the flexibility and freedom of creativity that was employed in this project. (News,2023)



Vibro-stone columns are an array of crushed stone pillars placed with a vibrating tool into the soil below a proposed structure. Such techniques increase the load bearing capacity and drainage of the soil while reducing settlement and liquefaction potential. Column diameters of 0.5m were sunk to a depth of approximately 8m. A vibrating tool suspended from a crane penetrated the ground by means of its own weight and vibrations. Reducing excavation and spoil. Crushed stone is introduced into the hole by a pipe attached to the vibrator. (Wikipedia,Vibro,2023)

The vibrating probe breaks down the pores of the surrounding soil, thereby densifying the soil. The stone that is poured in takes the place of the soil and keeps up the pressure on the soil that was created by the vibrating probe. The stone consists of local and reclaimed crushed coarse aggregates of various sizes. The column tops are capped in reinforced concrete as standard piles. (ICE,2023)



3. Task 2. Superstructure

3.1. Comparison of suitable materials. The case study identifies design, workability, strength, durability, stability, fire safety, aesthetics, environmental impact and sustainability as critical characteristics of the material chosen to create the laboratory superstructure. (Riley,2015) (Thomas,2022) (BenJeffs,2022).

	Concrete	Steel	Timber
Design and Workability	Concrete can only be cast into shapes from moulds, so it is limited in shape flexibility. When mixed and dried, alterations cannot be made without compromising structural integrity.	Steel is used for a lot more angular construction due to the unique properties of metals. Arches and bends don't weaken steel, shaping and forming can make it stronger. Steel is also more workable on site, during and after build.	Timber is very versatile. It can be shaped to fit most scenarios and can also be used in conjunction with and fixed to most other materials. Easily modified.
Strength	High compression strength, steel reinforcement increases tensile strength. Low toughness, high brittleness. Good resistance to cyclic loads.	Steel can be up to 8 times stronger when compared to concrete in terms of shear and strength. Steel retains strength in natural bends or curves as long as it is suitably thick.	Incorporating modern methods, timber can be very strong. When placed under stress the force will push outwards in the direction of the oval rings. GLULAM and CLT utilise this by stacking/laminating and distributing loads.

Durability	Concrete is very long lasting and durable but the extent of this is entirely dependent on the mix that is used. If properly cared for large scale buildings can last up to 100 years.	Steel is an extremely durable construction material. Being unnatural, it benefits from immunity to living organisms. It is also resistant to issues such as mould or rot and can be treated to limit the effects of corrosion.	Timber can last extremely long periods of time. Depending on the treatments given and the conditions it sits in with regards to moisture content and temperature and it is optimally treated, can last well over 50 years.
Stability	Excellent stability	Excellent stability	Excellent stability. When modern methods are applied.
Fire Safety	Concrete physically can't catch fire as none of its components are flammable, so it acts like a barrier. When affected by fire, concrete scorches and cracks but doesn't give off any smoke or toxic fumes making it much safer than most other materials.	Under high temperatures, steel can deform or even begin to melt, at around 1300 Celsius, steel has almost no strength and will fail, so, construction steel needs to be fireproofed.	Fire resistance of timber can be enhanced by coatings that are readily available. Wooden beams are not good conductors of heat only the outermost layer would be affected by fire, with the rest of the beam maintaining 85% of its original strength. Metal fixings are a weak point.

Aesthetics	Concrete is grey and smooth, a visually harsh material that is not ideal for any aesthetic intention other than plain, synthetic environments.	Modern architecture sees steel frames left exposed where possible due to the aesthetic they provide being considered popular and appealing.	Using timber is a good way to make things fit into a natural environment. Often removes the need for cladding.
Environmental Impact & Sustainability	Concrete production accounts for approximately 9% of global CO2 emissions. Concrete is recyclable but only for repurposing for construction projects like tidal protection on beach fronts. This does not negate more concrete being produced for buildings, it just lowers production for other purposes.	Steel manufacture accounts for around 6% of global CO2 emissions despite better efficiency of the process. Over the past 50 years, CO2 emissions have reduced by as much as 60% per tonne.	A very good insulator of sound and heat, reducing the need for cladding in various areas to cover over insulation. As long as enough trees are planted and not too many are used, timber construction can be sustainable for the rest of time. Using timber is good for the environment as the material is carbon negative from its absorption as a tree.

3.2. Superstructure Discussion

Any of the three materials analysed above could have been used to create the superstructure. Perhaps concrete is easiest to dismiss as it struggles to satisfy the complex shapes in the design of the structure, it is very strong under compression but rather weak under tension and would need additional methods to support the weight. For structural safety and longevity, steel or timber would be superior to concrete. Steel beams could be formed into the required shapes but requires fire proofing which raises the question of cost effectiveness.

The risks of timber construction were laid bare during the devastating fire of 2014. This would have been due in part to no treatment applied to the timber yet, as it was still in the installation phase and open to the atmosphere. Had steel or concrete been used, the fire would probably not have been quite as devastating. When considering the aesthetics, timber is the most pleasing to the eye, steel or concrete can also be considered pleasing with wooden cladding applied both internally and externally.

The case study shows the two main building materials used are braced glue laminated timber (glulam), for frame, beams and columns and cross laminated timber (CLT) for floors, structural walls and roof deck. The use of timber is vital to the purposes and goals



for the build – to be carbon neutral and, aesthetically, to not look like the typical clinical laboratory and create a more relaxed and natural atmosphere. In terms of building a carbon neutral building, timber has the added bonus of absorbing carbon during the life cycle of a tree.

4. Conclusion

Located at a brown field site with industrial history and poor shallow ground meant a deeper foundation was always likely to be needed for the Laboratory. CTF would have achieved this but the late-stage changes to an even more environmentally friendly version of piling demonstrated just how focused and committed the construction team were.

The profile of the Laboratory is most impressive, it is difficult to see how concrete or steel would have achieved this, the arcs and other shapes in the design lend themselves to the use of timber-based materials in both the superstructure and finish.

A special building, successfully created to minimise impact on the environment in its construction and operation, meeting its purpose and looking good whilst doing so.

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