Construction Technology Q2

New Museum Storage facility

Contents

Q2 A) Comparison Report looking at implications of Pre-Cast Concrete frame in lieu of Steel

Introduction

This report will consider implications in changing the construction of the building frame and foundations to concrete construction methods in lieu of the original steel frame structure. It will also look at thermal insulation strategies suitable for the external elements of the proposed concrete building.

Steel / Pre-Cast Concrete

There are many considerations when choosing frame material for this project, assuming design parameters are similar with both Steel and Pre-Cast Concrete (PCC), then cost comes high on the list.

This has two aspects to it, initial construction costs and lifetime costs, whilst important to keep build costs low, one also needs to consider operational and maintenance costs and considerations such as resistance to damage and fire.
With the rise of 3D modelling technology, steel frames become increasingly popular, with reduced error risk resulting from precise modelling, accurate production of all components, lack of waste and its environmental advantages, recyclable properties and modern aesthetic qualities. These benefits sit alongside the reduced “on site” time prefabricated components of modern methods of construction enjoy, the associated reduced risk cutting “on site” labour requirements and timescales, and less noise disruption to the surrounding community.

This argument is put forward by many Steel fabricators as main advantages over concrete. However, looking at PCC one can see this gives the same benefits as steel, off-site fabrication, reduced labour costs, speed of erection etc. It’s sustainability also matches the eco friendliness of steel with the same reduced waste benefits.

However, lifetime costs, fire and damage resistance, and the longer term maintenance view could persuade one that concrete could tip the scales if cost wasn’t an issue.

Therefore, when assessing Frame material for the construction of this Museum Storage Facility both steel and concrete are feasible choices, and both are widely used in the construction of buildings of this type, with each having its own advantages and disadvantages.

We can see these using this simple comparison matrix:

COMPARISON MATRIX FOR STEEL AND CONCRETE FRAME PERFORMANCE

CRITERIA	BEST PERFORMER
Low initial cash flow	Concrete
Low weight reduced foundation size	Steel
Fire protection	Concrete
Corrosion Resistance	Concrete
Maintenance	Concrete
Handling	Both need Major Plant
Quality control	Both Good
Shrinkage/settlement	Both Good
Availability	Both Long Order items but current steel shortage
Design freedom after work starts	Both PoorSteel Slightly easier to adapt
Speed of works	Both Good
Health and safety risks	Both need lifting/erection plans
Environmental impact	Concrete (low carbon available)
Propping requirements	Concrete
Insulating properties	Concrete
Grid sizes	Both span well
Element size	BothSteel lighter and can be plated and bolted in sections if reqd
Working sizes	BothSteel can be bolted and plated in sections
Plant requirement	Both need Major Plant
Skill of labour	Both need specialist for connections but much reduced over insitu work

Sound insulation	Concrete
Effects of weather during works	Both (although PCC may need insitu connections)
Programme of works	Both Quick
Lead in time	Both are Long Order items
Foundation size	Steel
Construction Cost	Steel although prices rising dramatically

Looking at the chart you can see there is not a lot to choose between the two, it really comes down to aesthetics, cost, and personal preference.

Environmentally both have a long way to go, with cement being concrete's largest Carbon Footprint at approximately a Ton of Greenhouse gas emissions per Ton of Cement, (bear in mind this is the cement and not the concrete, so the ratio is many times lower depending on mix) although there are major moves to cut this with the use of "Low Carbon" and "Carbon Capture" materials.

According to UK Concrete *"We have the potential to deliver beyond net zero by 2050 – removing more carbon from the atmosphere than we produce each year" (i)*

Steel has a much higher Carbon Footprint with approximately a ton of Greenhouse Gas emissions per ton of steel but due to the different weights of required units there is normally only about 1% variance between the two.

Sustainability is now becoming a key requirement of Building Operational Performance, and compliance with conditions of Part L of the Building Regulations is essential.

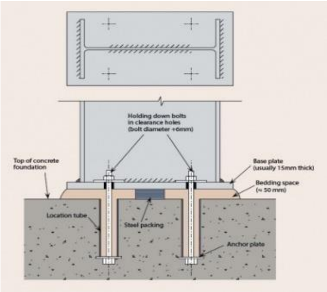
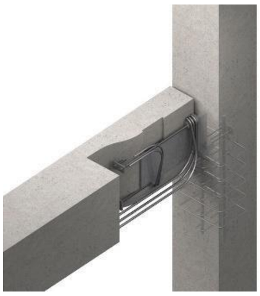


Fig (i) Steel Connections Fig (ii) Steel Base Detail Fig (iii) Steel Frame

Lead times for both are at all-time highs now and I would suggest, due to the 18m curved rafter requirements, there may be a longer wait time than normal for either option however, due to the lack of plants capable of producing multiple bespoke units of this size the concrete supplier will be harder to source.

PCC would provide a more stable temperature, which can be a problem when trying to heat buildings, however, due to our requirement for climate control in the lower storage area, this may indeed be a benefit. The concrete units also provide an aesthetically pleasing finish without the need for fire proofing, are more resistant to damage and easier to repair should damage occur.



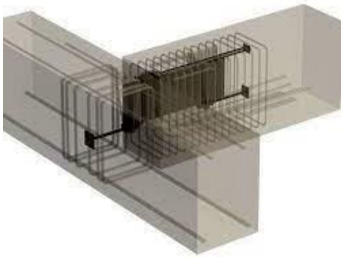


Fig (iv) PCC Connections Fig (v) PCC Hidden Connection Fig (vi) CAD View

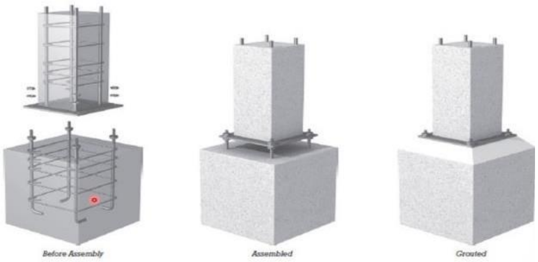


Fig (vii) PCC Columns on bases Fig (viii) PCC Simple Base Details

Fixing details are similar allowing PCC Frame erection to match that of Steel.

I would expect the steel framed building to be approximately 6% cheaper PCC but with the huge increase in steel cost this could well be negligible.

Thermal Insulation

Although a proven fast method of construction both frames still need to be insulated:

The frame itself provides a cold bridge to the outside if insulation isn't placed at the correct position to avoid interstitial condensation, cold bridging and prevent corrosion conditions.

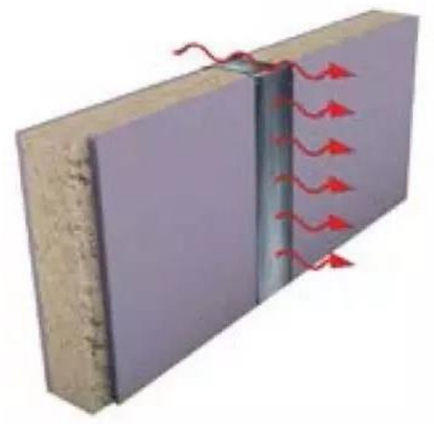
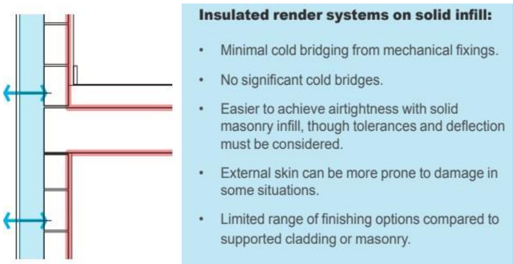


Fig (ix) Heat loss through the frame structure

For best thermal protection of the external elements of the building, the infill panels, constructed of either of masonry or lightweight steel frame should be sited between the structural members finishing flush with the outside face and we can then insulate the total structure complete with a system that also incorporates water protection and Robust Detailing.

Fig (x) insulating the structure and the infil panel system

Best thermal performance will generally be achieved by providing insulation on the outside of the structure, this ensures complete unbridged insulation allowing easy detailing to ensure the structure is watertight.



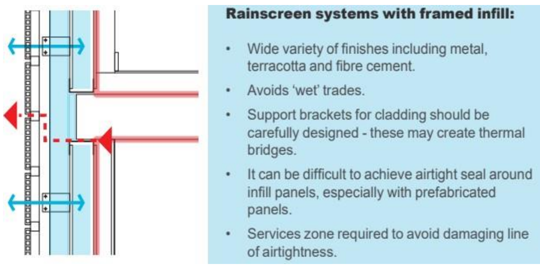


Fig (xi) Insulated Render System *Fig (xii) Insulated Rainscreen system*

Different external systems can be used to give required finishes on our Museum Storage Facility and detailed correctly, they will give a good insulated façade that will keep the internal structure warm and dry.

Summary

In conclusion, changing to steel frame is certainly feasible provided the order is placed early, connections can be a problem and may require in-situ works to complete. It can push costs up slightly and members tend to be larger, floor structure, although not requiring temporary propping, will be thicker than steel, which also enjoys composite strength from shear studs fixed on the formwork in connection with its poured slab. Slight decrease in ceiling heights shouldn’t be an issue, all artefacts must pass through the doorways anyway so down stand beams and lower ceilings won’t be a problem.

Integral fire resistance is a bonus as is longevity regarding to maintenance and slight advantages on temperature stability to assist the Ground Floor Controlled Environment Storage.

Therefore, if steel prices are indeed a major cause for concern and you require a cost that is more predictable, concrete may well be the way to go.

Q2 B) Strategies and options to increase on-site energy generation.

There are numerous strategies one can look at to generate energy on site and with a new build, open site you have the best opportunity to do this.

We will look at the different methods and assess their feasibility for this New Museum Storage Facility:

1. **Wind**

Fig (xiii) wind turbine

A wind turbine generates 1-2 kilowatt hours (kWh) of electricity, which is a great cost saving back up. However, wind turbine noise (wtn) or (amplitude), considering adjacent residential properties, and lack of permitted height with the surrounding structures, (11.1m to tip of blade) meaning minimum wind speed (12-14kmh) may rarely be realised, will no doubt rule this out! although an anemometer test could be carried out to check.

2. Ground Source Heat Pumps

Ground Source Heat Pumps would be top of my list for heat generation for this building, a good source of constant heat which for our Controlled Storage would be ideal.

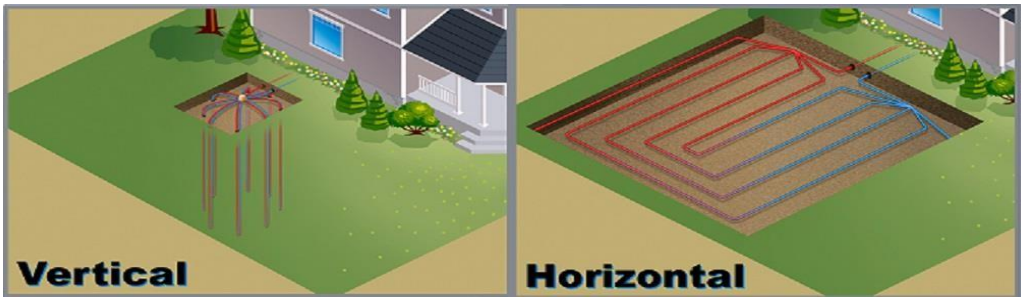


Figure (xiv) Ground Source Heating

A ground source Heat Pump extracts heat from the ground and transfers it to the inside of the building, it can also do the reverse and transfer heat from the building as a cooling operation.

A plant room is required, usually approx. 2.5mx2.5m housing the heat pump, cylinder and buffer which is connected to the pipework.

Fig (xv) Plant Room Fig (xvi) Horizontal pipework system Fig (xvii) boreholes

Pipes can be laid horizontally or in vertical boreholes, horizontal installation, certainly when completely landscaping a site such as ours, would definitely be a considered option, although still subject to temperature fluctuations in winter unlike boreholes, at say 100m deep, which give a constant temperature all year round. Initial outlay is a major factor, although grants are available, a 5 x 100m vertical system will cost around £80,000 while a horizontal of the same capacity will be half that amount.

3. Air sourced heat pumps

Air source heat pumps work a bit like a refrigerator but in reverse, taking heat from the air, absorbing it into a fluid, then boosting it through a heat exchanger into the heat pump via an internal compressor raising the temperature, then transfering it to the building's heating system.

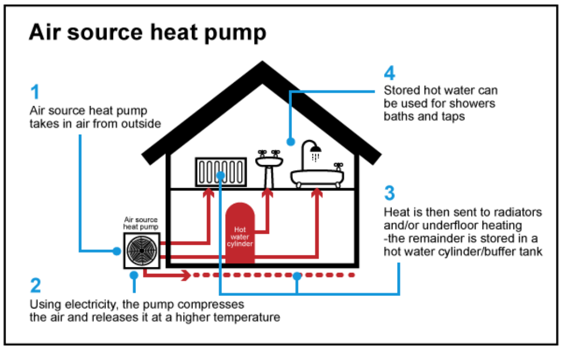


Fig (xviii) Air source Heat Pump

Fig (xix) Air Source diagram

This is generally used where there is no space for ground source and whilst cheaper to install does not quite give the same output.

4. Photovoltaic

Solar Electricity Panels or Photovoltaics (PV) capture energy from the sun, converting it into electricity.

.

Fig (xx) Installing Solar Panels

Consisting of many cells of multi-layer, semi-conducting material (mostly silicon), a flow of electricity is created when light shines on it, not necessarily direct sunlight but stronger sunshine equals more electricity.

This is Direct Current (DC) so needs an inverter to convert to Alternate Current (AC) for use in the building.

Generating around 355W of energy per panel in strong sun, with a larger multi-panel system, the building would have most of the electricity needed and excess generated can be exported to the grid for refund.

This would also be a very good option for energy generation on the site.

5. Battery storage

Solar panels, however, only create energy for immediate use, at night the building will return to aquiring energy from the grid, one option is to install battery backup, the transformed AC current is again inverted to DC for storage and then back to AC for final use. Whilst it seems to make sense to store your electricity, it takes over twenty years to break even on costs, batteries are still developing, and I would suggest this is one for the future.

6. Solar Panels

This may seem like PV but whilst PV panels convert thermal energy into electricity, Solar panels convert the sun's radiation into heat. More suited to smaller installations I wouldn't think these are suitable here.

7. Biomass

Generated from burning organic matter, wood, plants, manure, or household waste, although a renewable energy, Biomass still releases carbon dioxide when burned, considerably less than fossil fuels but I would suggest not suitable for our project.

Q2 C) Compare off site precast concrete for structural members and floors to ready mixed insitu concrete on permanent steel formwork.

Pre-cast Concrete benefits from a faster erection time, units prepared off site are designed to minimum weights and sizes, weight reduction means reduced foundation load allowing for lesser design. There is no need for propping on floors and installing the floor doesn't rely on the weather.

Fig (xxi) PC Concrete Floor, Fig (xxii) Crane work, Fig (xxiii) clear work space below

Connection detailing is a disadvantage, as are the handling and transport logistics for large units, craneage requirements and smaller supply chain.

In-situ concrete on metal deck, has the advantage that with the permanent formwork incorporating shear studs, the poured concrete then forms a very strong composite floor which is also more flexible than long order pre-cast units.

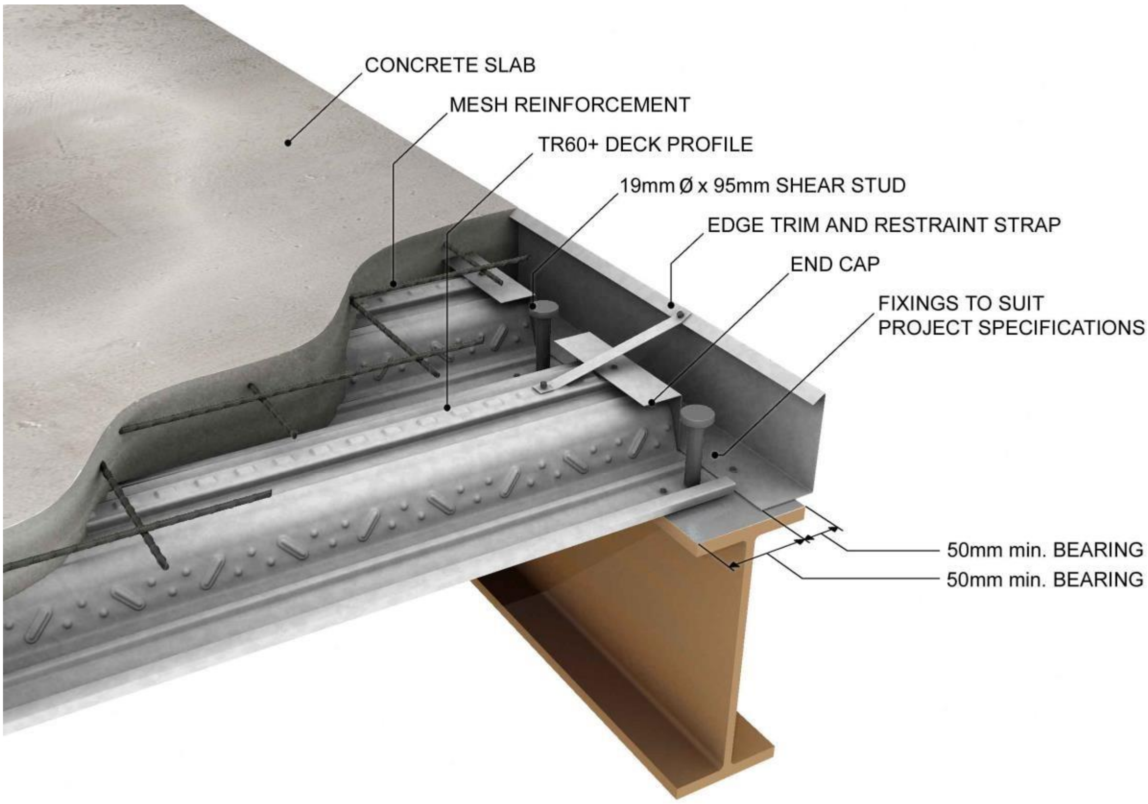


Fig (xxiv) in situ concrete on metal deck formwork

The disadvantages of in-situ on metal deck are the propping requirements until cured, meaning works cannot proceed below unlike with the PC option, reliance on weather conditions for pours, H&S risks, and the lesser quality that on site fabrication will have.

Figs (xxv) (xxvi) pouring in situ concrete on permanent metal deck formwork

Bibliography

(i) https:/thisisukconcrete.co.uk/ MPA-UCK-Roadmap-to-Beyond-Net-Zero

Fig (i) The Constructor

Fig(ii) Construction info

Fig (iii) Steltech

Fig (iv) Constructofacilitator

Fig (v) Invisible Connections

Fig (vi) BSF

Fig (vii) Stuctville

Fig (viii) E Allen Fundamental

Fig (ix) Weber St Gobain

Fig (x) Weber St Gobain

Fig (xi) Squarespace.com

Fig (xii) Squarespace.com

Fig (xiii) the ecoexperts.co.uk

Fig (xiv) yesenergysolutions.co.uk

Fig (xv) altoenergy.co.uk

Fig (xv1) isoenergy.co.uk

Fig (xvii) Nicholls Boreholes

Fig (xviii) Spitfire Homes

Fig (xix) Heat Pump tech

Fig (xx) Encyclopedia Britannica

Fig (xxi) Westcon Precast

Fig (xxii) Archi Expo

Fig (xxiii) Croon Concrete

Fig (xxiv) SMD

Fig (xxv) SMD

Fig (xxvi) SMD