British Museum - Structural Report

Prepared for the British Museum

October 2023

Alan Baxter

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1.0
Introduction

The British Museum is progressing with its strategy for transitioning to sustainable, low-carbon infrastructure. Building on the previous Stage 2+ design, this project focuses on the Stage 3 design of two key infrastructure upgrades needed to deliver this strategy. A major infrastructure building is proposed: the South West Energy Centre (SWEC), and the distribution of the site-wide services will also be upgraded. A new Intake Substation (ISS) is also proposed. This report discusses the proposals for the new infrastructure buildings and the services distribution routes in a separate section.

Steensen Varming are appointed as M&E engineer and Lead Consultant, alongside Wright & Wright as Architects, G&T (QS), RPM (planner and logistics) and us (structural and civil engineering) to develop the scheme to Stage 3. These notes have been prepared to record the main structural and civil engineering aspects of the RIBA Stage 3 scheme design.

We have prepared drawings summarising the arrangement of the existing site and buildings, the RIBA Stage 3 proposed structure drawings, and drawings summarising the services distribution proposals, which are issued separately.

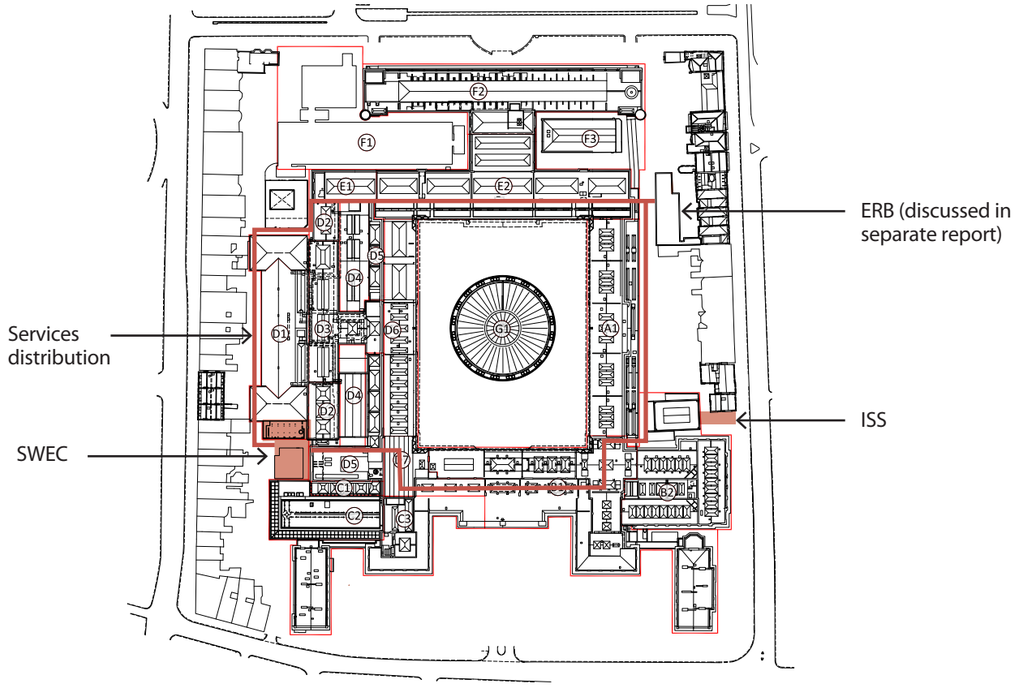


Fig. 1: Site key plan

Fig. 2: Site of proposed SWEC, currently occupied by portacabins

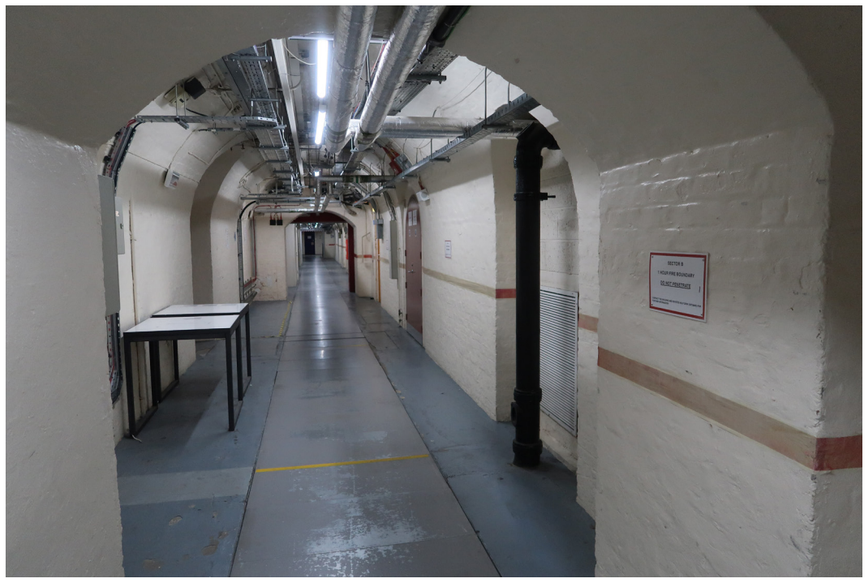


Fig. 3: Typical view of existing L01 corridor where a new services trench is required

2.0
Existing arrangement of the site and surrounding buildings

2.1 SWEC site

The SWEC site is located to the west of the estate, at the southwest corner of the Western Range. The site is bound by the 1930s Duveen building to the north, the 1840s Lycian building to the east, the 1970s New Wing to the south and the West Road to the west.

The site is divided by a principal east-west pedestrian thoroughfare connecting West Road to Level 01 of the Western Range.

There are two existing buildings on the SWEC site. To the south of the thoroughfare is a three-storey temporary portacabin structure next to the Lycian building and New Wing. To the north is the 1990s South West Boiler House (SWBH). The SWBH abuts the southern elevation of the Duveen building and the side of the Elgin-Lycian link building.

The portacabin structures are modular steel units stacked to form a three-storey building. The building's foundations are likely to consist of shallow strip foundations that may not extend into the sand and gravel layer. The existing SWBH is a steel-framed, brick-clad building supported on mass concrete pad foundations that match the depth of the adjacent strip foundations to the Duveen building.

Both buildings will be demolished to accommodate the new SWEC and associated infrastructure.

The Duveen and Lycian buildings are load-bearing masonry structures supported on concrete strip foundations founded around 2m below ground level in the sand and gravel layer. The New Wing is a reinforced concrete framed building clad in brickwork and founded on large mass concrete pad foundations around 2.8m deep.

The West Road and thoroughfare are congested with buried services currently. A services trench with High-voltage (HV) electrical cables is positioned beneath the thoroughfare. The trench continues into the Western Range corridor. Adjacent to the trench is the main drainage run (Combined surface and foul water) that serves the Western Range and Great Court. The drain also carries flows from parts of the New Wing, Lycian and SWBH, as shown in Fig. 6.

For further details of the existing site constraints and buildings, refer to drawings 1910/41/100 to 102.

Fig. 4: Existing portacabins with Lycian building and New Wing behind

Fig. 5: Thoroughfare into Western Range, existing SWBH (left) and portacabins (right)

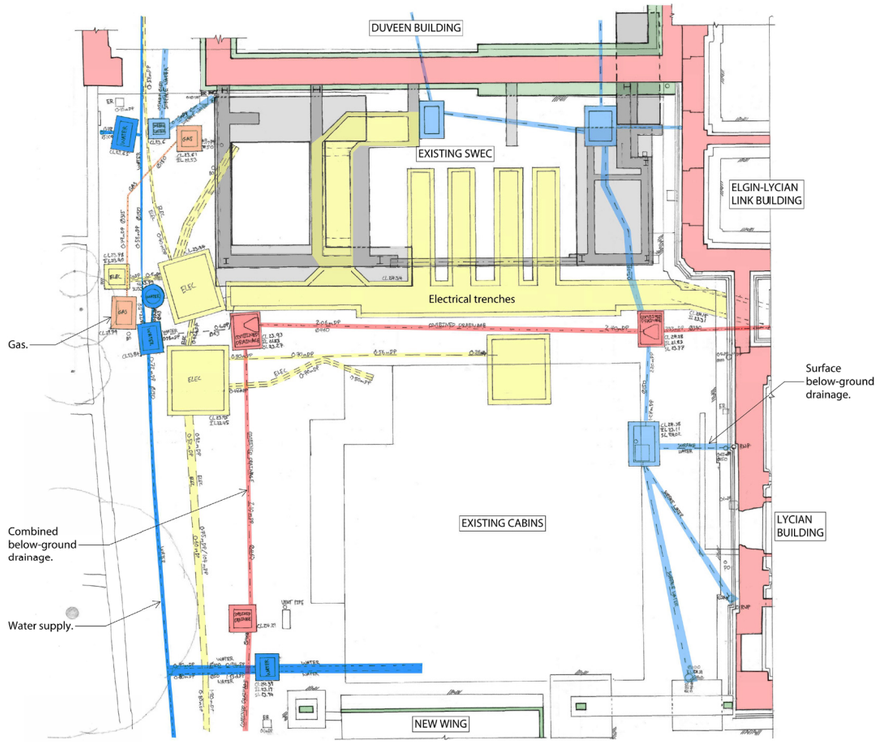


Fig. 6: Existing SWEC site constraints

2.2 ISS Site

The ISS site is located to the south-east of the estate, adjacent to the north-western corner of the White Wing. To the east of the site are the Museum site boundary railings along Montague Street, and to the west is the Hirayama Studio. The ISS is proposed to abut Hirayama Studio and the party wall that separates the Museum site and the neighbouring 1A Montague Street property.

A tunnel that links the White Wing and 1A Montague Street at Level 01 will be demolished and backfilled to accommodate the new ISS. There is also a portacabin where the ISS will be built, which will be removed.

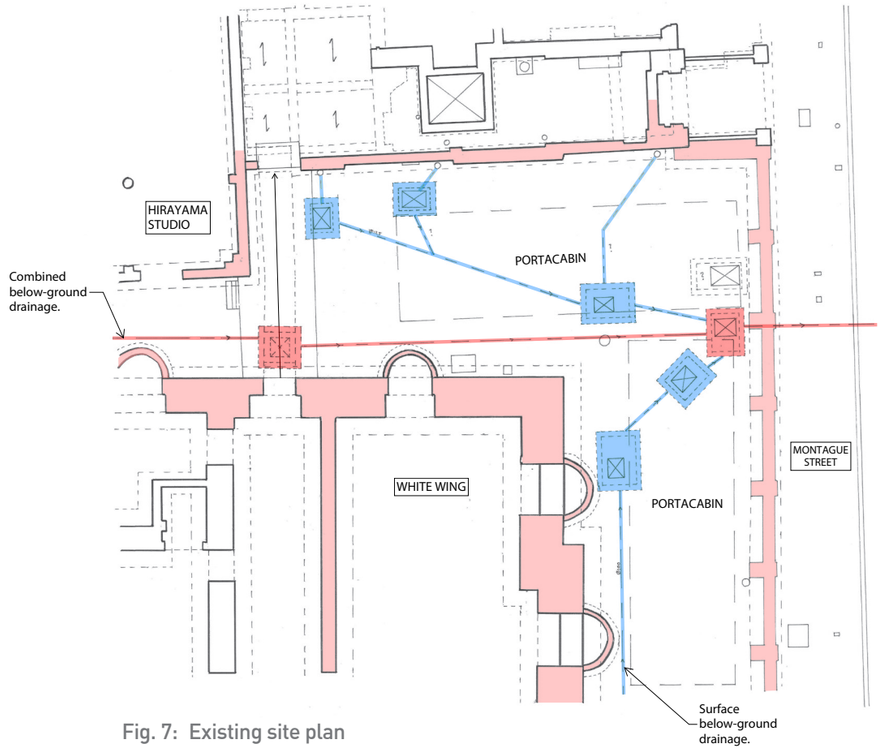


Fig. 7: Existing site plan

Fig. 8: Existing portacabin (l) and boundary wall to Montague St (r)

Fig. 9: Existing tunnel from 1A Montague St (l) to White Wing (r)

Fig. 10: Hirayama Studio (l) and boundary wall to 1A Montague St (r)

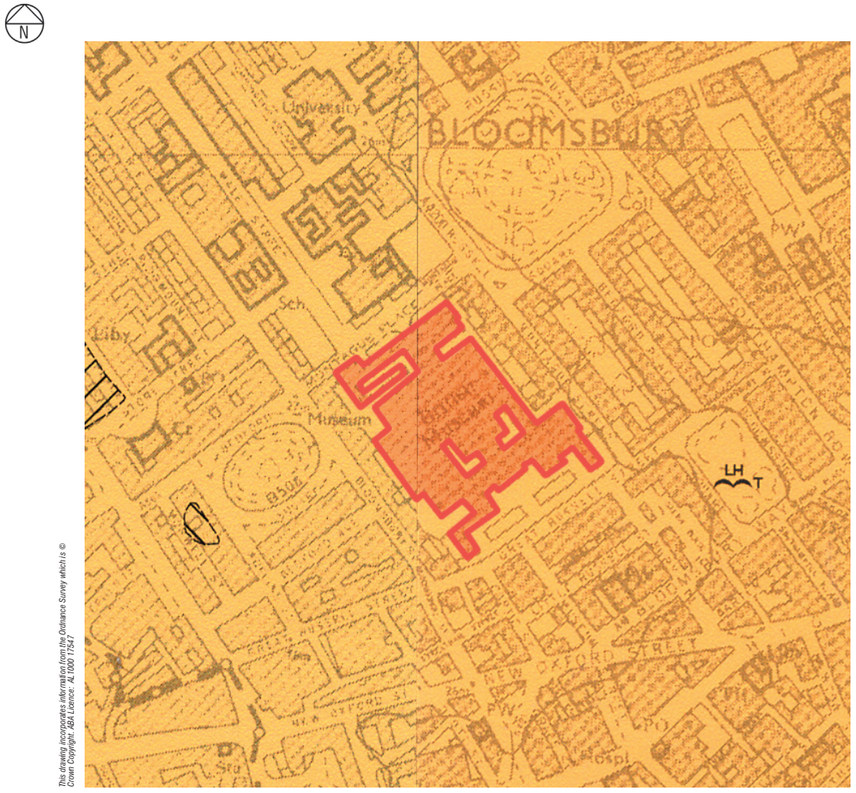
Fig. 11: View of proposed ISS location currently occupied by portacabin

3.0
Geology

The local geological map and record borehole logs from the British Geological Survey and previous projects on the estate show that the ground conditions across the site are reasonably consistent over the estate's footprint. They comprise made-ground over River Terrace sands and gravels, which sit over London Clay. The Lambeth Group Clay sits beneath the London Clay. There is perched groundwater in the sands and gravels above the impermeable London Clay.

A borehole investigation was carried out in the summer of 2022 as part of site-wide investigations to explore the constraints associated with the external service distribution routes along the service road. The findings of this borehole are consistent with the record information. At the time of writing, we are awaiting the results of the 12-month water table monitoring currently ongoing within this borehole. The results were received in September 2023 and their implications will be reviewed as part of the post-planning design.

Further details of the summer 2022 investigations are available in our report produced at the time, dated November 2022.



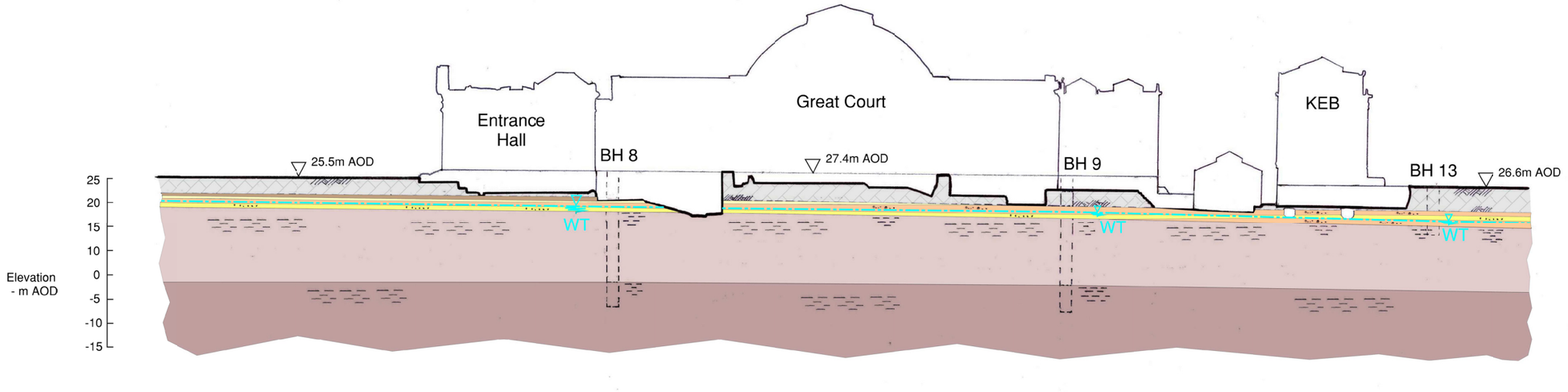
QUATERNARY DEPOSITS

Lynch Hill Gravel	River Terrace Deposits Gravel, sandy and clayey in part

SOURCE:

- British Geological Survey, 1:10 000 Series, Sheets TQ28SE and TQ38SW, 1999

Fig. 13: Geology map



Key

Description as per BH7

- Made Ground (mixture of loose ground with clay, sand and gravel and brick and concrete rubble)
- Clay (Firm orange brown with trace of sand becoming gravelly at base)
- Sand (River Terrace Deposits - Dense yellow brown medium to coarse with some clay)
- Gravel (River Terrace Deposits - very dense, brownish yellow, medium and course, with some coarse sand)
- Sand (River Terrace Deposits - Light yellow brown and grey coarse sand with fine to course angular to sub-rounded flint gravel)
- London Clay (Firm fissured grey brown silty clay)
- Lambeth Group (Very stiff fissured light brown grey/red brown silty slightly sandy clay)
- Height of water table

Fig. 12: Section A-A

4.0
Proposed Structure

The Stage 3 proposals focus on the new infrastructure buildings, the SWEC and the ISS. The services integration across the site is covered separately in section 6.

The proposed SWEC will be built on the footprint of the existing portacabins and SWBH, which are to be demolished. The construction of the SWEC will be delivered in 2 phases to allow the existing SWBH to be decommissioned. In Phase 1, the existing portacabins will be removed, and the south part of the SWEC will be constructed up to the thoroughfare. During this phase, the existing SWBH and the HV electrical services in the thoroughfare remain live. Once Phase 1 of the SWEC is complete and the new services are live, the existing SWBH will be decommissioned. Phase 2 involves demolishing the SWBH and constructing the remainder of the new SWEC over its footprint, bridging over the thoroughfare. The welfare floors of the SWEC building will not be used until the whole building is completed.

The proposals for the SWEC and ISS are discussed in turn in the following sections.

4.1 SWEC

The proposed SWEC is a 5-storey steel framed building for plant equipment, with welfare facilities on Levels 04 and 05. Electrical transformers and generators are on Level 01, switchboards on Level 02 with mechanical plant, such as water source heat pumps, on Level 03. Air source heat pumps will be positioned on the roof. The welfare accommodation comprises mess spaces, changing and washroom facilities, and offices for Museum back of house staff.

4.1.1 Foundations and substructure

The new structure will generally be founded on mass concrete pad and strip foundations, around 2m deep in general, in the dense sand and gravels, similar to all the surrounding buildings.

Around the perimeter of Phase 1, the new foundations have been positioned to fit around the existing ones, which means they are slightly offset from the adjacent buildings. Along these boundaries, foundations will generally match the depths of the adjacent existing foundations. Along the northern edge of Phase I, the new foundations will be set back from the thoroughfare to keep the construction hoarding line as close to the Phase I development as possible to avoid impinging on the thoroughfare during the works.

We propose to adopt similar foundation principles for the Phase 2 building. We hold detailed record drawings of the existing SWBH building and its foundations. Our appraisals show that the existing foundations could be retained in the ground and reused to support the new superstructure. We have, therefore, developed a solution that involves reusing these and adding to them where necessary, which will limit the intervention and reduce the embodied carbon associated with the substructure works. The condition and arrangement of the existing foundations need to be confirmed in due course. Until the viability of reusing the existing footings has been verified, we recommend that an allowance is made for replacing them. In the new lift's location, a section of the existing foundation must be removed to accommodate the pit.

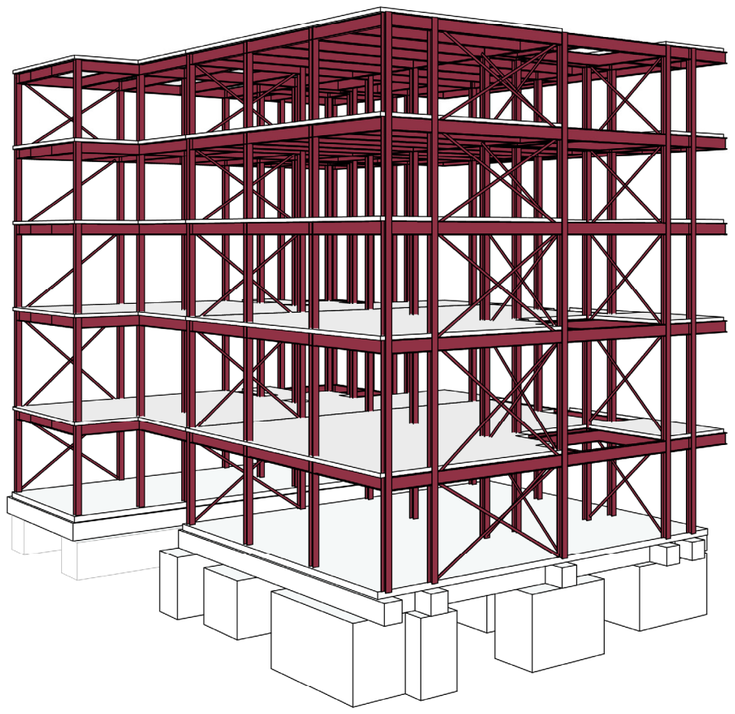


Fig. 14: 3D view of proposed SWEC structure

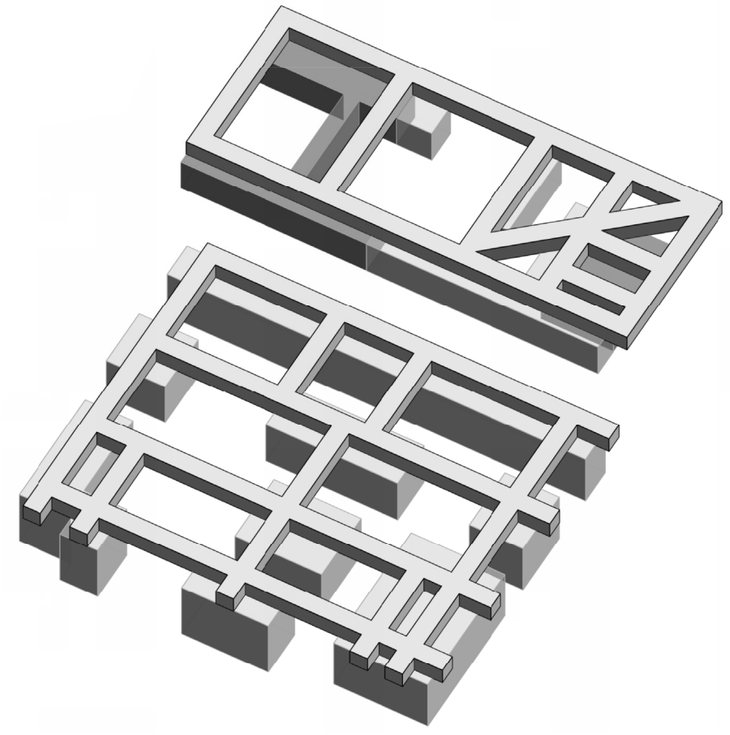


Fig. 15: 3D view of proposed foundations

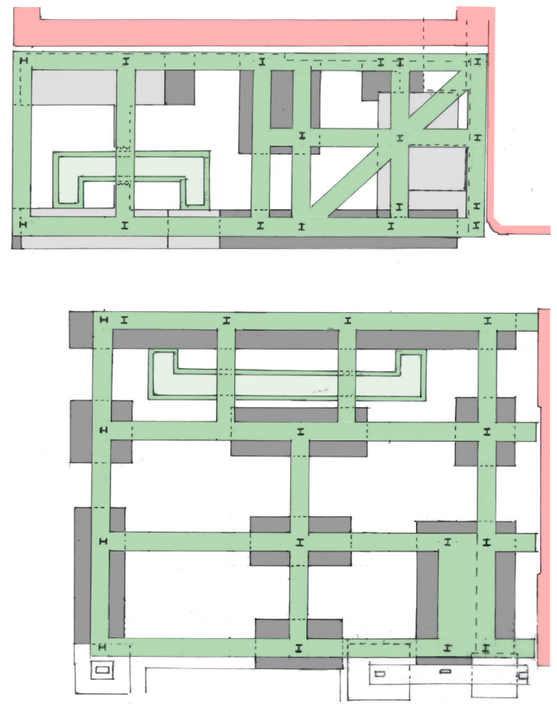


Fig. 16: Plan layout of proposed foundations

Reusing some of the existing foundations beneath the portacabins may also be possible. However, this is less likely as it was initially meant to be a temporary building, and its foundations are likely unsuitable for the new 5-storey plant building. In addition, we do not hold any record drawings of the portacabin's substructure. Therefore, at this stage, an allowance should be made for treating these as obstructions and grubbing them out before installing a new substructure.

We propose a grillage of reinforced concrete (RC) ground beams on top of the pad and strip foundations, which will cantilever over the foundations to support the offset superstructure that abuts the surrounding buildings. In addition, this solution reduces the concrete needed for the substructure and the amount of spoil that must be transported off the site, saving on the embodied carbon invested in the substructure.

The ground floor will comprise a robust suspended RC slab that spans between the ground beams to support the heavy plant. The existing foundations must be cut back slightly on the east and north perimeter to accommodate the new ground floor structure. This will need to be carried out using non-percussive tools such as diamond saw cutting to mitigate vibration transfer into the collection stores and galleries. On the east perimeter, this will involve cutting away brick corbels and the top of the Duveen Building concrete strip foundations on the north perimeter. The available record drawings indicate that the tops of the Duveen Building foundations may contain steel reinforcement. An allowance should be made for cutting this too. The drawings below show the details of these alterations.

4.1.2 Superstructure

The superstructure will be a steel frame arranged on a 7.5m x 4.5m grid. We have developed the superstructure design considering the buildability and access from the outset. The proposed grid and components will allow the frame to be transported to the site and installed on this constrained site without requiring significant splicing of members. We have designed the frame to provide the Museum with a robust building with future adaptability should the plant equipment or uses of the spaces change.

The columns at the perimeter of the new structure have been set back from the elevations of the Duveen and Lycian buildings to allow them to miss the projecting cornices at a high level. As shown in the plan below, the steel beams will cantilever at each floor level.

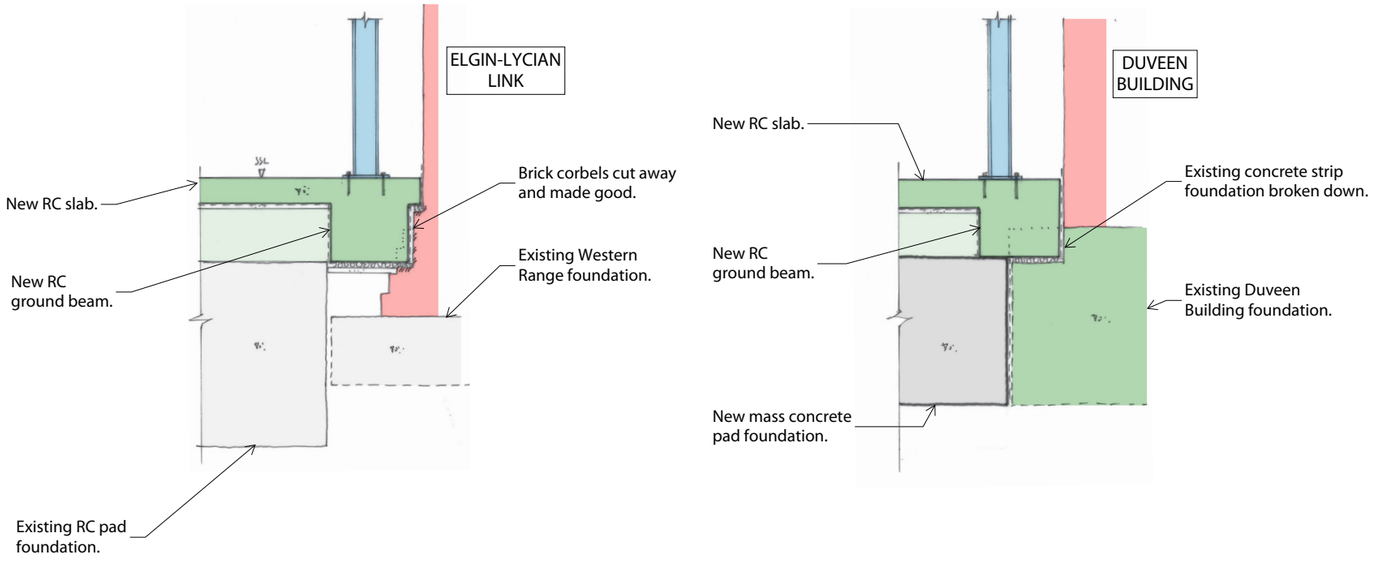


Fig. 18: Detail of proposed SWEC foundations adjacent to Lycian Building (l) and Duveen Gallery (r)

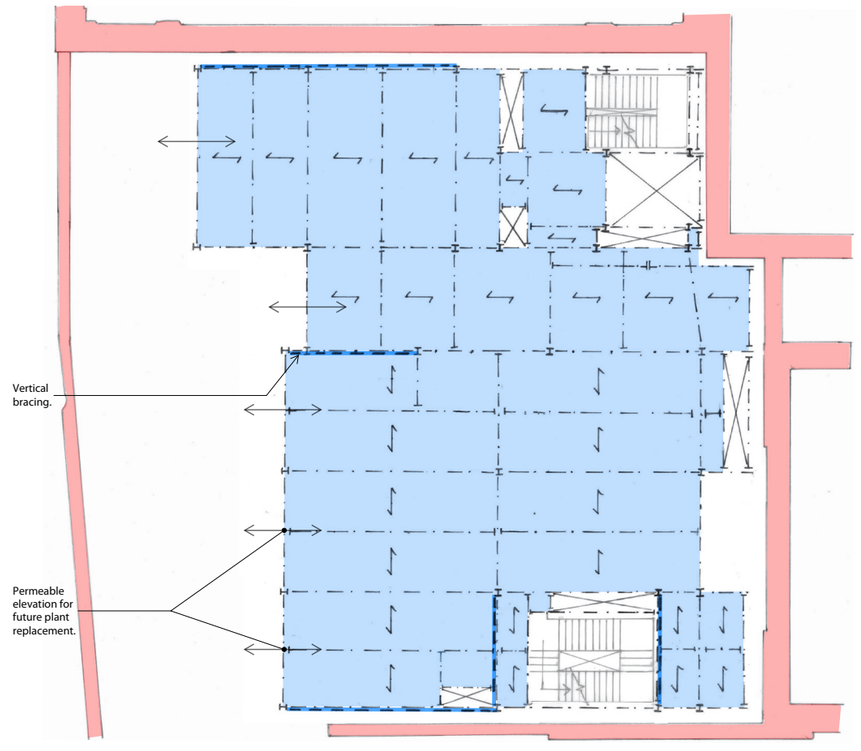


Fig. 17: Superstructure plan

Vertical steel bracing will provide lateral stability to the building. We have carefully developed the bracing layout and design considering the construction phasing. The permanent bracing within Phase 1 will stabilise the Phase 1 part of the building. This means that once the phase 1 structure is complete, no temporary bracing is needed within the building ahead of completing phase 2. Stability to the overall completed building will be provided with one additional braced bay within the north elevation of phase 2. Concrete floors will act as diaphragms to transfer stability loads between the braced bays. To achieve this across the two phases, post-fixed dowels will join the two slabs at the boundary between phases 1 and 2.

Although the position of the SWEC building is sheltered from the wind, at Stage 3, we have carefully considered the range of wind loads the building may experience during its life. We have considered the possibility that a nearby adjacent building, such as the New Wing or the Duveen building, could be demolished and replaced. The SWEC will experience higher wind loads if an adjacent building is demolished. We have designed the stability system to deal with these higher wind loads so that the Museum can make alterations to the buildings around the SWEC without altering it.

The new foundations beneath the braced bays will be connected to the RC ground floor structure to resist uplift due to wind by mobilising their self-weight. Reinforcement will be provided in the base of the foundations lapped into the ground beams to transfer these stability loads. In addition, holding down bolts to the base of the steel columns will link the bracing to the foundations.

We have developed the bracing layout in close liaison with the team to generate flexibility in adjusting and replacing plant equipment within the building in the future without major impacts on the structure. The strategy consists of positioning bracing around the vertical circulation cores and in locations throughout the building that allows the entire western façade to be open. This approach allows large plant equipment to be removed on skids and lifted into the West Road without the process being encumbered by the structure.

The steel frame will support robust, concrete profiled metal decking floors and roofs acting compositely with the steel beams to support heavy plant loads. The plant equipment is not vibration sensitive and therefore the floors are designed to have a natural frequency greater than 4.5Hz. We also explored an alternative concrete floor solution using prefabricated precast RC planks. The profiled metal decking concrete floor system will be adopted as it contains slightly less embodied carbon and has advantages when considering future adaptability.

We have considered how the phase 2 superstructure can be connected to phase 1 to limit the disruption to the already completed live plant rooms. As shown in the diagram below, we have designed the connections with steel fins that project into phase 2 so that access is not needed inside the completed plant rooms to install bolts. The temporary north elevation of Phase 1 will be protected with temporary coverings as defined by the Architect.

Fire protection to the building structure will be provided by designing the composite slab floors with adequate inherent fire resistance and intumescent coatings to the steel columns and beams. The fire consultant, Arup, have defined that 60 minutes of fire protection is generally needed, apart from the first-floor metal decking slabs, which will be designed to provide 120 minutes of fire resistance.

The staircases will be prefabricated steel flights and landings with in-situ concrete treads.

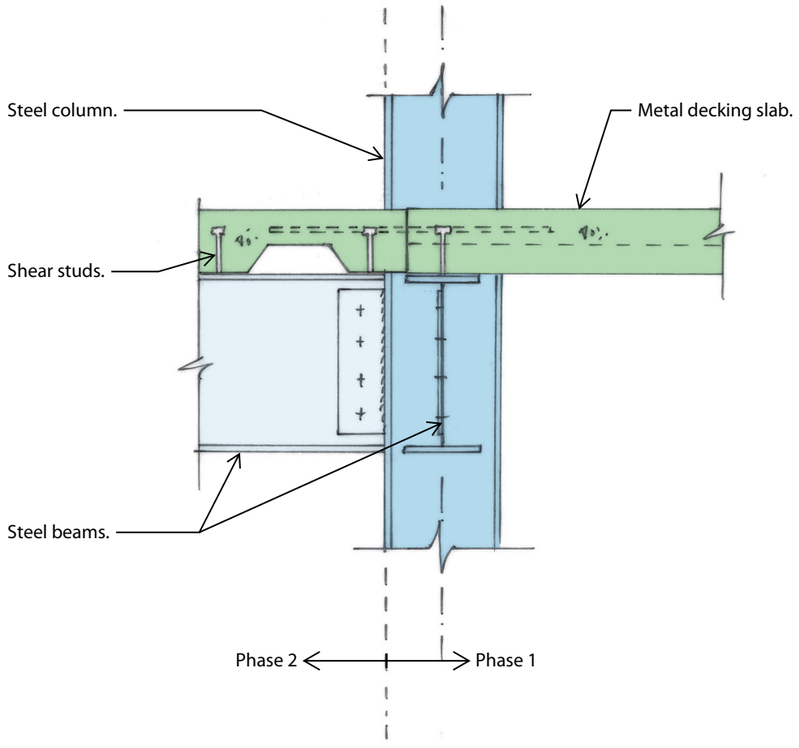


Fig. 19: Proposed floor structure

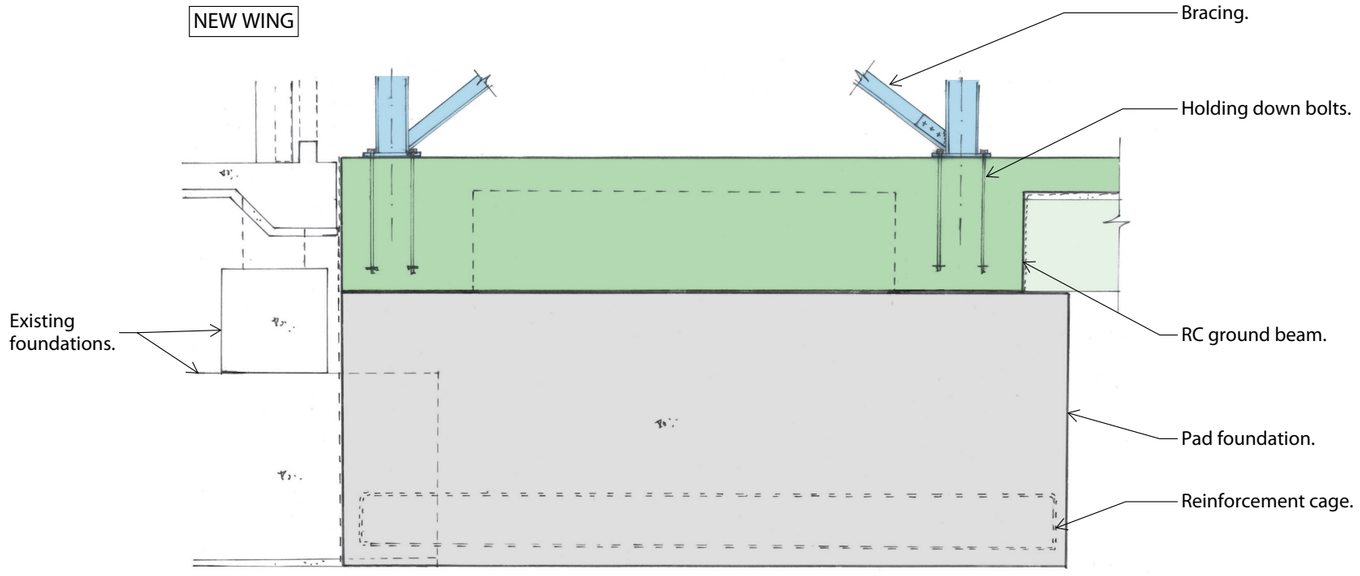


Fig. 20: Detail of proposed SWEC foundations adjacent to New Wing