

Terminal Velocity

Moving Gatwick Pier 6 Western Extension



Introduction

This paper reviews how a 200m long extension to Gatwick North Terminal Pier 6 was designed to be constructed off-site and then moved into place in the heart of Gatwick Airport.

Gatwick Airport Limited (GAL) want to increase the capacity of the airport as part of their 2019 – 2024 Capital Investment Programme. The biggest project to be delivered is the Pier 6 Western Extension, which will add eight new aircraft stands in a 200m long, 2 storey extension to cater for over half a million additional passengers each year.

I worked on this project as one of the main structural engineers, mostly responsible for coordination of the numerous strands of structural design and coordination with the other designers and client.

The project completed the RIBA Stage 4 design and CAT 3 check at the beginning of 2020. Due to circumstances since then, construction has been delayed until 2023. The piling rig was on-site and ready to put the first pile in the ground the week national lock-down was announced in March...

Key Design Team:

Architect – Pascall + Watson

Structures – WSP

MEP – WSP

Airfield – Amey



Existing Pier 6 Site

The western end of Pier 6 used to house the only stand suitable for the large Airbus A380 in Gatwick, together with two other stands for regular aircraft. These have been demolished to construct the new extension. Prior to construction of the extension, it was therefore necessary to relocate the A380 stand to Pier 5 and to construct a new stand at the eastern end of Pier 6.

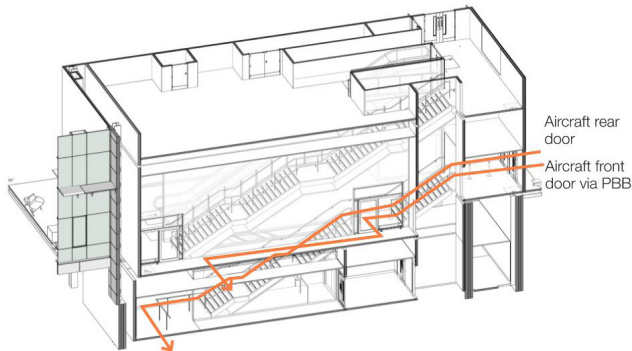
Two existing smaller stands on Pier 5 were combined to create the new larger A380 stand. A new core was created to allow multiple airbridges to service the incoming aircraft for faster arrivals and departures.

The new smaller stand on Pier 6 included a fixed access bridge to new core, providing direct access to the apron. These enabling projects were both completed and became operational in 2019. Also in 2019, the end of Pier 6 was demolished (to the dashed line indicated) and a temporary façade installed on the end of the Pier.

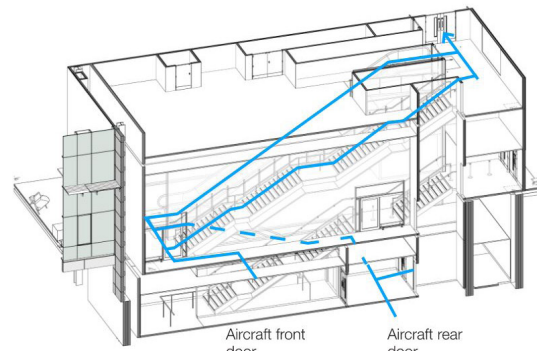
Pier 6 Extension Design Philosophy

The new extension is a braced steel frame with composite floor slabs. Foundations are individual piles and pilecaps under column locations.

The building adopts new philosophies in how passengers are anticipated to use the airport. Each stand has a Vertical Circulation Core (VCC) and a gaterroom area. Self-boarding E-gates allow access, via the VCC, from the first-floor (L15) departure gate down to the apron and directly onto the plane. Arriving passengers also access the VCC from the apron and are taken to the second-floor (L25) arrivals corridor. This direct 'walk-in' 'walk-out' strategy aims to decrease aircraft turnaround time and so increase capacity. The new building also has enhanced facilities and retail offering, as many passengers skip the central facilities to go straight to the gaterooms.



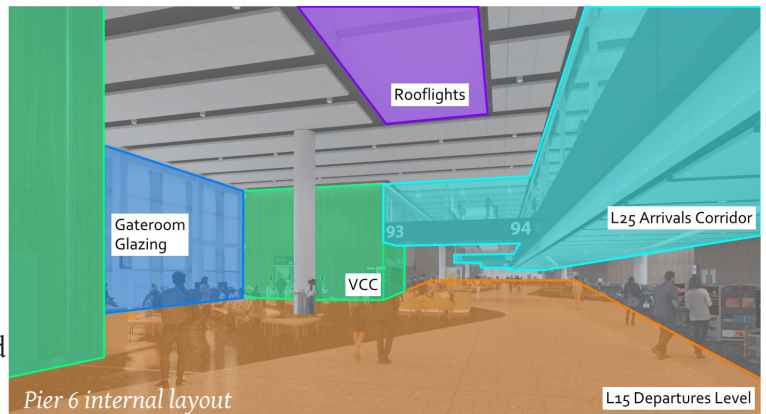
Departure passenger flows



Arrivals passenger flows

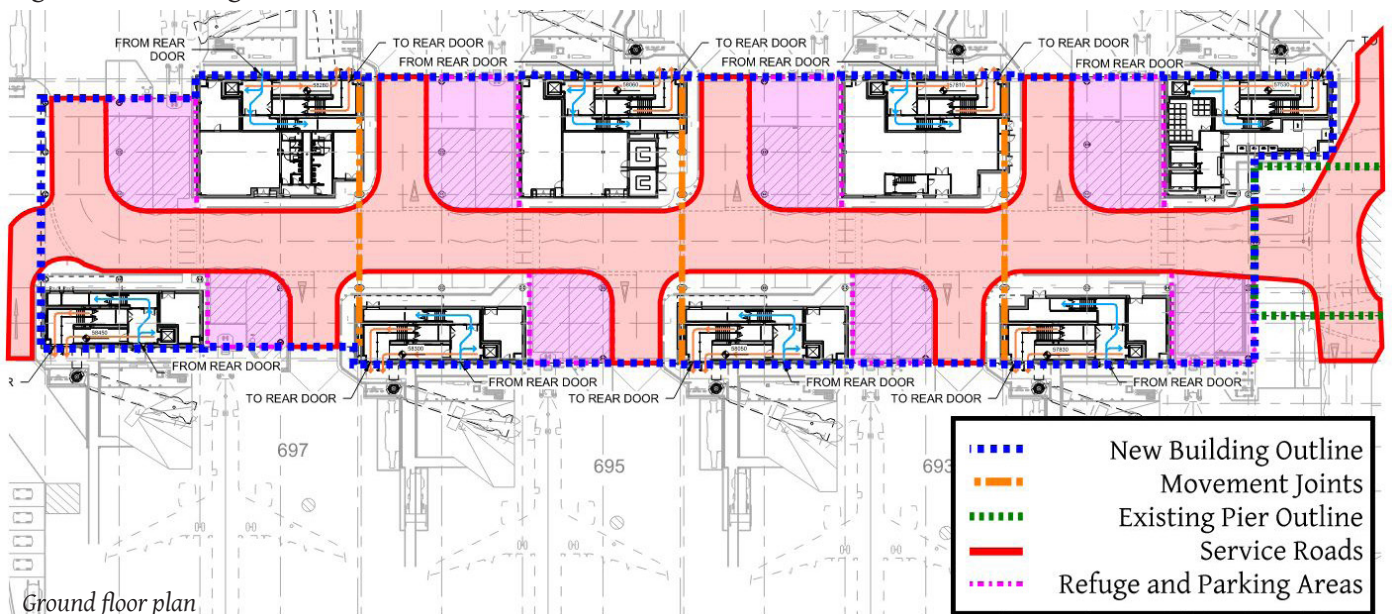
The L25 arrivals corridor hangs from the central roof trusses on one side, and the structure has been safeguarded to allow the infilling of the voids for future flexibility.

As can be seen below, the building has three movement joints provided by a double line of structure, splitting the building into four independent modules. These align with the edges of the VCCs, giving limited areas for bracing north-south. East-west, bracing can only be accommodated in the VCCs but this has to step to allow for doors, plant access and future airbridge safeguarding.

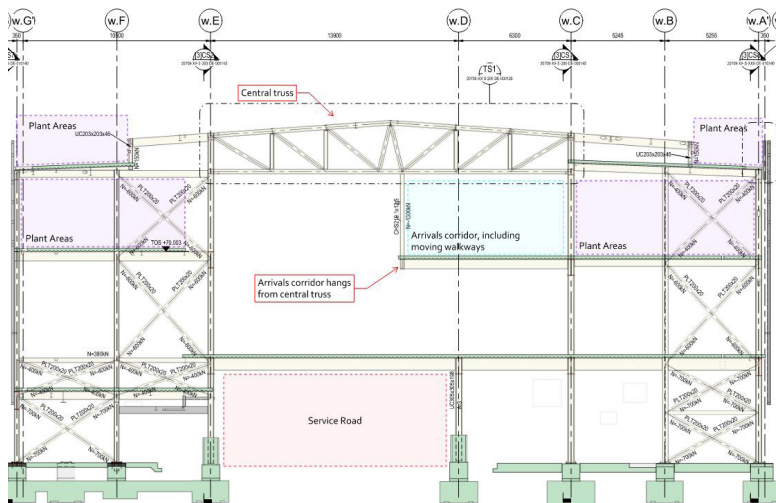


Pier 6 internal layout

Establishing a regular column grid was difficult as it needed to avoid the roads, service areas and pavements under the building. It also needed to allow for long stair and escalator flights within the VCCs. Inside the building, the aspiration is to provide an open welcoming space with minimal structure and a 'floating' arrivals corridor. Finally, the column grid had to be compatible with the off-site design and movement strategy. This culminated in a 12m regular east-west grid.



Ground floor plan



Structural Section

The Pier 6 extension is a complex building and detailed coordination was required within the design team and with the client. The design was completed to BIM Level 2, with regular 4D and 5D quantity extractions. The project was coordinated in a collaborative manner using Revizto. The client wanted a very high level of assurance in the compatibility of the designs to minimise on-site queries, this was especially relevant as much of the fit out was to be installed before the building moves and 'zip up zones' to created between modules when in place. This led to a high level of model detail with all MEP penetrations modelled and coordinated, secondary steel accurately modelled and some complex connections and corbels modelled to ensure fit with finishes and service runs.

Construction method

The proposed Pier 6 Western Extension site is located in the centre of Gatwick Airport, surrounded on three sides by taxiways and one side by the existing Pier 6.

To construct this traditionally on-site provides numerous challenges due to construction risks, crane limits due to radar corridors, deliveries to the airside location and airside passes required for all construction staff. On completion of the first Stage 3 design, this was projected to increase the construction programme and cost to unacceptable levels.

We therefore developed an updated design to allow the building to be constructed off-site on a temporary site in the four structural modules and then transported to the permanent Pier 6 Site on Self-Propelled Modular Transportation units (SPMTs).

This Large Scale Modular (LSM) design method allows the structure to be built and partially fitted out on the temporary site concurrently with the permanent foundations and ground works. As the temporary site is landside, outside the security area, it allows for simpler security and delivery logistics.

The temporary site is approximately 1 km from the permanent site and each move would be completed overnight with an average moving speed of 1km/h.

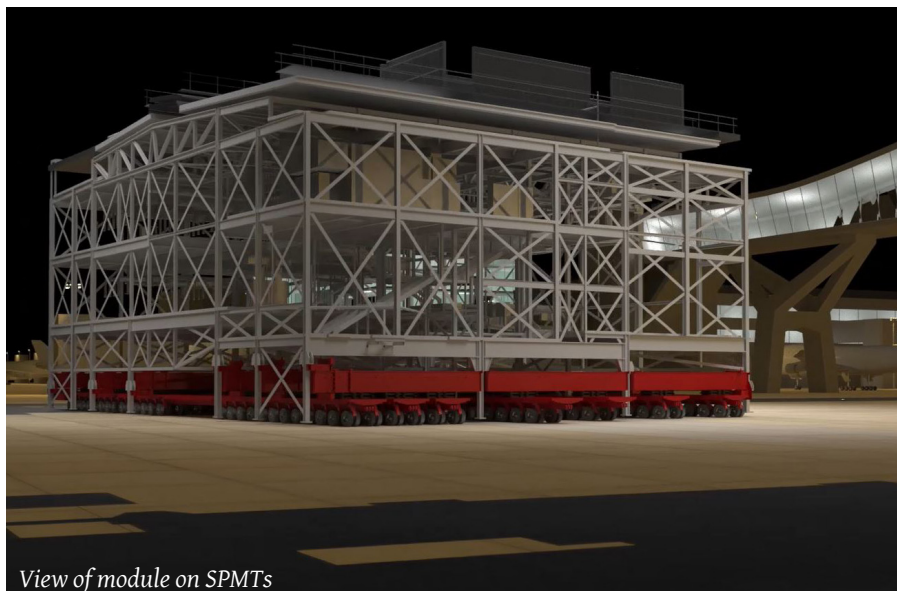
LSM Design Challenges

Designing a building to be constructed in one place and moved to another presents some unique challenges. These are mainly structural but also have implications for others that were constantly developed and coordinated.

The most obvious challenge is how to lift and then keep the whole structure stable as it is moving (or more precisely when it comes to a sudden stop from braking!).

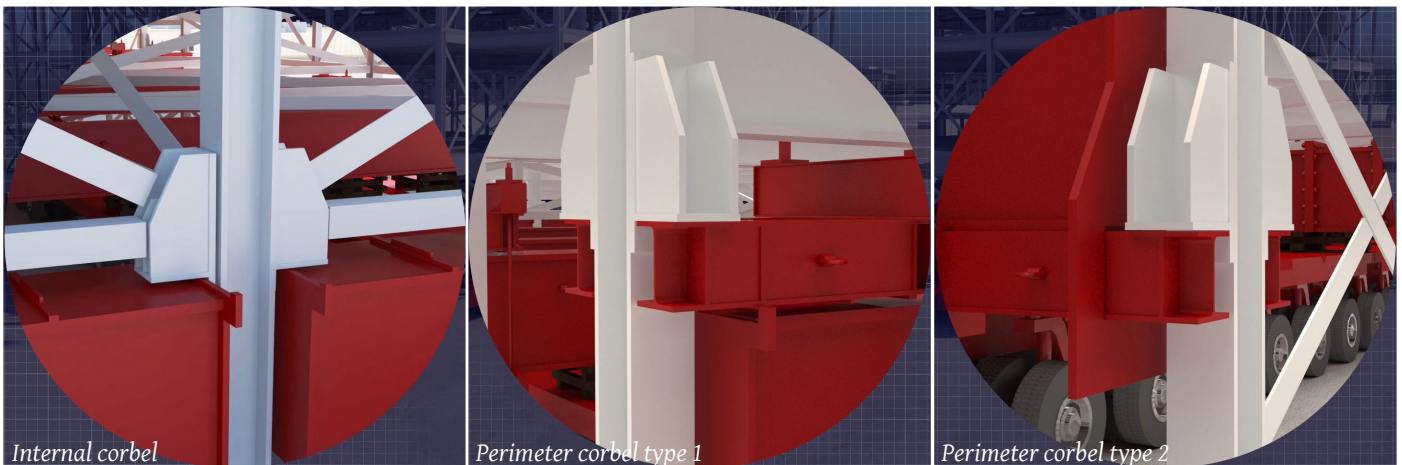
Lifting is achieved with hydraulics in the SPMTs. SPMTs are platforms with axles, these can be joined to form long trains which were arranged between the structural column grid. Transport beams are then installed perpendicular which engage with temporary corbels fixed to the columns.

The transport beams support high loadings and must be very stiff to reduce differential movement between columns. The module column grids were optimised as far as possible to provide consistent spacings, allowing the transport beams to be removable and be reusable between modules.



View of module on SPMTs

The corbels are installed in pairs on either side of the column to give balanced loads. Corbels are bolted to the column flanges, so they are removable, with the column flanges orientated to the same side as the corbel. Perimeter columns are only lifted on one side. This could cause a large eccentric force on the column and therefore a kick out at the base. To mitigate this, a 'fork' detail was developed to ensure the force applied to the column is not eccentric.



The stability system changes in each phase of construction. On the temporary site, bracing is provided to ground in one direction, whereas in the other direction bracing cannot be provided to ground as this would obstruct access for the SPMTs. Instead, temporary bracing is provided below L15 creating a diaphragm, distributing lateral loads between all the columns creating moment frames.

Once on the SPMTs the structure is stabilised by additional bracing provided in the frame. This is mainly provided in the facades and in plan to create a torsionally rigid box.

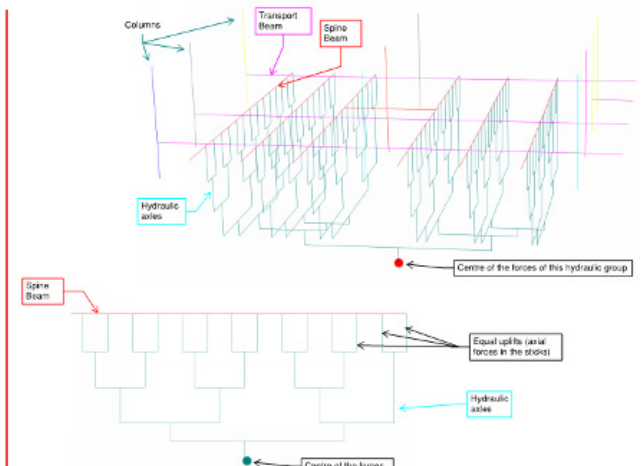
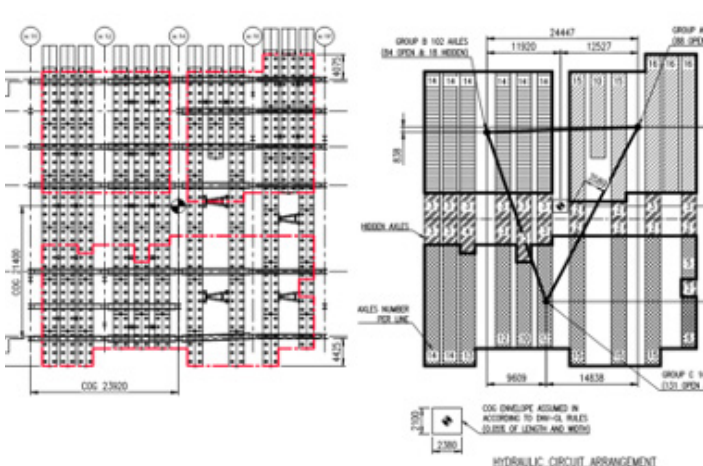
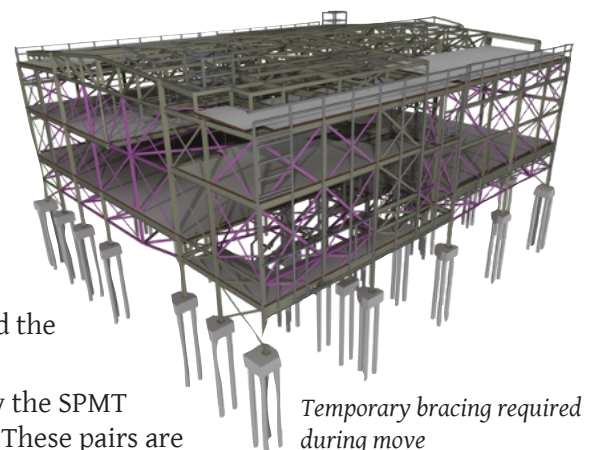
In the permanent location, columns are erected that were not possible on the temporary site and bracing installed to ground.

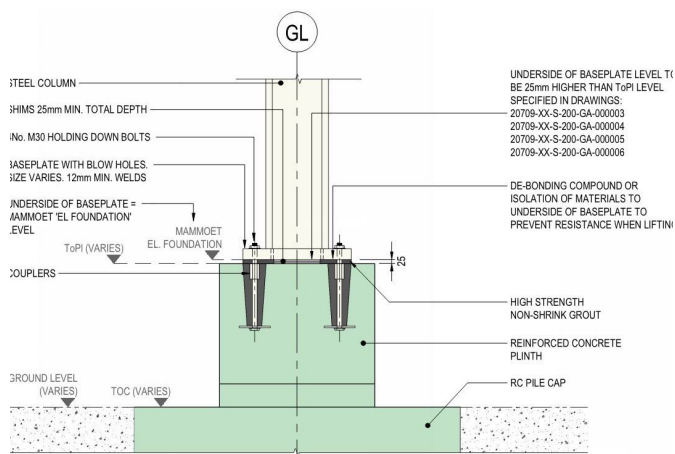
LSM Analysis

The construction sequence requires the structure to be analysed in each stage. The moving phase requires modelling of the SPMT hydraulic support system. The wheel axles are connected in 3 groups, pressure in each axle of each group is the same, with the total load spread equally. This allows the pressures to be varied and the module can remain level over undulating terrain.

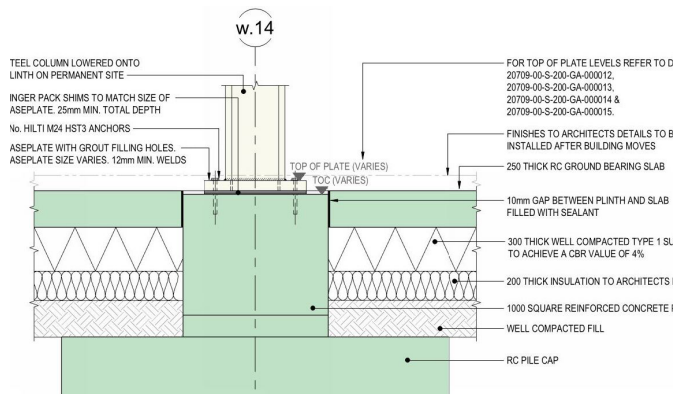
This behaviour was modelled with a simple technique suggested by the SPMT operator. The wheel axles are connected in pairs using rigid links. These pairs are then again connected in pairs and so on until a single node remains. A pinned support is placed under this node. This creates the effect of all the axles in a hydraulic group having the same force.

Under gravity loads, the hydraulics act as a 'cushion' and we tuned the SPMT positions to most effectively spread the loads equally to the three groups. However, under braking, the force is instantaneous and the hydraulics don't react in time to spread the load. Each axle acts as a pinned support in this case.

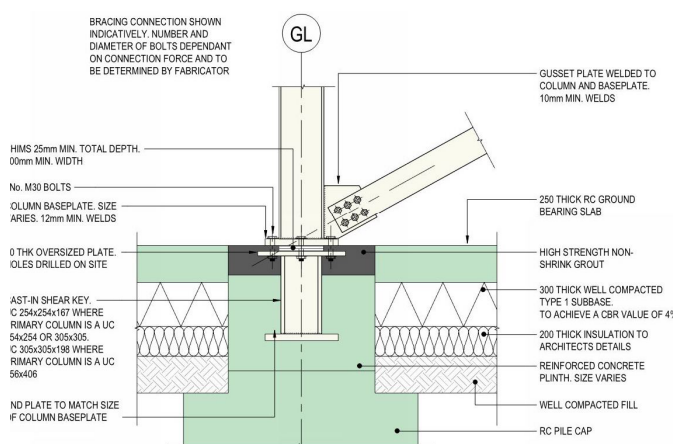




Temporary site baseplate



Permanent site baseplate



Permanent site shear key baseplate

On arrival at the permanent site, the building lands directly on the permanent foundations which must be at ground level. The permanent site has variable slopes and levels so the foundations on the temporary site are set to these same relative levels by providing plinths.

SPMTs only lift 600mm and at an angle (not straight up). The temporary site foundations therefore have couplers cast in bolt boxes and separate bolts to attach the baseplates to these. This allows the baseplates to be unattached from the foundation before the lift.

On the permanent site, the pilecaps are buried and plinths are provided to bring the level to ground. Most baseplates are then finger packed for construction tolerance and then post drilled to connect to the foundation. Some baseplates have high bracing forces. Post drilled bolts would not be sufficient, so a shear key design was developed allowing steel to steel bolted connections.

Summary

This paper can only scratch the surface of an incredibly interesting and complex project.

The LSM design introduces many additional considerations and there is a fine balance to be struck between the level of build off-site against the additional structure required to achieve this. The LSM design becomes more challenging if fragile finishes (like glazing) are introduced as structural movements have to be more controlled. Increasing the level of build also quickly increases the mass of the module and so requires additional temporary steel. However, it is beneficial to maximise the off-site build as this leads to great efficiency and risk reduction in the programme. Eventually we settled on a balance of installing the roof, limited finishes and most of the service runs and plant, which are installed in DfMA modules.

We were also extremely aware of the sustainability impacts of the design. From the outset we strove to standardise the layout of each module, even with the permanent design constraints, to allow the majority of temporary steel to be reused between each module. The steel is all designed to be removable and through our extensive BIM coordination we could even alter finishes and services to allow access for disassembly. In an aviation environment, the LSM also greatly reduced the number of construction vehicle movements, saved 30min operative time a day on security and reduced escorted transport in the airport.

Unfortunately, due to events this year, construction did not quite commence in March and is likely delayed until 2023. It is also not currently thought that the LSM construction method will be utilised as the programme and logistic constraints are now relaxed.