Specialist GRC Engineering and Fabrication Detailing

Profile and Selected Projects

2023

- Specialist GRC/GFRC Engineering & Detailing
- Facade Engineering & Detailing
- Specialist Precast Engineering & Detailing
- Specialist Stone Engineering & Detailing
- Complex Steelwork and Metalwork Engineering & Detailing
- Modular Design
- MiC - Modular Integrated Construction / 模塊化集成建築
- PPVC - Prefabricated Prefinished Volumetric Construction / 预制体积建设技术
- APCS - Advanced Precast Concrete System / 先进预制混凝土系统
- DfMA Conversions & Fabrication Detailing

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Bryden Wood

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Our Experience with GRC

- Our work designing GRC started in 2014 (9 years experience)
- We were the designers for the GRC cladding system for three of the central London Crossrail (now Elizabeth Line) stations: Tottenham Court Road, Liverpool Street, and Whitechapel
- Other work includes facade cladding, architectural ceilings, optimisation studies, remedial works, and permanent shuttering
- Our close contractor links mean we understand the challenges in fabricating and installing
- With our digital skills and MMC background we have a unique ability to deploy GRC successfully at all project stages
- Our engineers are experts in the material and its properties - we have developed novel innovations in GRC in structural applications
- Our company is a fully multi-disciplinary design firm, so in addition to fabrication design and detailing, we can also carry out architectural coordination, structural engineering, façade engineering, and optimisation studies
- Our company works on projects and has offices around the world, spanning a range of countries, clients, and sectors
- We are also specialists in pre-cast and handset stone cladding

Bryden Wood will be presenting at this year's 2023 GRCA Congress in London, UK

9 to 12 May 2023

Congress Centre

28 Great Russell Street

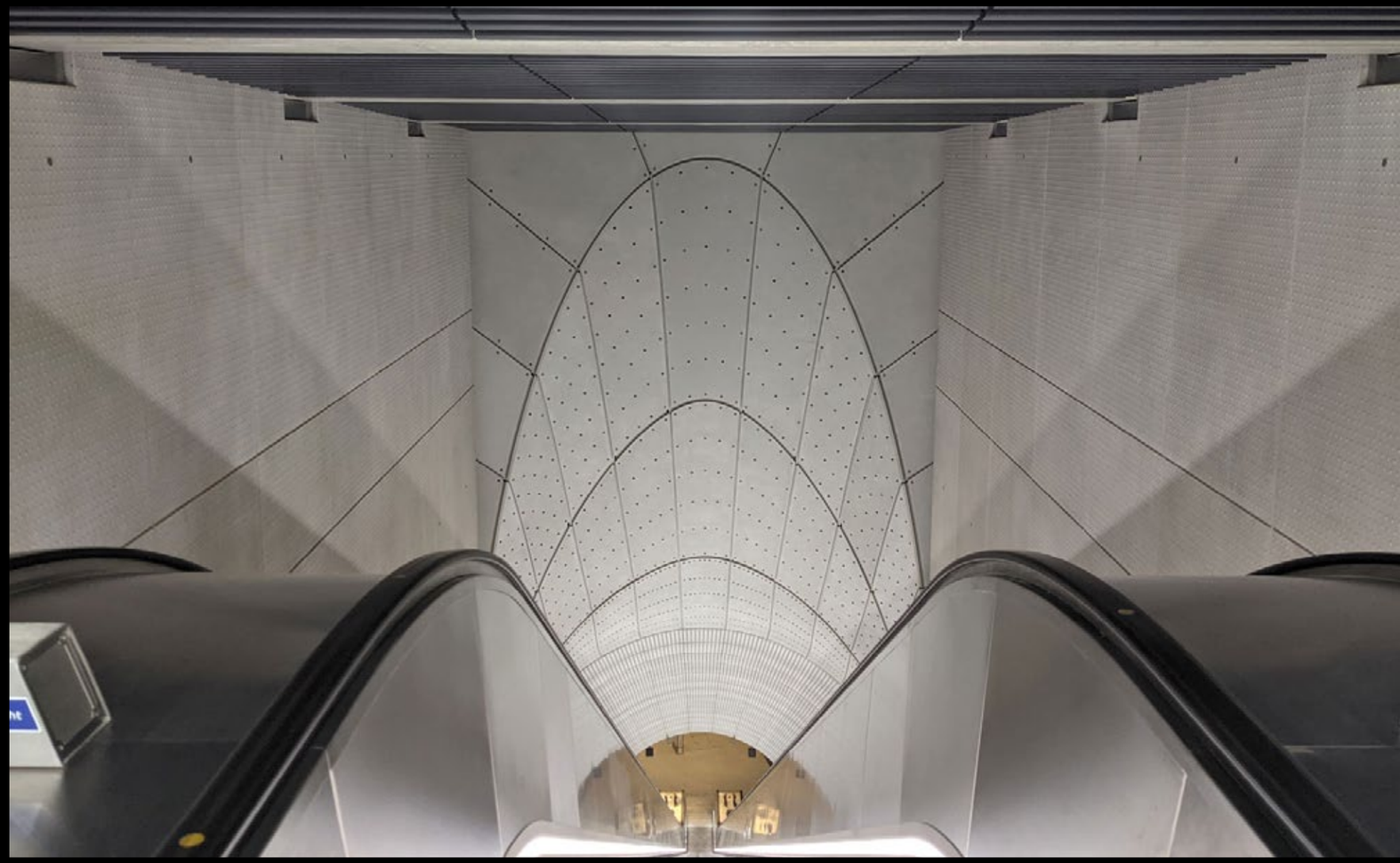
London WC1B 3LS

United Kingdom

https://www.grca.online/about-grca/grca-congress-grc2023

Please stop by and say hello to Markus Huber

(likely presenting the afternoon of May 10th)



Please find an introduction to our company in the next section.

Jump to Page 16 for GRC case studies.

1.0 Introduction

1.1 Who we are

Unique approach, exceptional ideas

We have spent 25 years developing our unique approach – the approach that we bring to every project.

We deliver exceptional results and save our clients money, time, resources and frustration by applying our time, technology and the full breadth and depth of our integrated expertise to:

- understand our clients' value drivers;
- interrogate and clarify the brief, and;
- agree the best possible outcomes – before designing the best way to achieve them.

We take nothing for granted. We will always pursue the solution that adds most value, even if that means something quite different from the solution initially envisaged.

The exceptional quality of our ideas comes from the chemistry of people, disciplines and innovative thinking that we bring.

The application of technology and data

Everything we do is supported by the creative and rigorous application of technology and data. We can model every aspect of every project, which means predictable outcomes, accuracy in programme and cost, and transparency of risk. It allows us to see, at every step, what improvements we can make, where we can drive value and efficiency, and provide evidence when we deliver.

Working with us

We believe in collaboration and sharing expertise and ideas – yours and ours. We like to question and challenge – ourselves and our clients. We work in an open, integrated and cross-disciplinary way with energy and rigour. It's not always easy, and it's not to everyone's tastes, but most people find it refreshing, fun and highly effective.

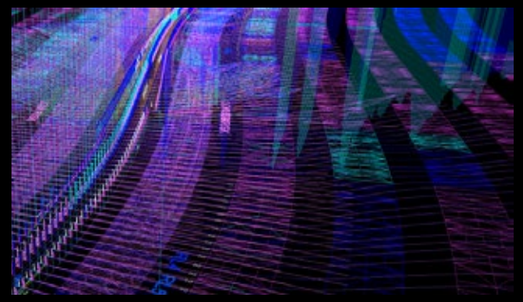
From strategy to delivery. Proven results

The range and depth of our people's expertise means we can take projects from inception to completion – or add value at any point along the way. We work conceptually and on high-level strategy, as well as on minute detail and the practicalities of delivery and project completion.

We are creative thinkers and solution finders who get things done.

Whatever the scale and sector, we apply the same approach to every project – because it's been proven.

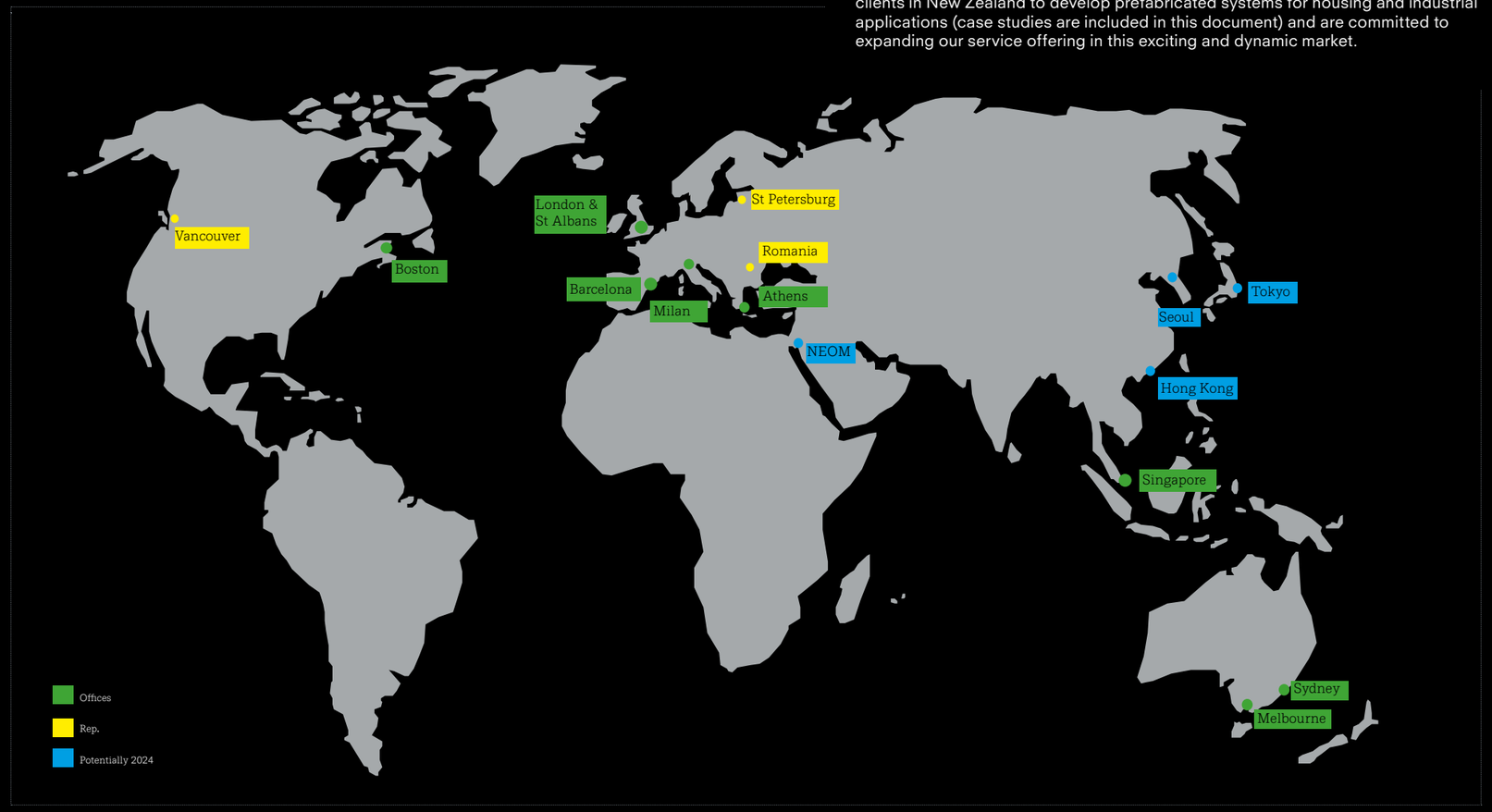
Proven to deliver better outcomes for your business, and a better built environment for all of us.



A global, connected team

In addition to our company headquarters in the UK, we have established offices in Spain, Italy, Singapore, Australia and a representative network serving other markets.

Since 2021 we have maintained full-time representation in New Zealand with a special focus on structural engineering and Systemisation. We have worked with local clients in New Zealand to develop prefabricated systems for housing and industrial applications (case studies are included in this document) and are committed to expanding our service offering in this exciting and dynamic market.



Integrated design: one team, one vision, the complete skillset

We bring together architecture, structures, civils and building services to create a complete design. Our multiple specialists work together to give you seamless delivery from a single, integrated design team. Working with a single team means a coherent, comprehensive and balanced response to your requirements that works equally hard for you in terms of value, quality and aesthetics.

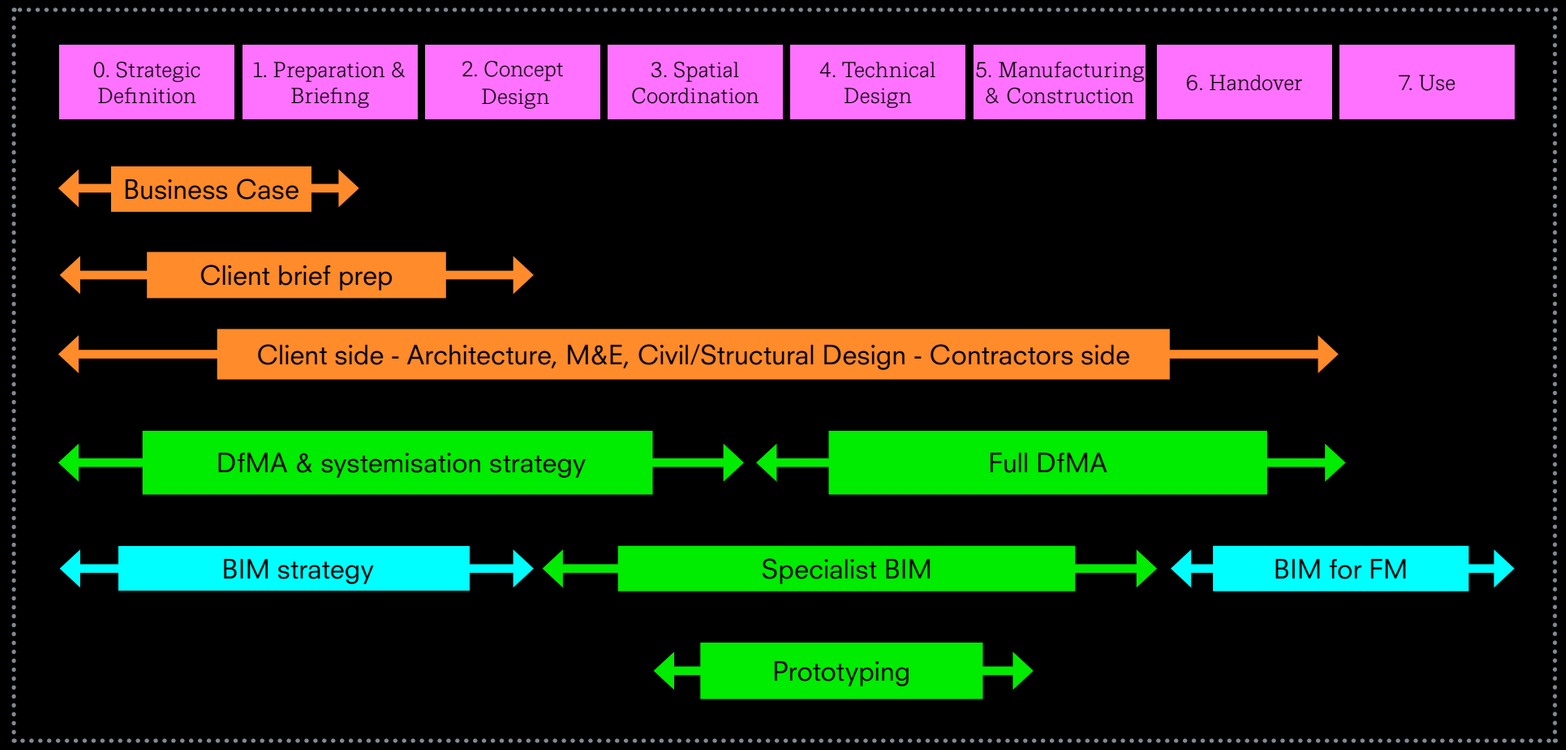
We maintain a clear design intent right the way through your project, to deliver the vision we set out at concept stage. Our team is growing constantly and currently has the following approximate percentage of people in each department:

- Architecture: 27%
- Structural / Civil Engineering: 20%
- Building Services Engineering: 21%
- Systemisation: 15%
- Creative Technology: 10%
- Other teams and Support: 7%

1.2 Adding Value to your project

As this diagram shows, our work spans a wide range of stages. We can work and add value on both client and contractor side. The earlier we are involved in a project the better, but it is never too late. We can always make a positive difference to project outcomes.

In our typical integrator role, we adapt and adjust our scope to the needs of the project, and will bring other disciplines in where and when they can add value.



Typical consultant scope for clients

Typical work for contractors and fabricators

Digital delivery scope for clients

1.3 Design for Manufacture and Assembly

Design for Manufacture and Assembly (DfMA) is a way of thinking at Bryden Wood. Central to our Design to Value philosophy, it is the fundamental idea around which we have developed our skills and capabilities and a key way in which we are increasingly unlocking value for clients.

At the core of our approach for over 25 years, our DfMA expertise has put us at the forefront of a global initiative in Modern Methods of Construction to bring the benefits of the manufacturing sector – safety, productivity, quality, speed and performance – into the construction industry.
We have developed a wide range of Design for Manufacture and Assembly solutions across sectors, for global clients and UK government. Our expertise is unparalleled in this field, which is becoming more and more widely adopted in both the public and private sectors in the UK and across the globe.

What is DfMA at Bryden Wood?

We believe that DfMA represents the future of construction. This approach to MMC brings the principles and benefits of manufacturing to the construction industry. Design for Manufacture and Assembly seeks to add value at every stage of the design and build process, by identifying opportunities for standardisation of components and/or processes. It is not something that can be retro-fitted to a traditional design process. It must be a core part of project thinking. In this way, it facilitates lean construction and a greater degree of sustainability. Starting with Design and ending with Assembly, DfMA is a complete process -from inception to delivery.
DfMA at Bryden Wood means innovation both across disciplines and sector boundaries. It energises our entire operation. Many of the capabilities we have developed over the last 25 years – integrated design, systemisation, creative technologies, algorithmic design, prototyping – have emerged as our approach has become more sophisticated.

What are the benefits of DfMA?

DfMA unlocks a wide range of benefits associated with the manufacture and assembly of products. Overall capital cost and time saving reductions of 30% are not uncommon. These arise from:

- Reduced capital cost, delivered by efficiencies in the production and quantity of component parts required
- Reduced capital cost, delivered by efficiencies in the number and nature of assembly processes required
- Greater quality and consistency, as components and processes are refined, and mistakes and variation are reduced
- Reduced construction time and better health and safety, as processes are learned, repeated and refined
- Less waste, as the quantity of components and materials can be calculated precisely
- Greater sustainability in construction and lean design, as standard parts can be produced to exacting environmental standards and re-used at the end of life of an asset, as part of a circular economy
- Greater quality and variety of design, as standardisation of core elements frees up architects' time to add value in aesthetics and the user experience
- Reduced risk, as standard components and processes are less subject to variation and uncertainty in supply and performance
- Better whole life performance and meeting the principles of Design to Value, as a result of better design, higher quality and the ability to incorporate ease of operation and maintenance into the components.

1.4 Systemisation

Delivering the benefits of DfMA at scale

The world is at a point where we have to build a lot in a short time. Mega projects alone account for 77% of overall annual project value*. The problem for all of us – and for the built environment – is that mega projects tend to over-run on both cost and programme. At the same time, they're considered by some to be too 'unique' to benefit from DfMA. We have to address this misconception.

The solution: systemisation

We are already delivering the benefits of DfMA at scale. We call this systemisation: a system of standard components that give enough flexibility to allow mass customisation, while working to the requirements of architectural design. Importantly, our approach works with existing supply chain, procurement, manufacture, logistics and assembly processes.

A flexible solution

Systemisation offers benefits for any large scale project or programme with the potential to use a significant degree of standardised components, for example:

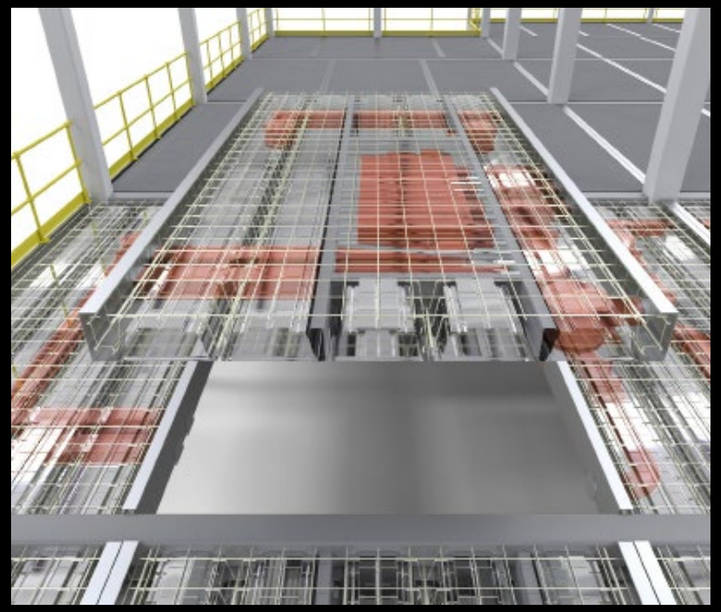
- Mega projects
- Complex projects and projects with significant constraints
- Repetitive assets or frameworks
- Redeployable assets
- Projects using automation or robots

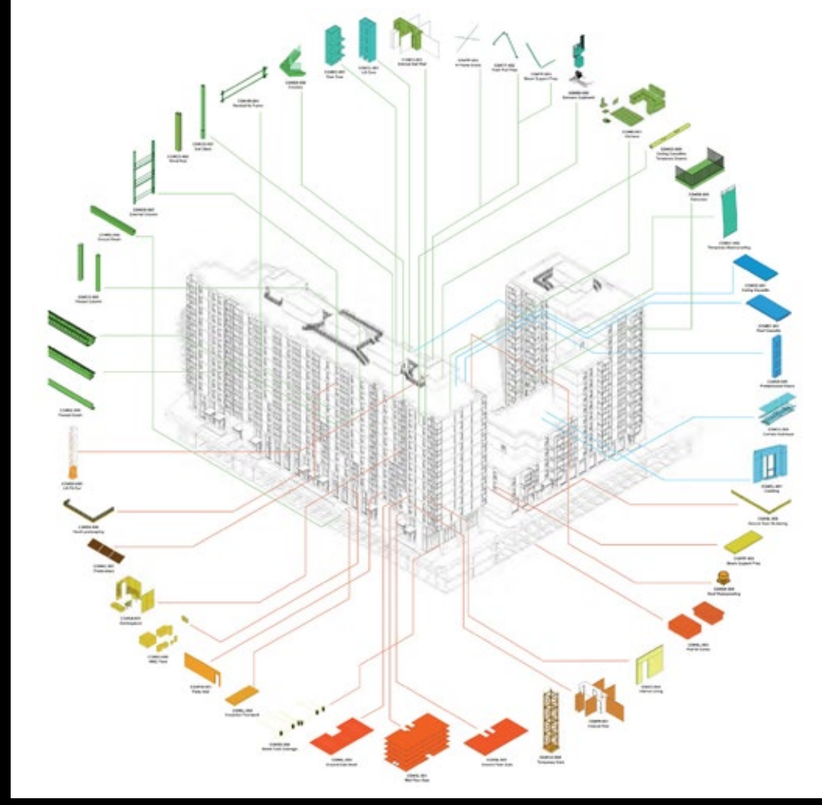
Unique output, standardised construction

Systemisation uses a small number of components that allow a huge amount of flexibility. They can be configured in an unlimited number of ways, providing a huge range of solutions for any site-specific issues. They offer mass agility, and the ability to work at scale.

Systemisation that works with existing supply chains

We develop workable, real-world solutions that use existing components, capabilities and capacity. We add value by bringing them together into kits of components or new construction systems. The skills, techniques and components required are already available, so systemisation fits with existing supply chains. As a result, major contractors, project managers and manufacturers can easily implement – and benefit from - systemisation.





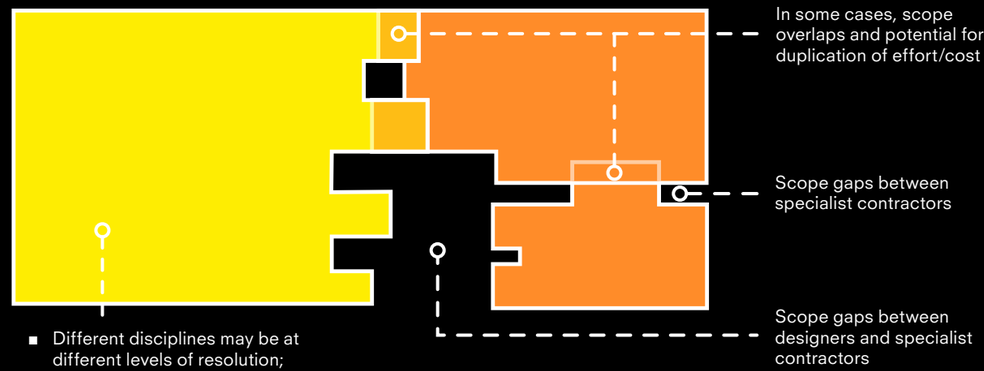
From design to delivery

Complexity throughout a structure might be thought to impose custom solutions that make systemisation impossible – but we have addressed this. We concentrate all the complexity into a limited number of design elements or nodes. Each is unique, but can be made using the same set of components with the same cost, time and process. This could be CNC machining, laser or water-jet cutting and additive manufacturing.

The rest of the structure or package can then be standardised, with all the benefits that brings.

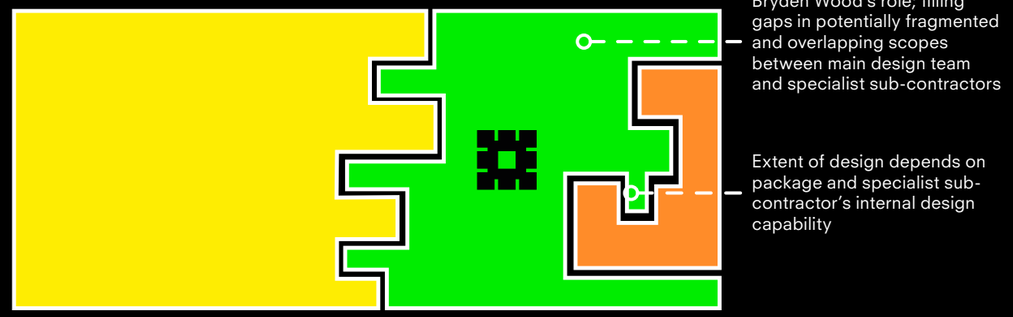
1.5 Our Special Façade Engineering Offer

Conventional design scope interface at end of stage



- Different disciplines may be at different levels of resolution;
- Unlikely that disciplines are fully coordinated and integrated;
- Potential for scope gaps in some areas, but duplication of effort in others;
- Potential for conflicting/ contradictory information
- Potential for inflated cost due to risk/provisional sums.

Common Bryden Wood integrated design role



How we work

Complementing client design:

- Envelope architecture
- Secondary support
- Specification
- Energy model, sustainability and carbon assessment
- Façade engineering
- DfMA approach
- Parametric design

Complementing contractor design/detailing:

- Construction-focused performance design
- Full interface detailing, integration, coordination
- Fabrication detailing
- BIM & Data
- BIM to Machine
- BIM to Supply Chain

Who has the most to gain?

- Main contractors
  - interested in innovation
  - exploring the benefits of alternative construction systems or DfMA conversions
  - looking to de-risk certain packages, e.g. facades
- Specialist subcontractors for facades, M&E prefabrication etc. particularly on complex projects
- Fabricators and suppliers of precast, GRC, GRG etc.
- Clients
  - who understand the benefits of special or modern methods of construction and want to guide their contractors to adopt them
  - with geometrically complex projects who want early proactive input to make sure that architectural ambition can be made practically deliverable for their contractors

Benefits to contractors and projects

- Adjust role to fit actual project needs (integration and gap filling)
- Integrated detailing and performance design (useful version of "façade engineering")
- Focus on fabrication and construction
- "Architectural standardisation"
- BIM link to factories and supply chain
- Realistic Value-Engineering

Summary

- Reduced subcontractor risk and reduced packages costs
- Reduced and simplified subcontractor detailing
- De-risk main contractor with and allow more efficient procurement
- Reduced programme from integration and BIM to logistics & machine design

1.6 Our driving principle Design to Value

Every aspect of the built environment sits within a multi-dimensional and fluid matrix of dependencies and consequences. No element can be viewed or managed in isolation.
But over a number of decades, the process of delivering built assets has become fragmented. Responsibility, risk and reward are increasingly split among an array of organisations and as a result, value is diluted at every stage.
This does not deliver the best results for clients. Design to Value does.

Design to Value – a unifying approach

The most efficient route to the most efficient solution is first to make sure you analyse and understand a project from every angle. Maximising the value of an asset is finding the right balance of a wide range of criteria.
Design to Value is well understood and applied in the manufacturing industries. It leads to objective analysis of every aspect of a process, every element of resource requirement, energy consumption, knowledge, and cost. It leads to testing of the value parameters each of these elements is being measured against. It is rigorous, logical and data-driven.

Its application in construction is transformational.

Design to Value may lead to a solution that is very different to the one initially conceived, but it will be a solution that is fully thought through, appropriate and complete. A built asset that delivers value across the piece.

Iterate in digital

Our approach is to dismantle a process rigorously until we reduce it to its smallest components. Then we call on a breadth and depth of expertise to optimise every component, so that when we combine them in the complete solution, the whole will operate to the maximum efficiency of all of its parts.
We create a digital model of every component, containing as much value data as we can source, ranging from energy consumption to physical space requirements to expected lifespan to cost. In the digital design environment, we experiment with a huge number of permutations of components, introducing variables, then measuring, iterating and refining, over and again.

From the earliest stages, we work with 3-D visualisations of processes and physical assets. This allows us to iterate and test many variables. Users can take a virtual reality walk through the process, to test the physical environment and anticipate issues.

Automation in construction

There are elements of some processes that are unique and so will require a bespoke built solution. But there are also many elements that are, or could be, automated or standardised across multiple processes in one or more sectors and industries. Discovering standardisation adds its own value; not having to reinvent the wheel with every project; being able to apply the learning gathered from previous projects to the current one; and resource and cost efficiencies in all stages of design and production.
There are many elements of built assets that are, or could be, automated or standardised across multiple processes in one or more sectors and industries. The benefits of standardisation are visible every day in the manufacturing industry, at global scale. We bring them to construction, in our Platforms approach to Design for Manufacture and Assembly (P-DfMA).

A proven approach

We do not come to any project with a ready-made solution. We bring only our Design to Value principles, using the combined powers of data, technology and imagination to establish what the most effective solution will be.
We have been working this way for over 25 years, delivering major projects in pharmaceutical and process facilities, data centres, aviation, healthcare, education, residential, water infrastructure, transport infrastructure, custodial facilities.

Design to Value is proven to deliver better results for our clients, and for the built environment.

1.7 Platforms

The development of construction Platforms is the culmination of our work in DfMA for multiple clients, in numerous sectors, over 25 years. The P-DfMA approach brings together everything we have learned, and continue to learn, about a manufacturing-led approach to construction and makes it widely available for the benefit of not just the construction industry, but society as a whole.
Platform design brings a solution to the challenge of a growing world population and the undeniable call for high-quality and sustainably designed infrastructure for vast numbers of people, such as housing, education, healthcare and transport.

What are construction Platforms?

An important development in Modern Methods of Construction (MMC), the term 'Platforms,' commonly used in manufacturing, refers to sets of components or assemblies that can be put together in a multitude of different ways to create multiple different products.
In the context of the built environment, the Platforms approach to design for manufacture and assembly (P-DfMA) identifies commonality across sectors – schools, apartments and healthcare facilities all have similar structural spans and ceiling heights, for example – to define the 'kit of parts' of components and processes that we can use to deliver a wide variety of built assets.

Like the manufacturing sector, we have focused as much on the 'process' as the 'product'. On-site assembly processes are standardised and simple, using colour-coded components.

All parts are readily available from existing suppliers and can be assembled easily and intuitively, in countless ways, to sustainably create a huge range of spaces. All of these factors support our broader focus on process engineering and Design to Value.

Why P-DfMA?

The power of P-DfMA is in its ability to create standardisation at component level, while retaining flexibility of design at asset level. Construction Platforms support highly site-specific designs and the widest range of architectural ambition, while still bringing the benefits of a manufactured approach.
The Platform design method also drives greater value within the construction industry. Using repeatable, cross-sector, components creates the economies of scale that, as in the manufacturing sector, will allow us continually to drive down time and cost while increasing safety, productivity and quality. All core principles of Design to Value.

Straightforward assembly means we can use upskilled or even non-construction operatives, working under safe and controlled conditions. This facilitates new jobs and opportunities to help tackle the challenge presented by an ageing construction workforce.

Platform design brings automation to construction - both in the manufacture of individual components, and in the assembly processes

that create whole assets on site. It is this automation in the construction process that will transform the safety and productivity of the sector, as we have seen across so many other industries.

P-DfMA unlocks the true power of digital design and simulation. Components that work within defined parameters and rules allow us to use automated, computational design processes, creating digital models in minutes. We use this speed to test many more ideas, drawing from a much wider, richer range of possible solutions than is possible using traditional means. These iterative designs, generated using the latest digital construction technologies, can be tested and refined through simulation of energy balance, pedestrian movement, air flow and ventilation, etc. The result is highly optimised designs in which consistent performance through the whole life of the asset has been considered and 'baked in'.

Finally, when we consider the role the construction industry must play in moving the built environment forward sustainably, it's important to recognise that Platform design offers the most sustainable way to build. Repeatable components can be highly optimised to minimise material use and facilitate embodied carbon reduction. A manufacturing approach means less waste and rework, efficient logistics and 'just in time' delivery. Sustainable, lean design with high quality components and digital simulation facilitates efficient assets that minimise in-use carbon.

In short, a Platform approach to Design for Manufacture and Assembly will finally allow us to create a construction industry which is fit for the future.

1.8 Apps and configurators

We are not software developers, but we do make software. We don't want our design automation technology to be used only by us – we want it to be available to as many people as possible. That means we build computational design apps that aren't just for architects and engineers. We make construction technology that is available for use by people who would not usually engage directly in the design process – whether that is our clients, or the wider public. We do this because we want to share the intelligence that we embed into our apps.

Digital construction: engaging beyond the usual

Whether building for web, mobile or XR, our apps aren't just about re-presenting fixed design content. They are about the user being able to create and control the content themselves, interacting, designing and having fun with transport, buildings and even robots.
We aim to make our digital design apps as exciting and as engaging as possible so that people will want to use them.

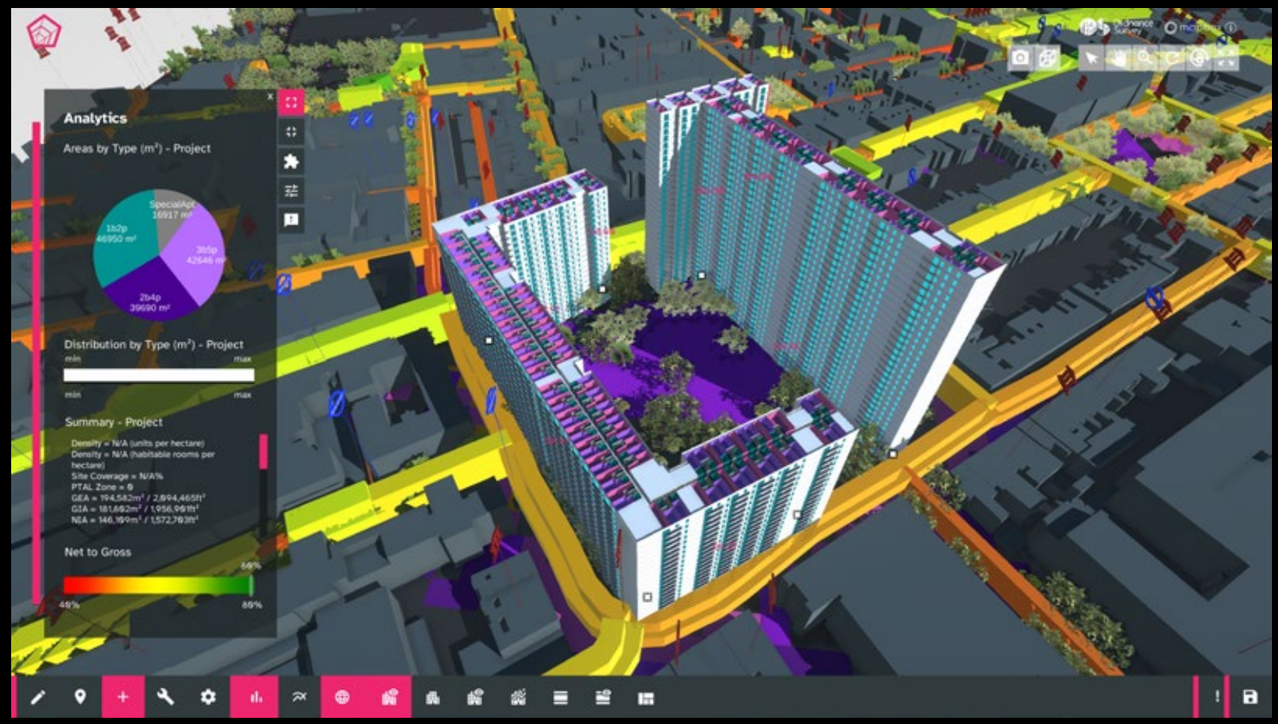
The role of configuration in construction technology

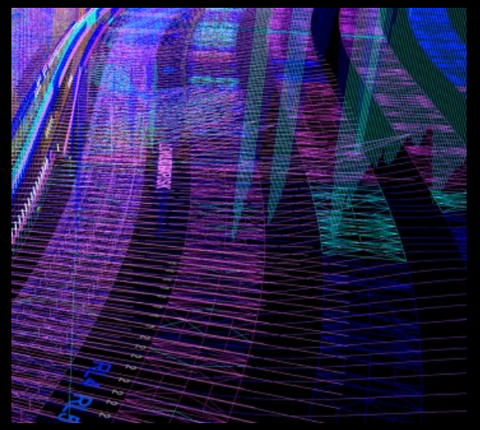
There is a common thread that runs through the wide range of computational design apps that we build: configuration.
We build configurator apps to give users the ability to configure a building in minutes – using pre-engineered components and according to pre-determined assembly rules – rather than design it in weeks or months. They allow users quickly and intelligently to develop designs that have different aspects of compliance built in – in terms of regulations, but also in terms of delivery, safety and ultimately quality.

Configuration technologies allow clients to control standardisation across their projects. They also free up designers and architects to focus on the parts of the design process where they can be most useful and add most value. And because our computational design configurator apps encode logic and rules by which design systems work, they can allow many more users to participate and engage in parts of the design process that may otherwise be seen as too technical. The app takes care of that part of the process and allows the users to explore and be creative.

BIM and beyond: from configuration to delivery

Of course, we want to take our designs beyond the configurator and integrate them into other aspects of the digital delivery process. From our design configuration apps you can automatically generate your detailed design models that go beyond industry standards – for both Building Information Modelling (BIM) and fabrication – in minutes.





1.9 BIM and digital delivery

BIM (Building Information Modelling) is not just about architectural design software. BIM is really a set of digital processes that, when used correctly, can help us design better buildings.

BIM has been foundational to our work at Bryden Wood since before it even had a name. We began our BIM technology journey by using automotive design software to create detailed and data-rich models of our projects. We had colleagues from all disciplines working together in a collaborative, 3D, integrated design environment to solve complex Design for Manufacture and Assembly (DfMA) problems and produce beautiful buildings.
And that is what BIM still is for us. We use digital modelling (along with other new construction technologies) to inform and evidence everything we do.

Technology in construction: learning, improvement and collaboration

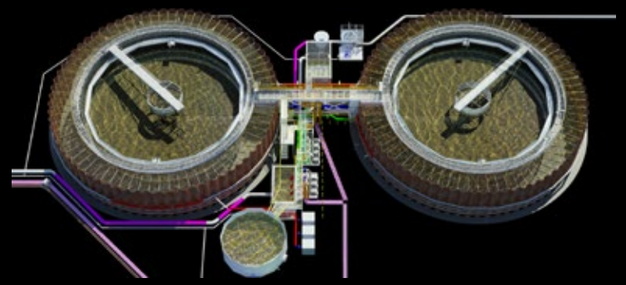
As with many other parts of our work, we have been keen to share and promote what we learn about effective new technologies in construction, and new approaches. We were part of the UK government's efforts to produce BIM standards that could be applied across the whole construction industry. We have built relationships with major software vendors to help foster collaboration and integration around Open Source BIM. We care about changing people's attitudes to BIM design, sharing our technologies and experiences as well as supporting open standards such as IFC, COBie and Uniclass.

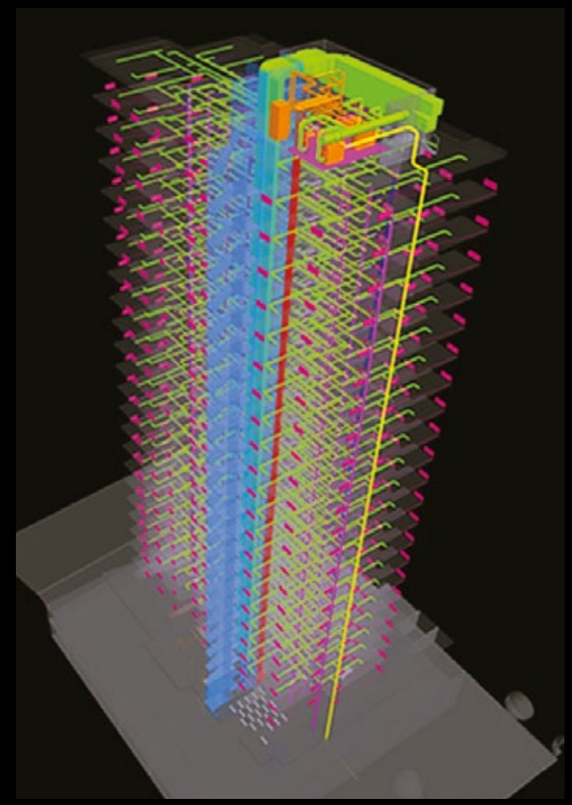
Deep and broad experience in BIM technology

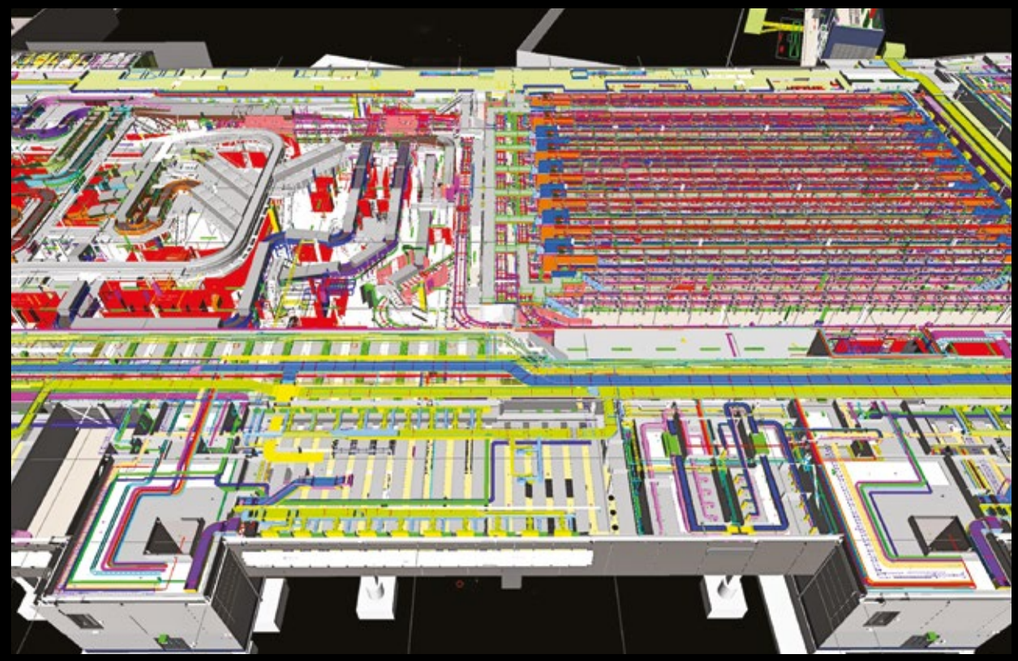
We have been on a long and very informative BIM journey; from the early pioneers, through the PAS documents and most recently to the ISO standards. These have not just changed the construction industry in the UK but are shaping how countries and companies around the world understand the potential of BIM technology and support them in realising their goals through BIM.
Through the breadth and depth of our experience with BIM design across projects and sectors, we understand that there isn't a 'one size fits all' approach to BIM.

BIM Level 2 and beyond

BIM Level 2 is our baseline. But there is so much more to explore beyond. We tailor our approaches to suit specific client requirements and best possible outcomes.
We create highly sophisticated models – in both data and geometry – that can support true digital delivery by connecting to any and all platforms and products that support the translation of a project from digital idea to built assets.







1.10 Integrated Supply Chain and Logistics

Procurement of DfMA requires a new relationship with suppliers, particularly more direct relationships with a range of component manufacturers. The design of repeatable elements can be refined in line with supply chain capability and capacity. By working with and designing ‘towards’ a supply chain the benefits of their existing skills can be optimised, with benefits to cost and quality.

Bryden Wood works with global clients to study how DfMA solutions can optimise logistical efficiency and control, and develop procurement strategies for DfMA systems integrating component supply chains with project delivery logistics to maximise the productivity of DfMA implementation.

Procurement via a digital marketplace

Efficient rollout of a DfMA approach requires an agile, digitally enabled approach to procurement.

Already it can be seen that online market places are changing procurement in a number of sectors. Online procurement services can link customers to multiple small scale fabrication shops to facilitate the supply of machined parts - it is not difficult to imagine the equivalent linking major programmes to multiple SME’s.

Rethinking the supply chain

In order to fully realise the available benefits from DfMA and MMC the end-to-end supply chain for construction components has to be considered.

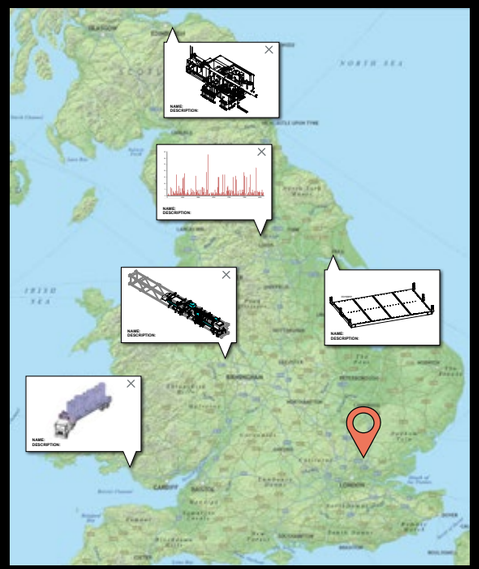
For example, individual components could be cost-effectively procured at scale from the existing specialised supply chain and delivered to a client-controlled consolidation centre. From this point, components would be grouped and transported to site on a just-in-time basis for installation according to the construction programme.

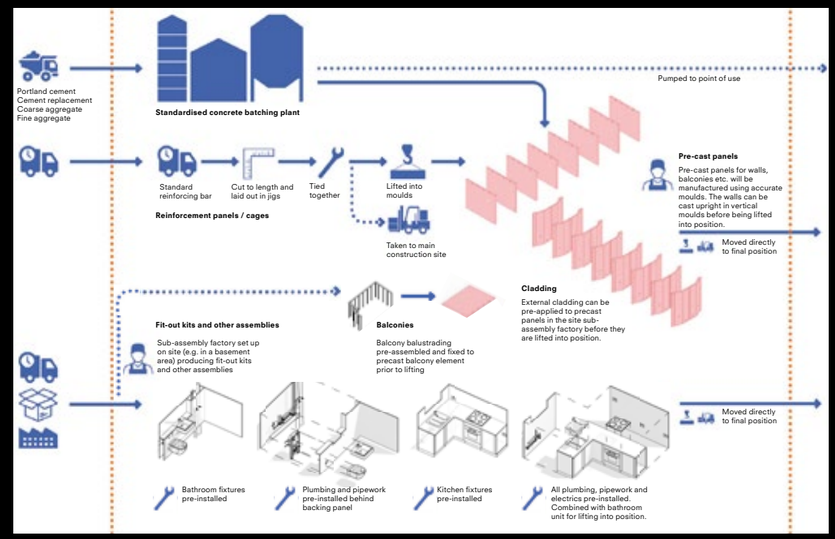
Logistics hubs

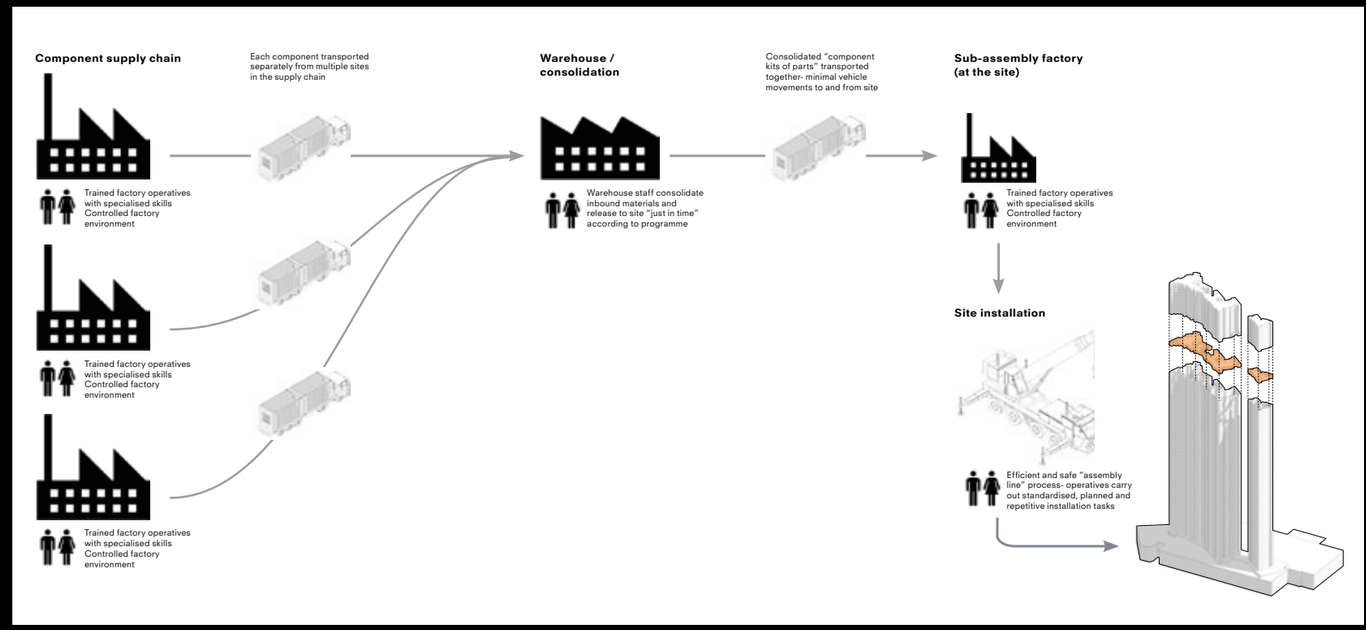
A DfMA-enabled production and assembly flow would allow more rigorous control of logistics, with loads of materials and sub-assemblies highly targeted to specific modes of transport, work areas and rates of flow production. Centralised consolidation centres or Logistics Hubs can carry out a range of functions:

- Consolidation – products are transported to site in a way to maximise utilisation of transport;
- Configuration – products are re-packed into ‘work-packs’ in a way to provide operatives on site all the products they need to deliver their works for their particular area;
- Pre-fabrication / pre-assembly (including sub-assembly workstation) – products are pre-assembled before being transported to site.

Bryden Wood seeks to investigate multiple scenarios to facilitate a more detailed consideration of the location and purpose of logistics hubs on DfMA projects. These scenarios yield data and visualisations that can be used as a baseline against which to test emerging considerations. Supply chain mapping tools (created using AnyLogic simulation software) further facilitate decision making and scenario testing.

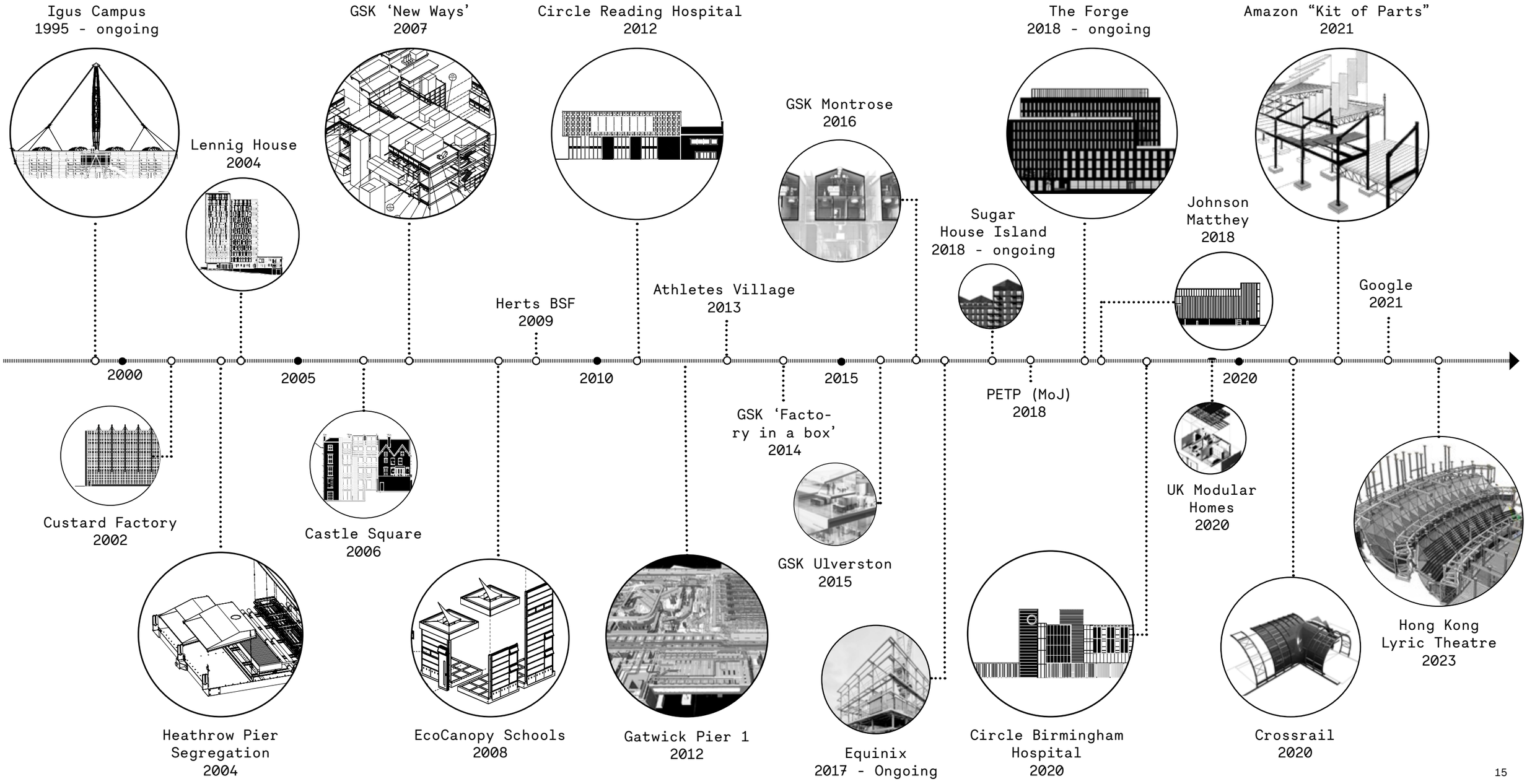






1.11 Methodology - Technology timeline Delivering sustainable and MMC solutions

For over 25 years, working with multiple clients, in several countries and in numerous sectors, Bryden Wood have developed a unique set of skills, knowledge and approach that we bring to the project.
The timeline below shows a selection of relevant projects through which we have shaped our understanding, and commitment for, Sustainability, Design to Value and Design for Manufacture and Assembly.



2.0 Case Studies GRC Projects

2.1 Crossrail - GRC Cladding

Project Summary

Client: Laing O'Rourke
Our Partners: GRC UK
Construction Value: £18.8billion
Status: Open to public

How we added Value:

- Compressed site construction/install programme with optimisation of off-site fabrication
- Design of lightweight panels for ease of installation and thus improvements in site health and safety.
- Tolerance and accuracy maintained by CNC cutting and forming machinery across all moulds, panels and steelwork.
- Reduced the total quantity of tunnel lining fixings and total number of assembly parts compared to architects original design intent.
- Fully codified SolidWorks models were the key deliverable, and formed a key part of the checking and coordination procedures by the station architects, reducing the number of system wide typical drawings required.
- The SolidWorks models were used directly by the fabricators to create the moulds for the panels and the steelwork elements.
- Innovative glass reinforced concrete (GRC) 'tusk' solution used to span the largest arches and provide precise fixing points - where large scale double curved panels meet.

Prefabricated tunnel lining system

Bryden Wood completed the detail design of the internal GRC facade, associated bracketry, secondary steel and interface detailing for three central flagship Crossrail underground train stations: Tottenham Court Road, Liverpool Street and Whitechapel Stations.

Due to the high level of complexity and the aesthetically critical detail required, this unique project was put under extreme time pressures. Bryden Wood used several different workflows to ensure a timely and high standard delivery of this project.

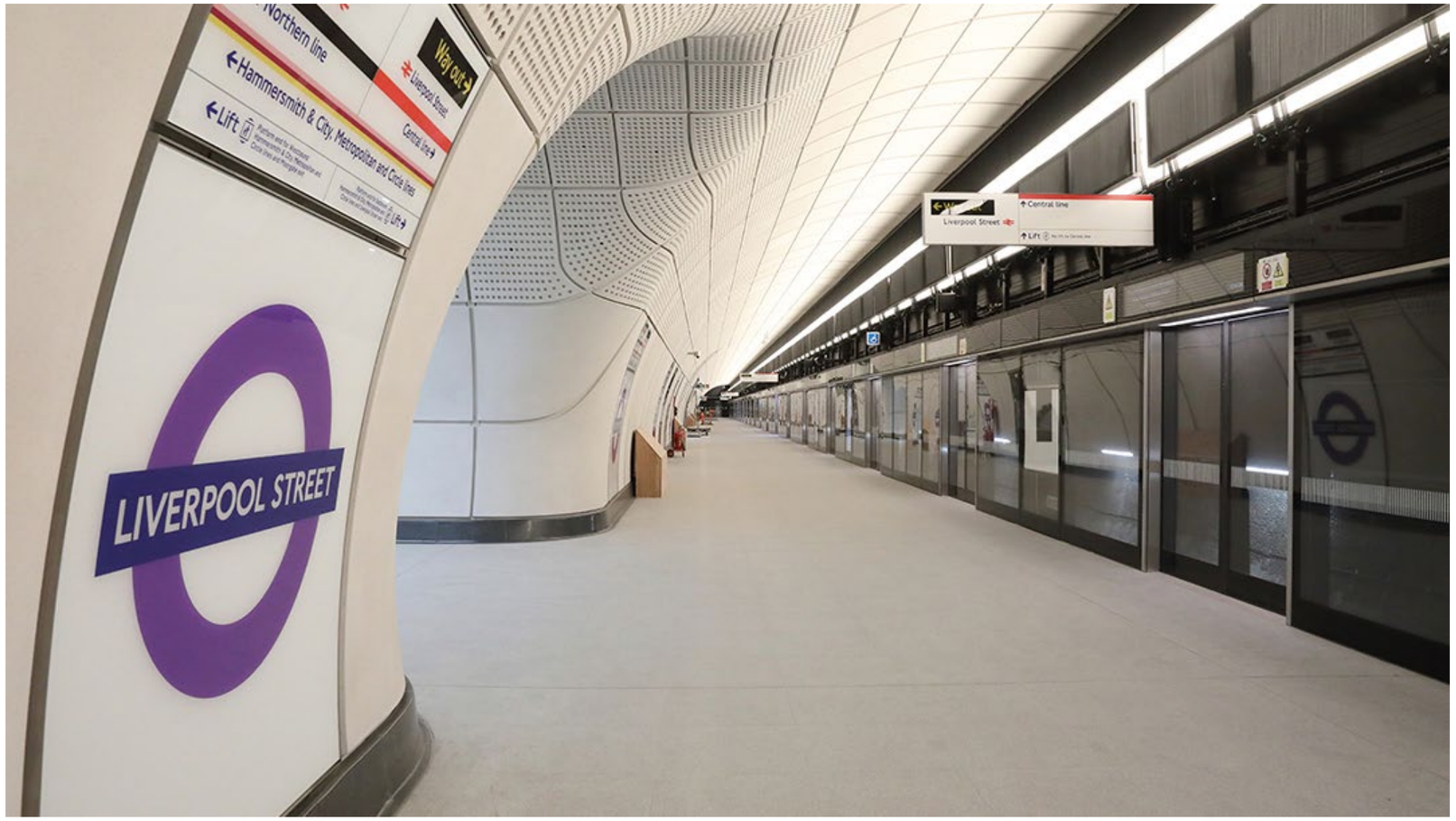
The scope included full fabrication models of the station platforms, concourses and cross-passages in both circular and rectilinear configurations. Multiple optimisation studies were carried out in order to consolidate variations. Point cloud surveys of the tunnel's sprayed concrete lining were taken to accurately measure and design around. Full bill of materials information including individual part numbers were assigned to all GRC and steel parts which greatly benefited the supply chain, and made logistics planning an integral part of our design.

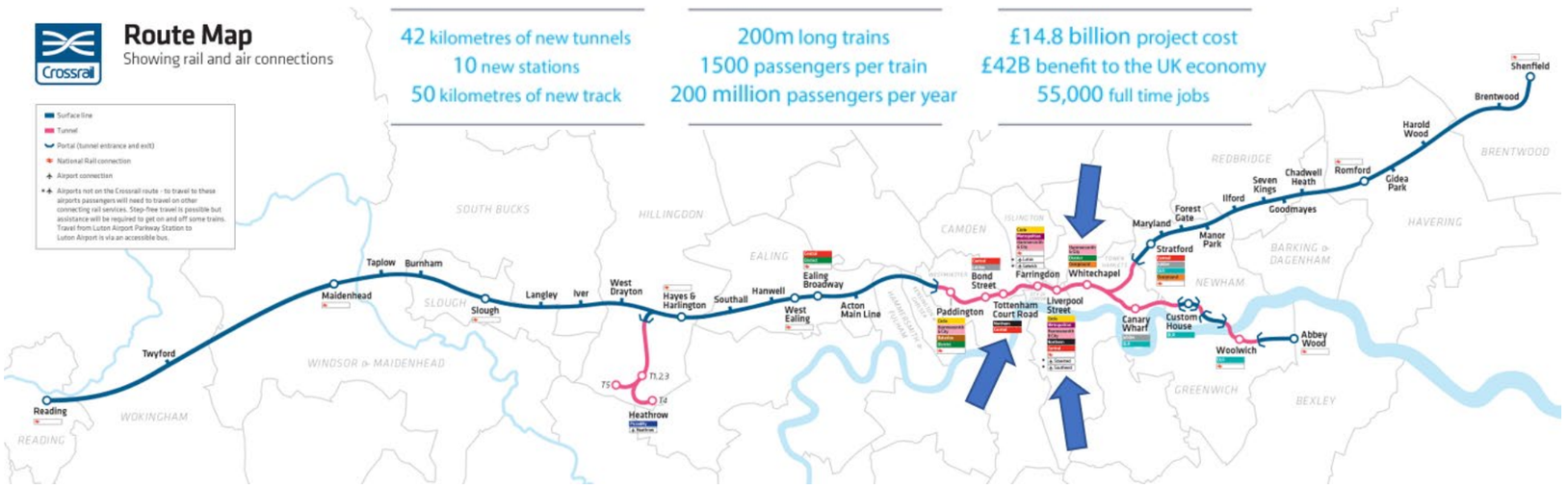
32,000 m2 area of GRC panels

27,000 individual panels

2,300 bespoke moulds

3.1 km of platform/passageway/escalator tunnel

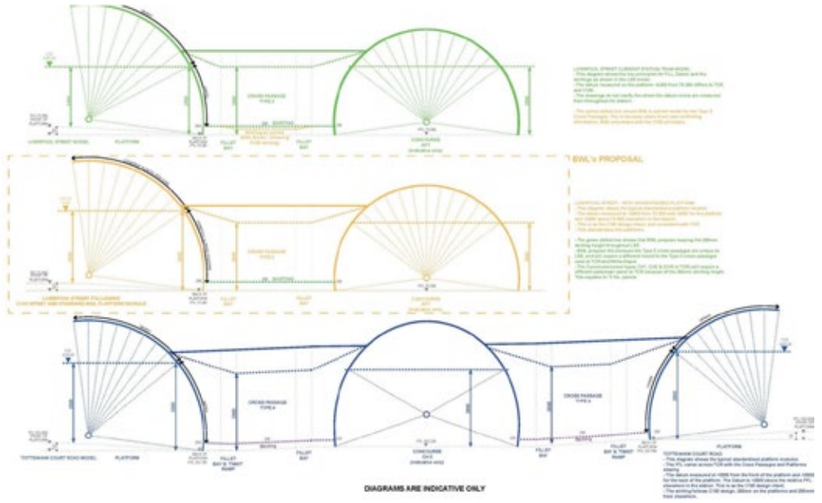




2.1 Crossrail - GRC Cladding

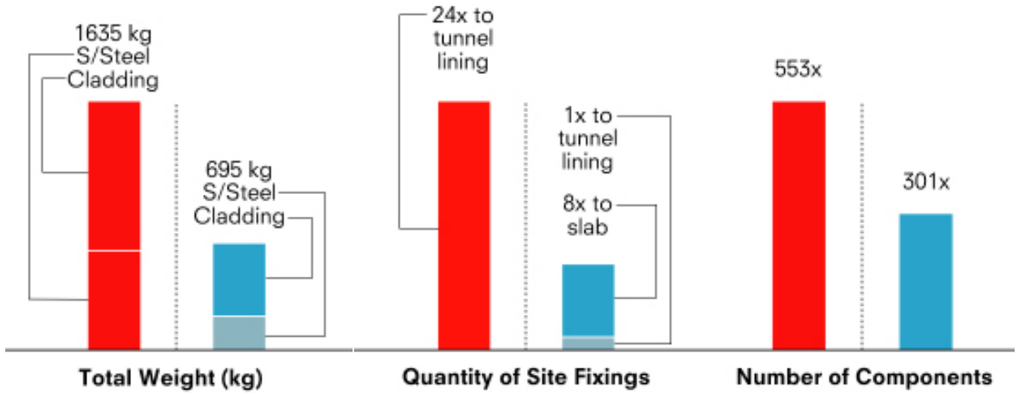
Rationalisation

- Architectural coordination between stations to achieve common details
- Optmisation of bay sizes and geometry to reduce number of moulds
- 268 unique moulds eliminated for >£1,000,000 savings and shortening of fabrication programme



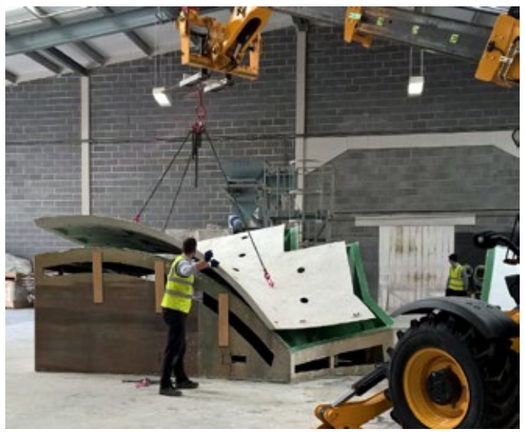
Value Engineering

- Reduction of GRC weight
- Reduction number of concrete site fixings
- Overall part count reduction
- Reduction of steel tonnage



Innovation

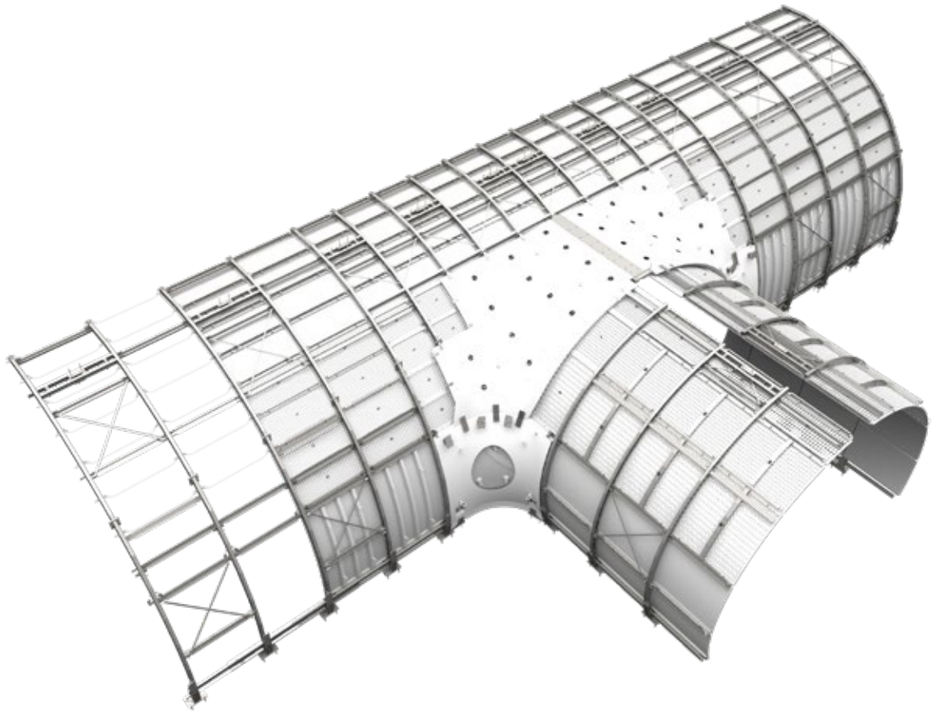
- Collaboration with manufacturer
- Use of GRC as structural arch support for GRC cladding
- Bomb blast testing
- Load testing
- 5-Axis CNC mould fabrication



2.1 Crossrail - GRC Cladding

Mock-Ups / Prototyping

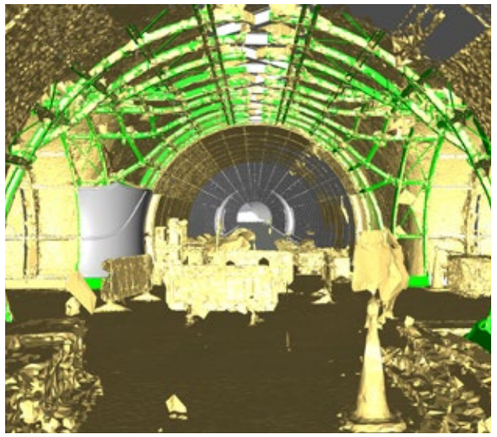
- Full scale mock-up was designed and developed with GRC manufacturer and steel fabricators:
- Mould material experimentation
- Panel finishing testing
- Process optmisation
- Tolerance verification
- GRC as structural elements
- Installation methods
- Quality control

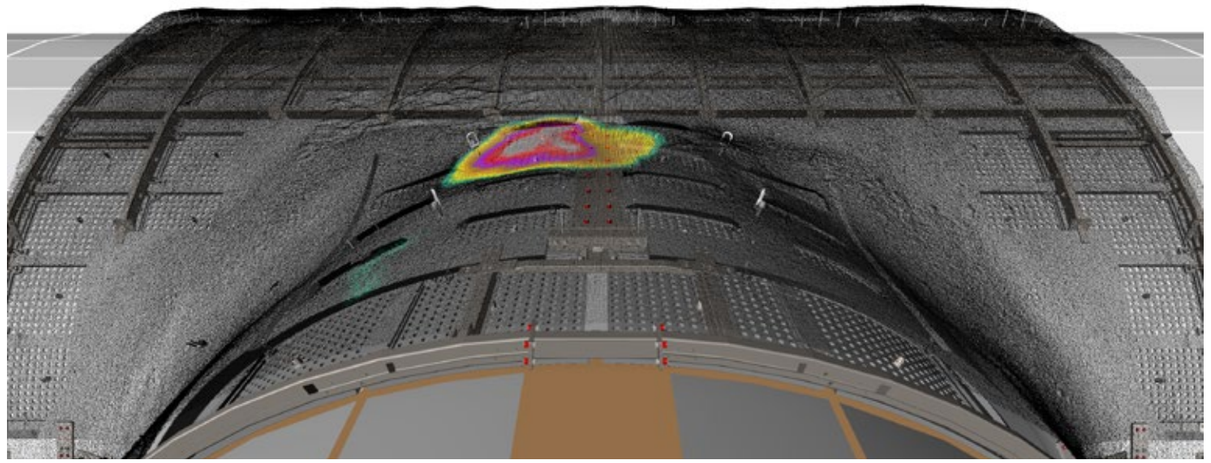


2.1 Crossrail - GRC Cladding

Point Cloud Surveys

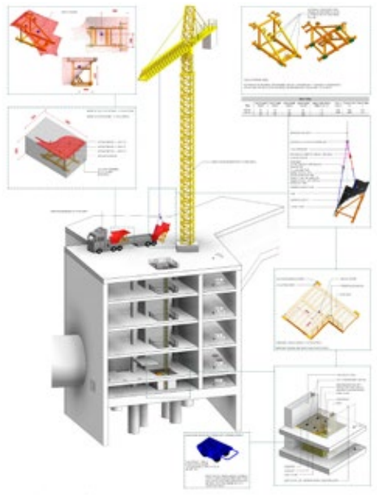
- Where sprayed concrete tunnel lining was built out of tolerance, clashes were identified and highlighted to site teams to scabble back where necessary.

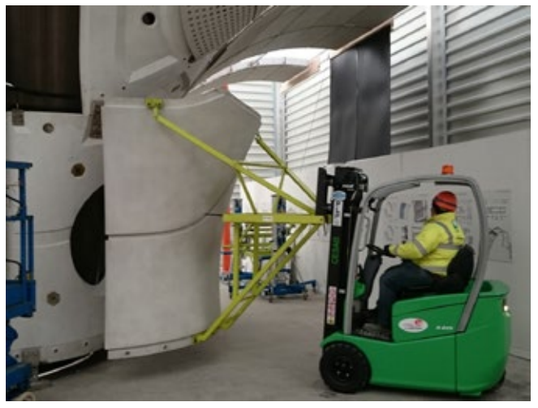




Transport & Lifting

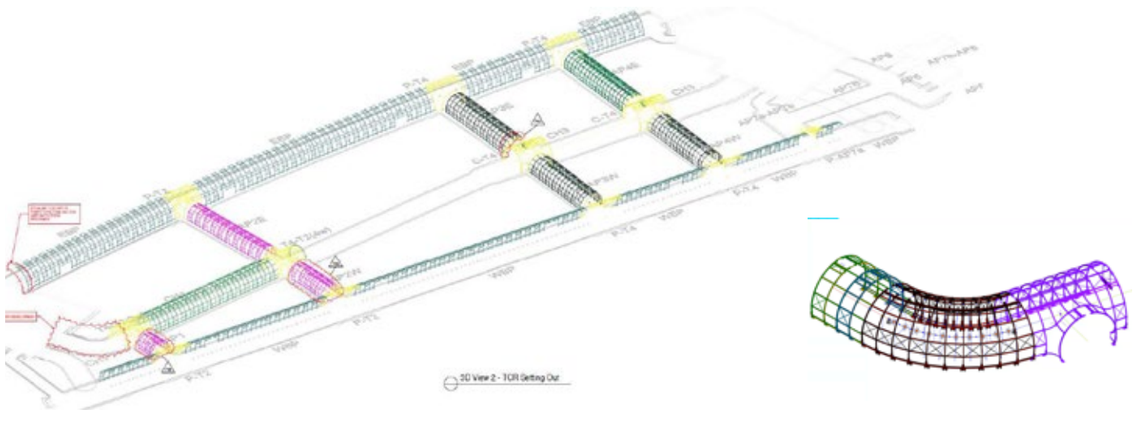
- Stillages for transport and lifting
- Lifting methods and planning
- Movement and handling studies for clearance and route planning
- Installation methods





Setting Out

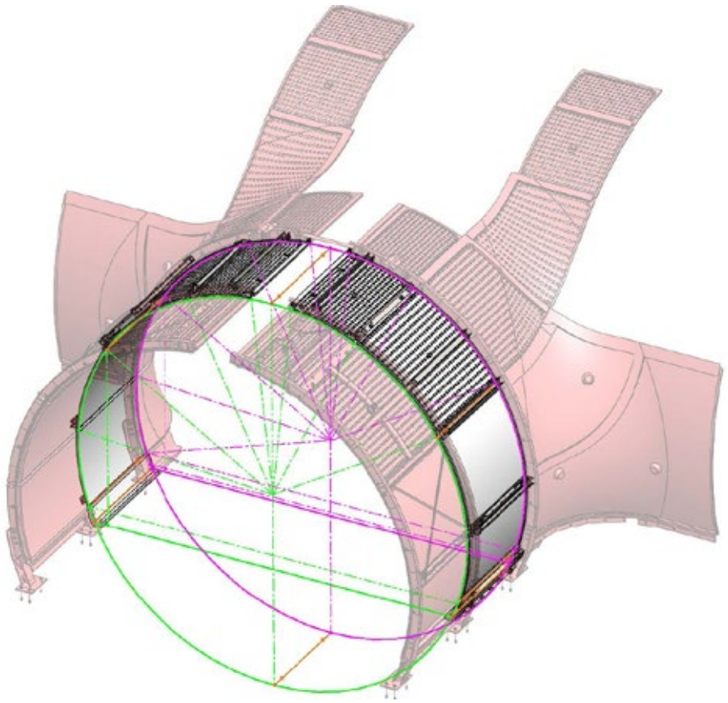
- Setting out coordinates provided to site teams on drawings and via digital twin model.
- Laser surveying equipment used to set position of elements within +/- 3mm global tolerance.

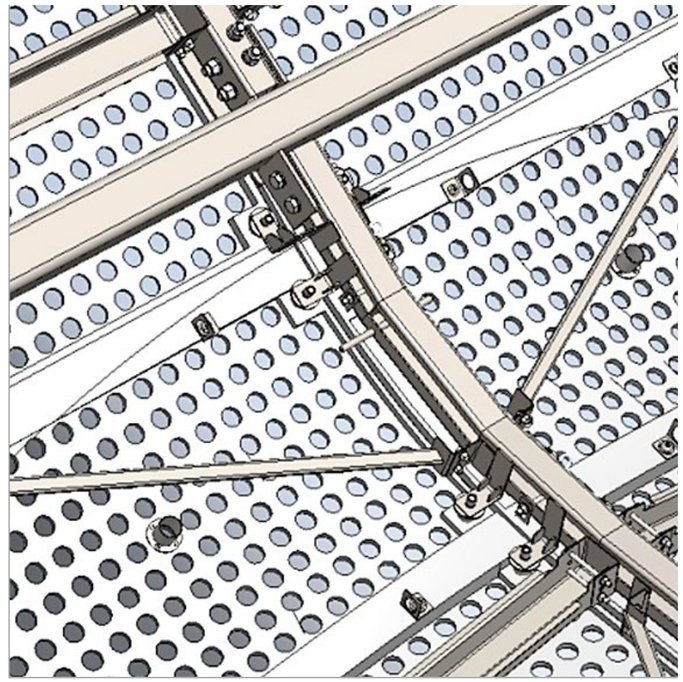


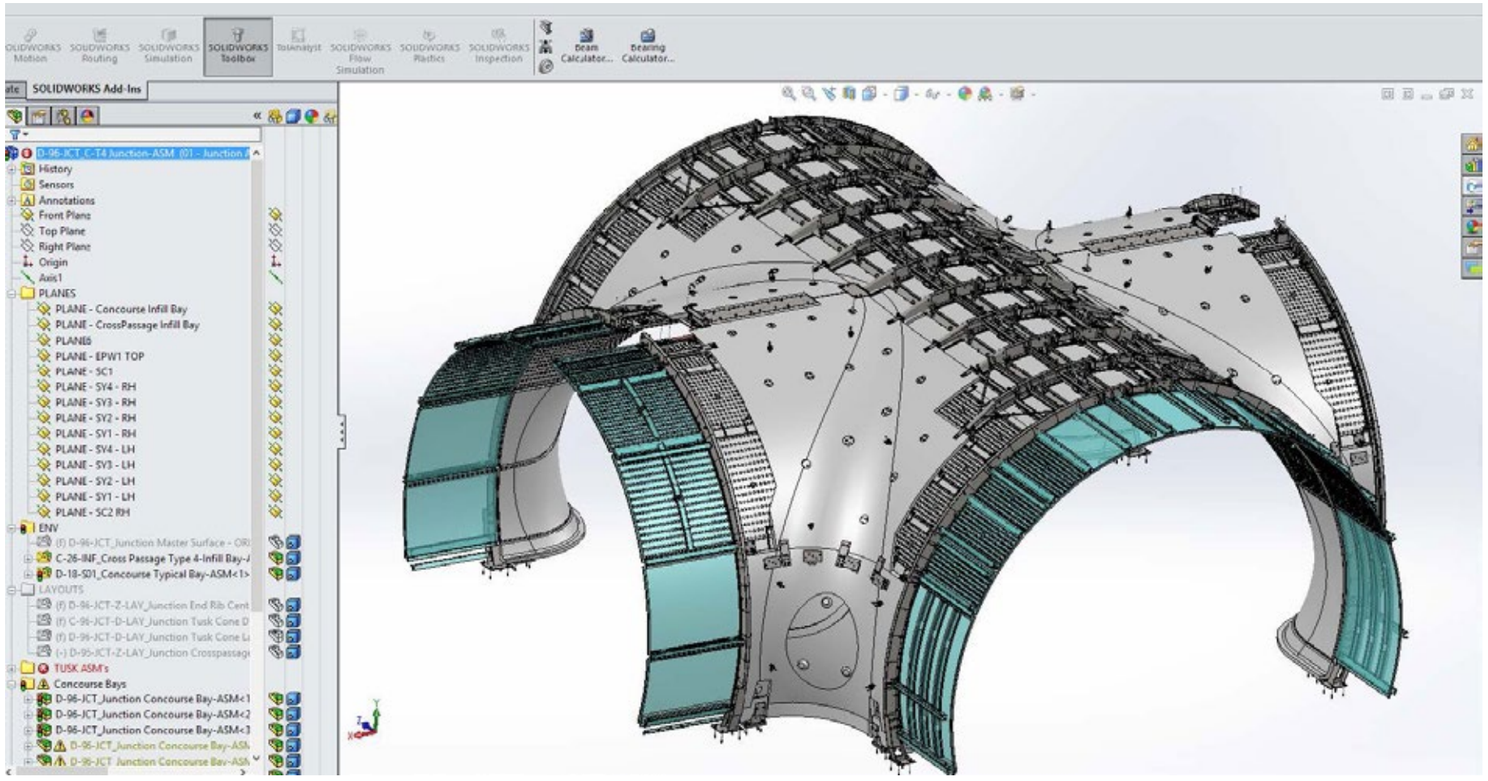
2.1 Crossrail - GRC Cladding

Modelling & Coding

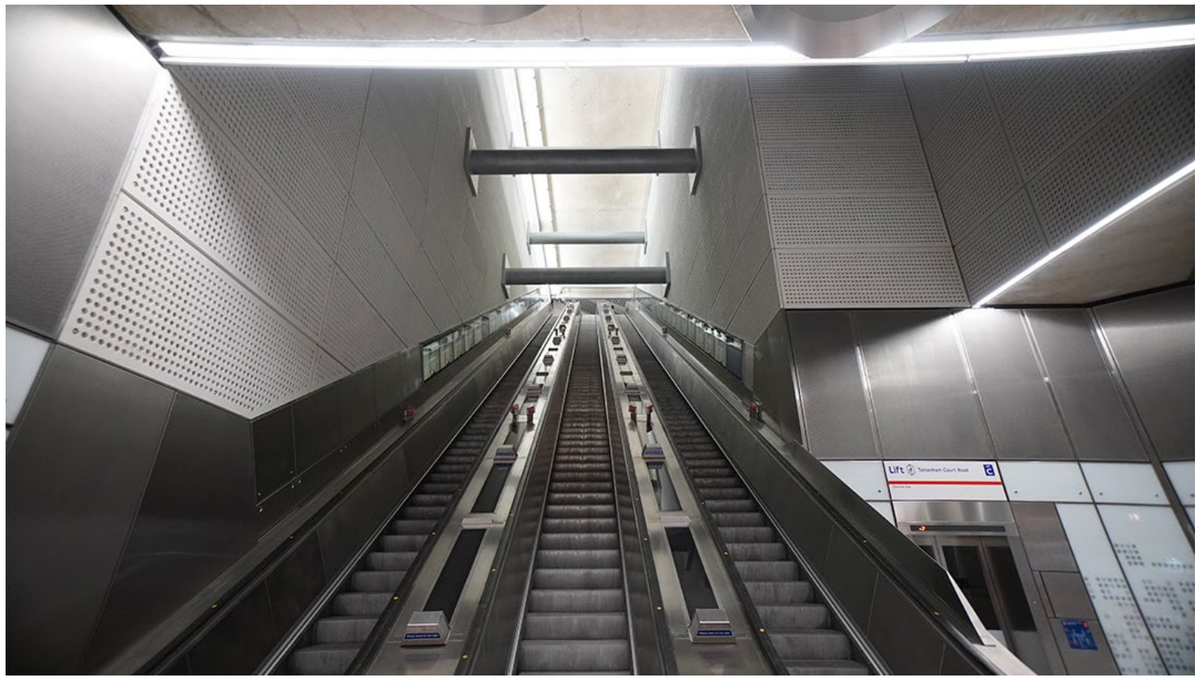
- Models handed over to fabricators for direct use in mould making and steel fabrciation processes.
- Modelling hierchary aligned to manufacturing assemblies.
- Embeded coding strategy used across all levels of design, fabricaiton, site installation for tracking and logistics.
- 100% construction and fabrication detail modelled







2.1 Crossrail - GRC Cladding



2.2 Ponton Road - GRC Cladding

Project Summary

Client: 46 Ponton Road
Our Partners: Laing O'Rourke / ExpLORe
Construction Value: Confidential
Status: Complete

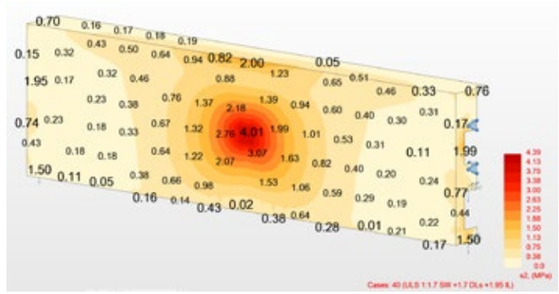
How we added Value:

- Full fabrication details of GRC panels & fixings for cladding mullions, spandrel panels, and other bespoke elements.
- Developed through-bolt fixing design to reduce manufacturing costs and still allow for preferred installation sequences.
- Each variety of GRC panel and fixing bracket were systematically coded for factory and site reference.
- Use of schedules linked to architect's floor plans and tabulated fabrication drawing to minimise the number of drawings needed for manufacture.

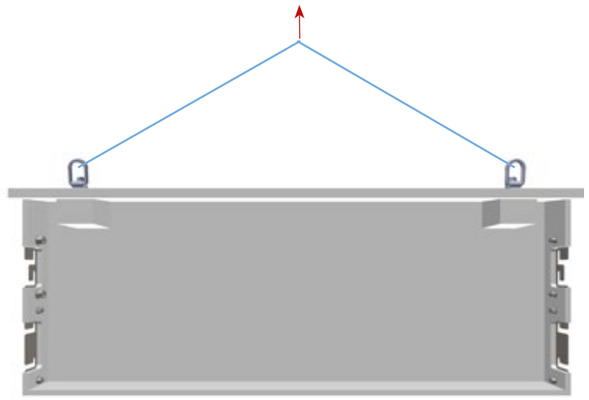
GRC Cladding Panels & Supporting Bracketry

46 Ponton Road development is made up of three blocks of flats ranging between 10 – 13 storeys located in Nine Elms which is a fast transforming district in Battersea. The design intent is a redevelopment of the site to provide affordable housing that will comprise of 357 residential units, mixed with urban design and a waterside community.

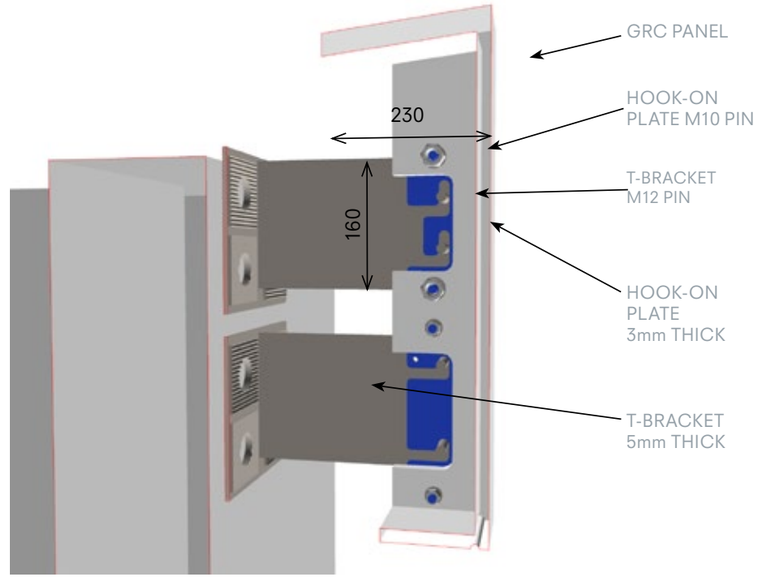
Bryden Wood was appointed by Laing O'Rourke/Expanded for the joint design of the GRC cladding package which encompasses all three blocks at 46 Ponton Rd. Our client requested not to use cast-in fixings so Bryden Wood developed a through-bolt design for GRC fixings that would also follow the required installation sequence and meet the standards of onsite lifting and safety procedures.



Structural Verification



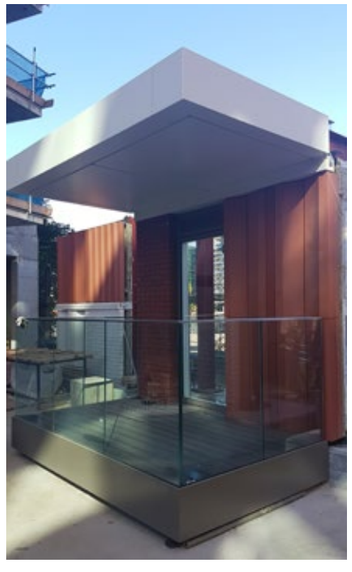
Lifting



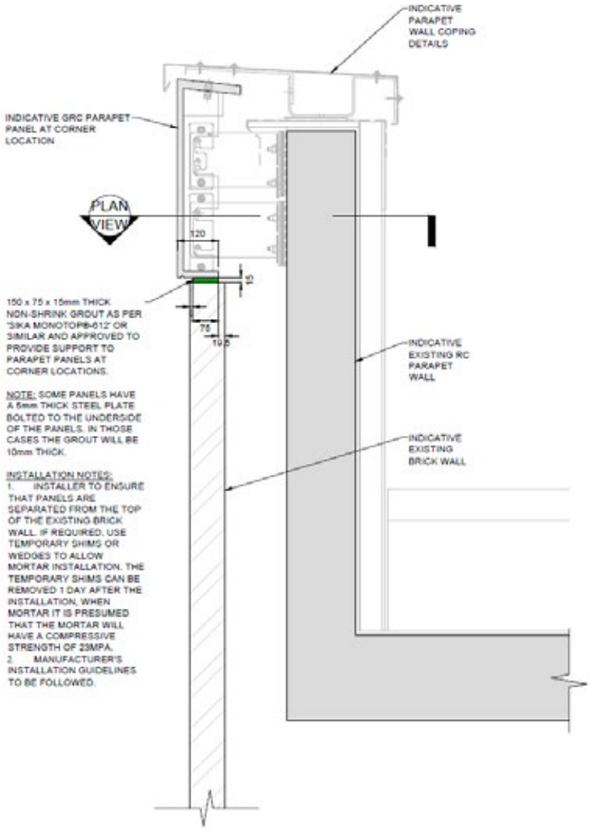
GRC Panels, Bracketry, Fixings

Architectural Concept

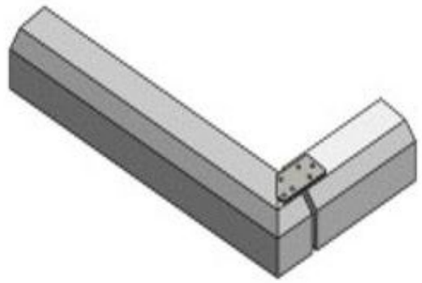
Mock-Ups



2.2 Ponton Road - GRC Cladding



Detail Drawings



Detailed Model

Manufactured

Mock-Up Model

Finished Site

2.3 Whiteleys - GRC Cladding & Façade Design

Project Summary

Client: LOR
Construction Value: approx. £1bn
Status: Under construction
Disciplines: Structural, Facade, DfMA

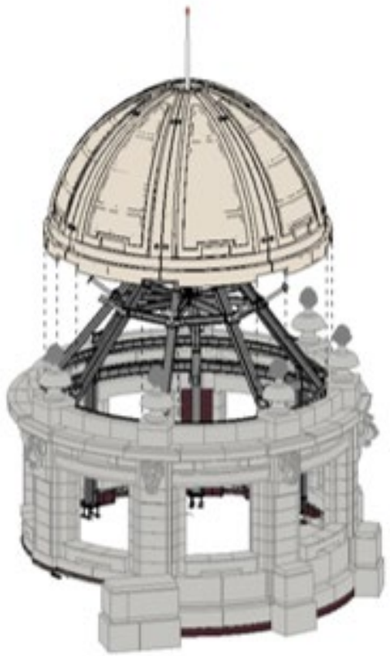
How we added Value:

- Designers for GRC cladding elements and precast facade
- Fabrication design, structural engineering, and facade engineering services provided
- Design and modelling of complex double-curve GRC panels, along with >200 single curved atrium panels.
- Design and model two feature cupolas to match heritage cupolas.
- Optimised bracket types to provide less variance
- Worked closely with factory and site teams to improve constructability

BWT are involved in multiple roles on this unique architectural refurbishment and extension project. The redevelopment and restoration of Whiteleys will protect the site's heritage and enhance the retail offer, whilst also helping to create a pedestrian-friendly Queensway. The proposals will also provide residential accommodation – a mix of apartments and townhouses – and new local amenities including a hotel, cinema and a variety of restaurants.

BWT are providing DfMA, structural, and façade engineering services for GRC, new build natural stone, and precast for also the retention of the heritage façade.

The Whiteley Building



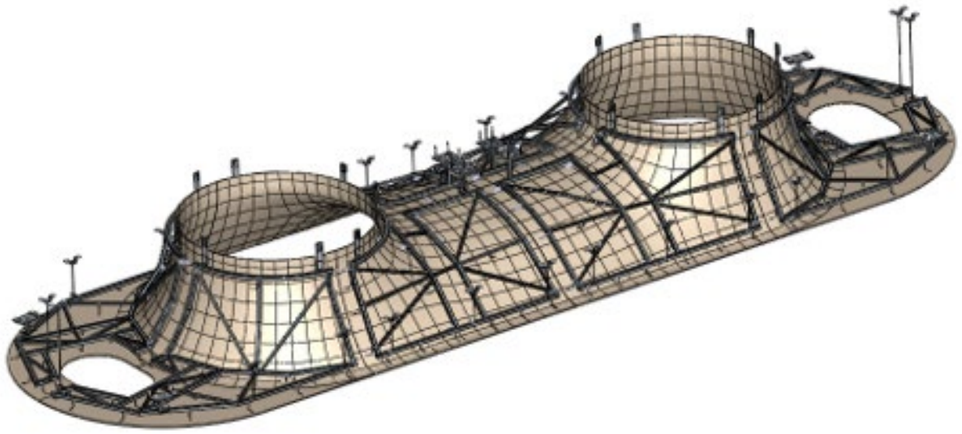
Full Detailed Model

Designed to be Manufactured

Easy & Effective installation

Final Dome Installed

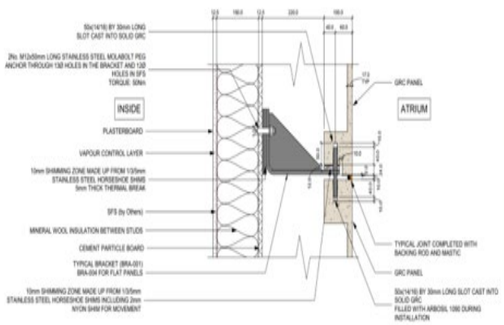
2.3 Whiteleys - GRC Cladding & Façade Design



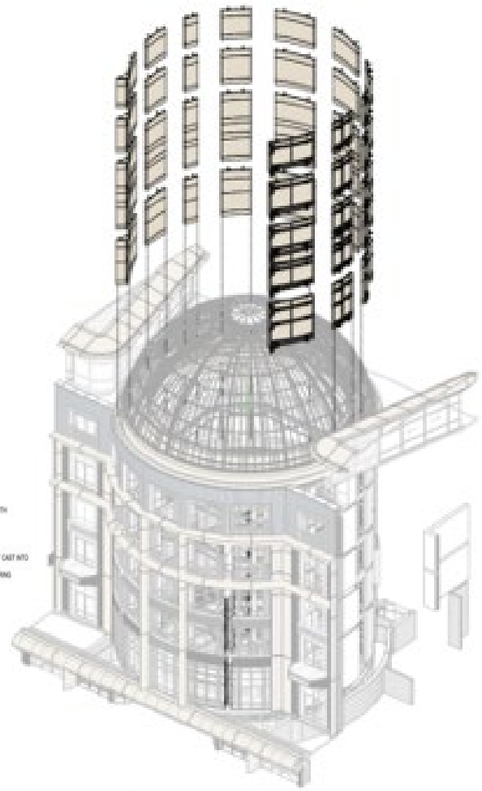
Full Detailed Model

Designed to be Manufactured

Manufactured Panel



GRC Design Coordinated with Facade Elements



GRC Atrium Panels

Render of Atrium Panels

Atrium Panels

2.4 Northern Line Battersea and Nine Elms Stations - GRC Cladding

Project Summary

Client: LUL
Our Partner: GRCUK
Main Contractor: FLO
Construction Value: £1 billion
Status: Open to the public

How we added Value:

- 100% digital delivery to the client with a direct model link from CAD to the CAM manufacturing process
- Full coordination and collaboration between all packages in Projectwise
- High degree of system repeatability ensuring precise manufacturing tolerances with flexibility to accommodate adjustment and differential movements

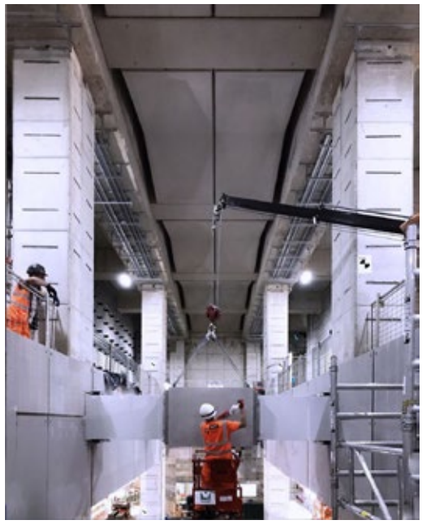
GRC design development for London underground

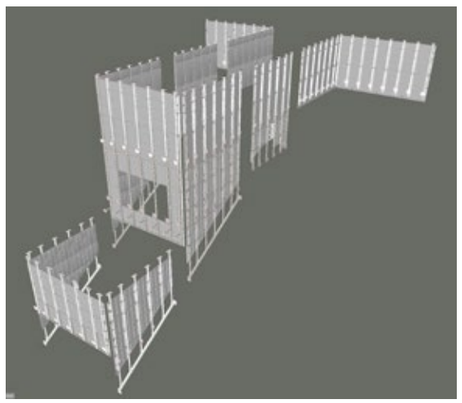
Bryden Wood have been appointed to develop the GRC internal cladding and supportive steel for the new Battersea and Nine Elms stations of the Northern Line Extension development. Working closely with all stakeholders including London Underground and FLO, Bryden Wood have developed the station GRC cladding concepts into repeatable systems, ensuring high manufacturing & installation accuracy, individually de-mountable panels for access and maintenance, panel adjustability and supportive steelwork to accommodate the potential differential movement in the superstructure.

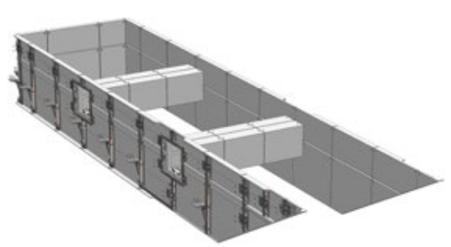
Developed design information is delivered to the client 100% digitally and is processed directly from the 3D CAD data to the CAM manufacturing process without the production of drawings or additional intermediary process. This workflow guarantees the manufactured products geometric details are precisely as designed without compromise.

All packages including the GRC are coordinated in Projectwise, a centralised data management and 3D coordination system, allowing coordination and collaboration between stage 4 developed designs throughout the entire station box.

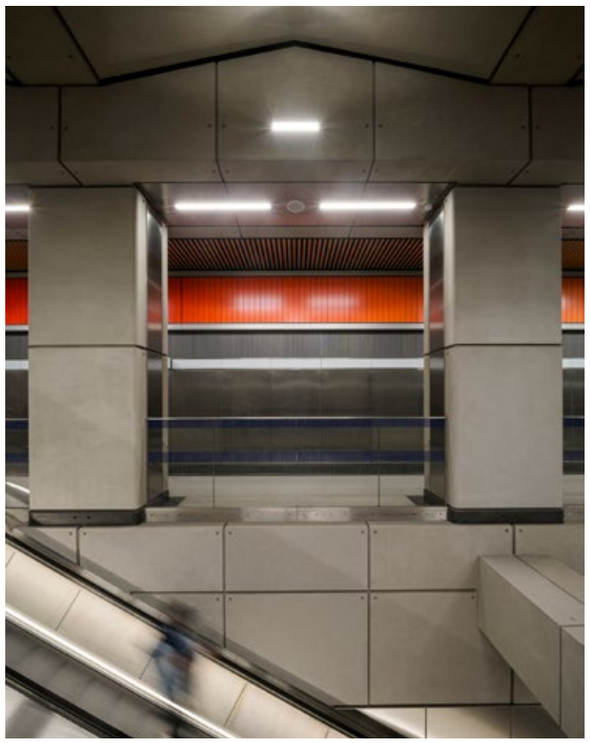
3D point cloud scans of the entire station have enabled Bryden Wood to design to real as built superstructure positions, reducing the need for fully adjustable system and material use. Early in the design period Bryden Wood worked collaboratively with the manufacturing and installation contractors (GRCUK/Vetter) incorporating design decisions that aid in the handling and installation of the GRC panels and supportive steel system.

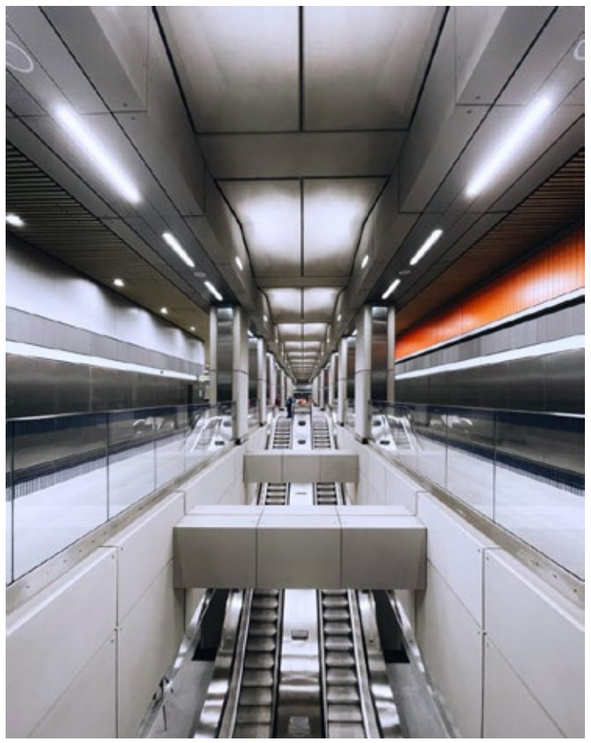


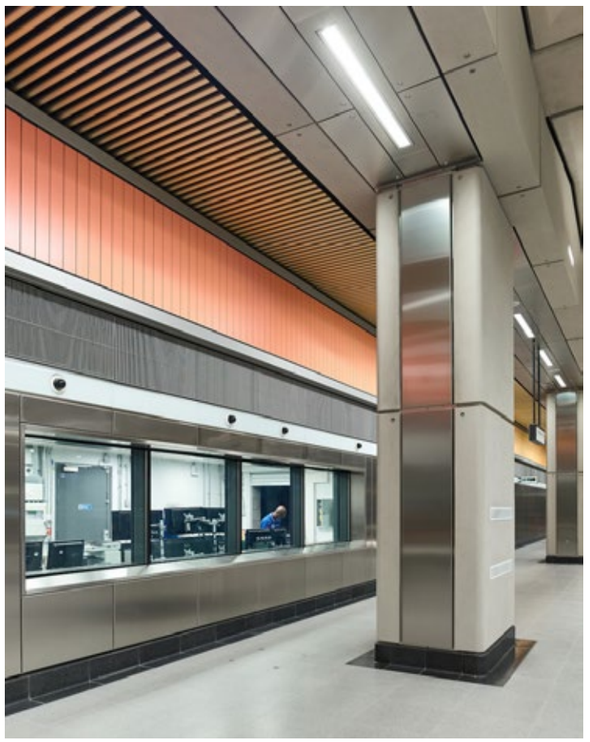


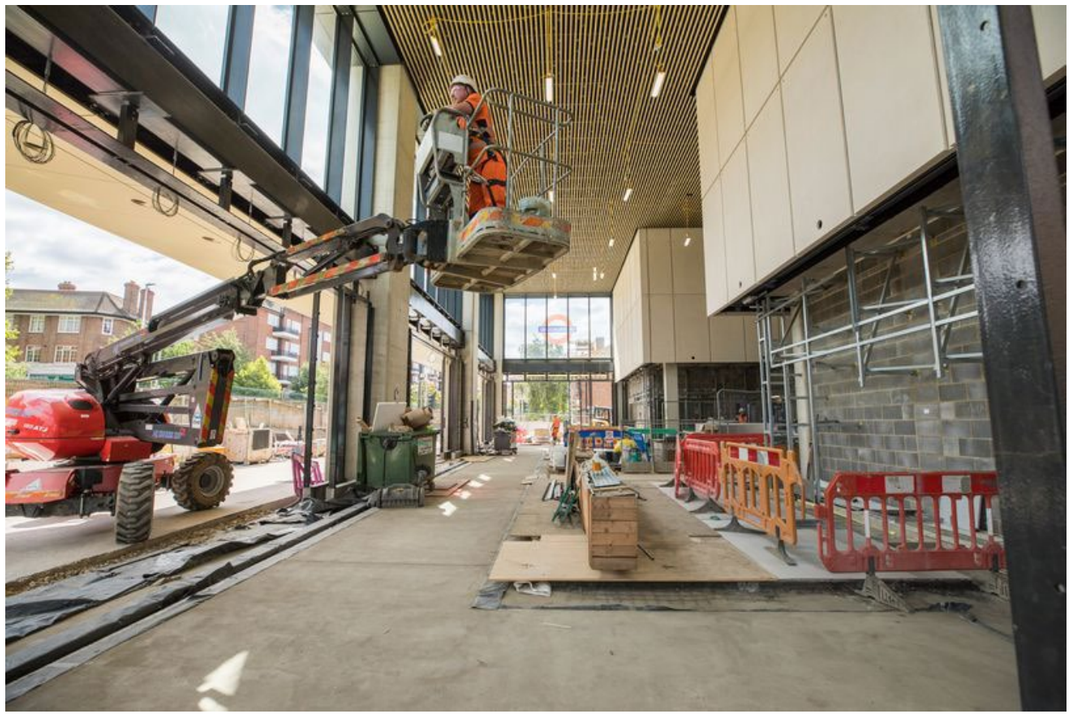


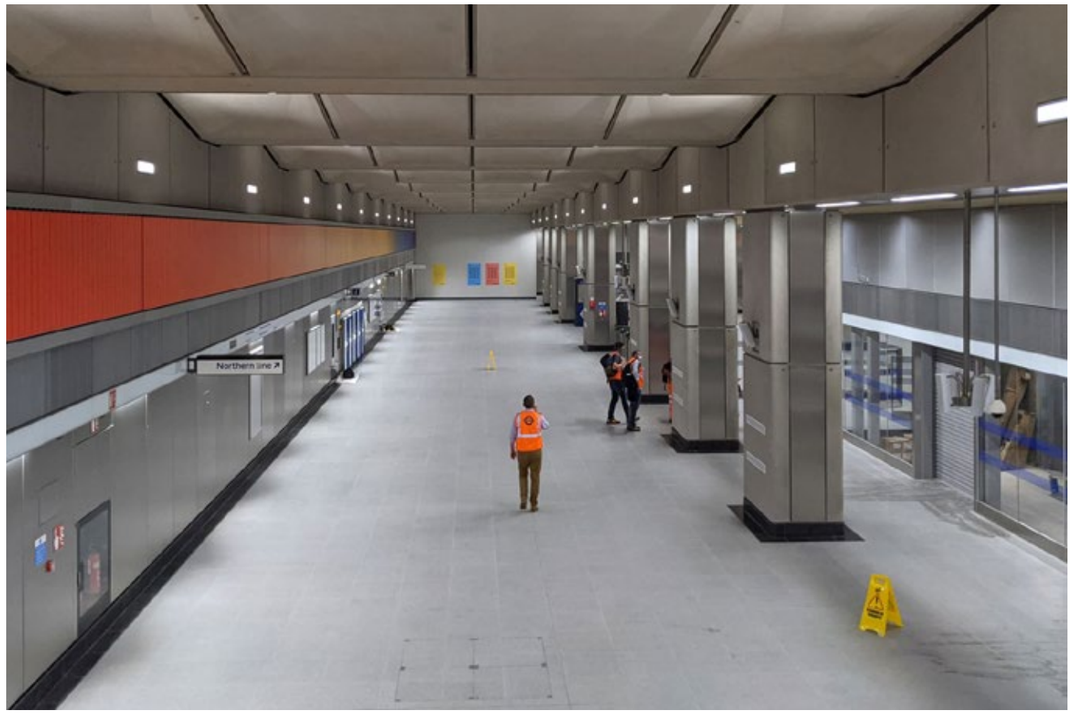
2.4 Northern Line Battersea and Nine Elms - GRC Cladding



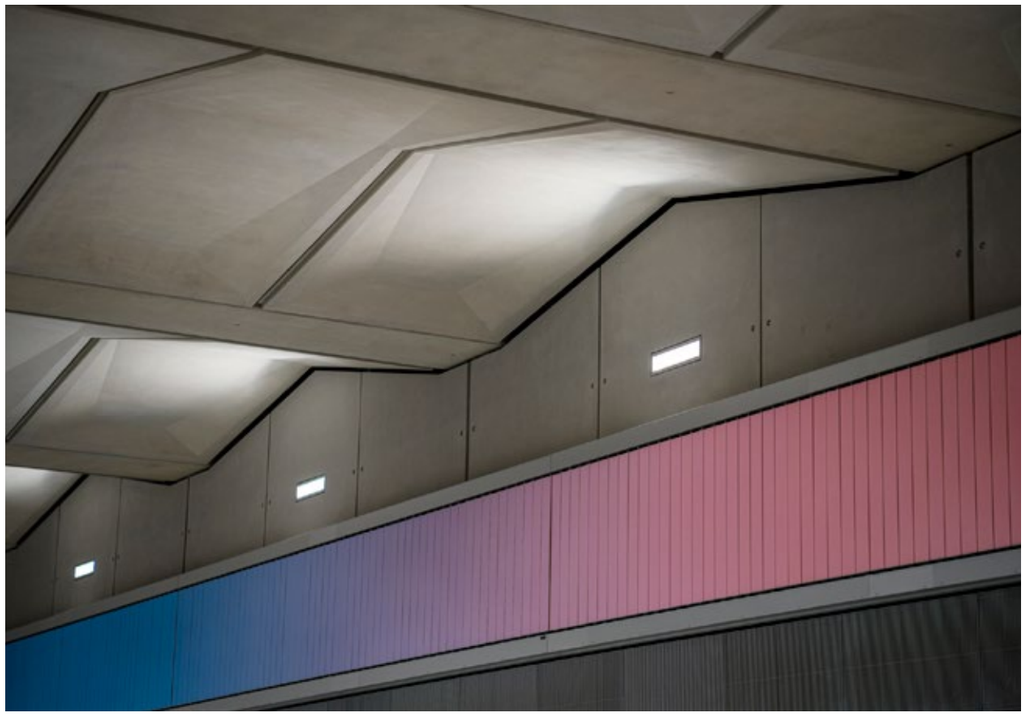


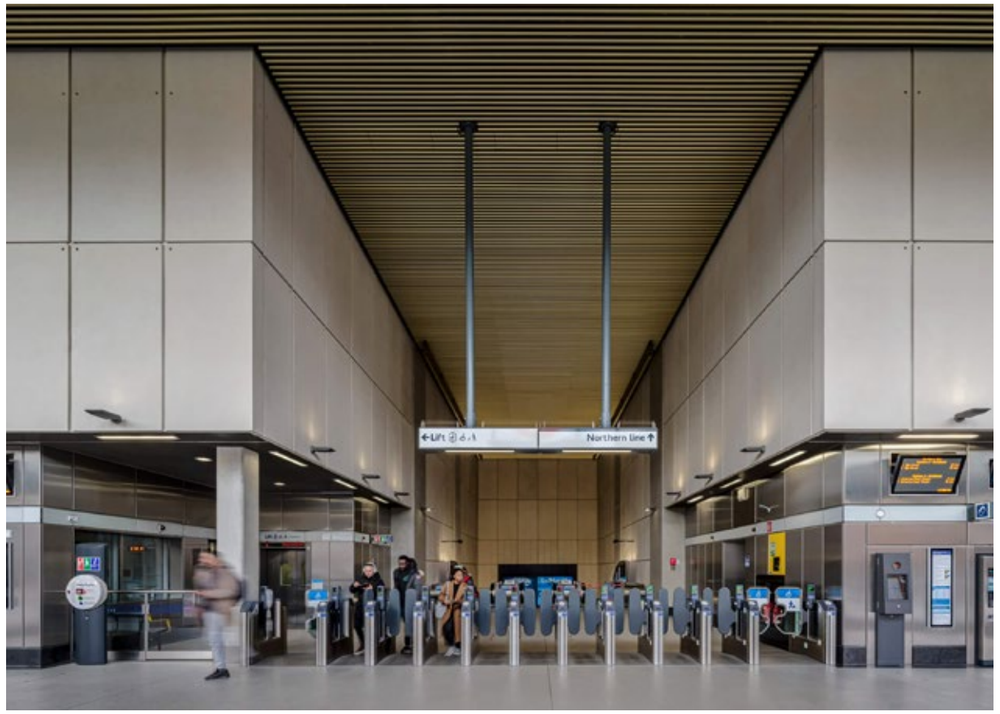






2.4 Northern Line Battersea and Nine Elms - GRC Cladding





2.5 Southbank Place - Precast Cladding with Integrated Windows

Design verification and factory QA

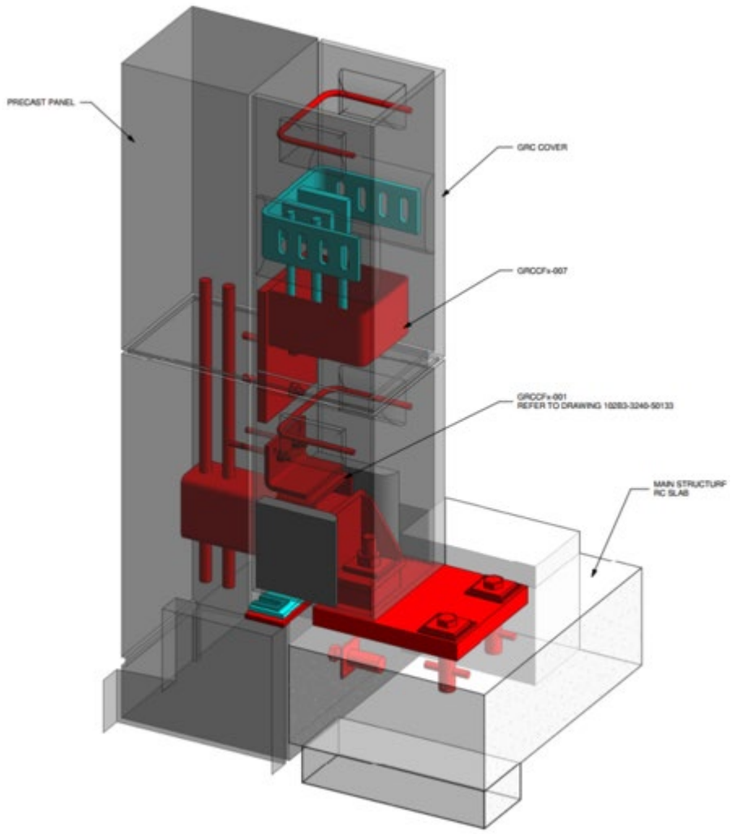
The following studies were undertaken during the design, fabrication and installation of Southbank Place. The images show the process used to confirm calculations that show potential deformation of the panels during stages of construction, assembly and installation.

Calculated deformations were confirmed with as-built point cloud scans of the unitised products, ensuring glazing would fit and allow for future thermal movements. This therefore minimises any waste in the factory and ensures installation rates on site can be met.

The design allows for all main stages during casting, demoulding, storage, transport and install on site - this design is fully aligned with the factory and installation process. Bryden Wood and Explore have built in an automatic load and QA check by considering strength gain of concrete and acting loads as function of time.

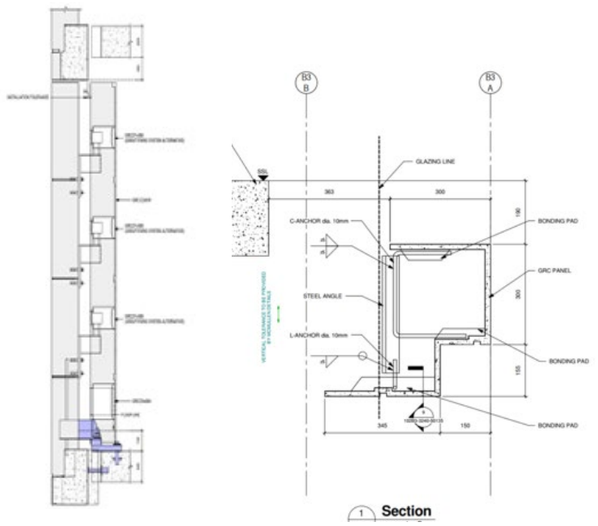
By choosing the correct timing, it ensures that the initial lift is the most critical time in the design life of a panel.

This reduces waste in the factory and ensures only cracktested panels are delivered to site.



3D Detail illustrating structural connections. Southbank Place

Full scale GRC mock up is is built to test compression strength



GRC panel design detail. Southbank Place

‘We are proud to have been part of such a complex and high profile project and look forward to continuing to deliver such quality and efficiency in the future’

2.6 Edinburgh St James Centre - GRC

Project Summary

Client: Nuveen Real Estate
Our Partners: Laing O' Rourke, Expanded/ExpLORe
Construction Value: £1bn
Status: Complete

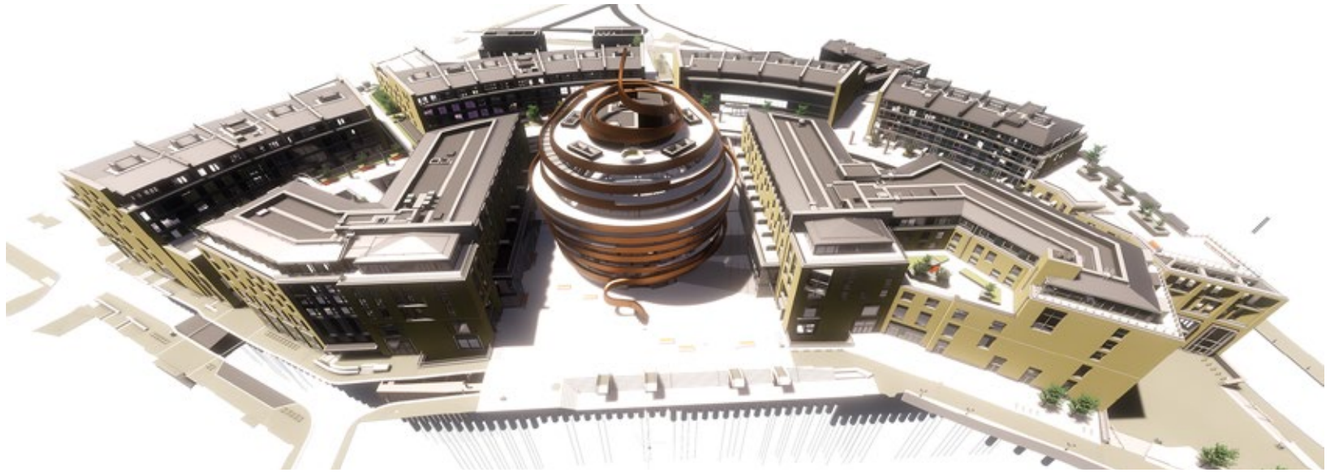
How we added Value:

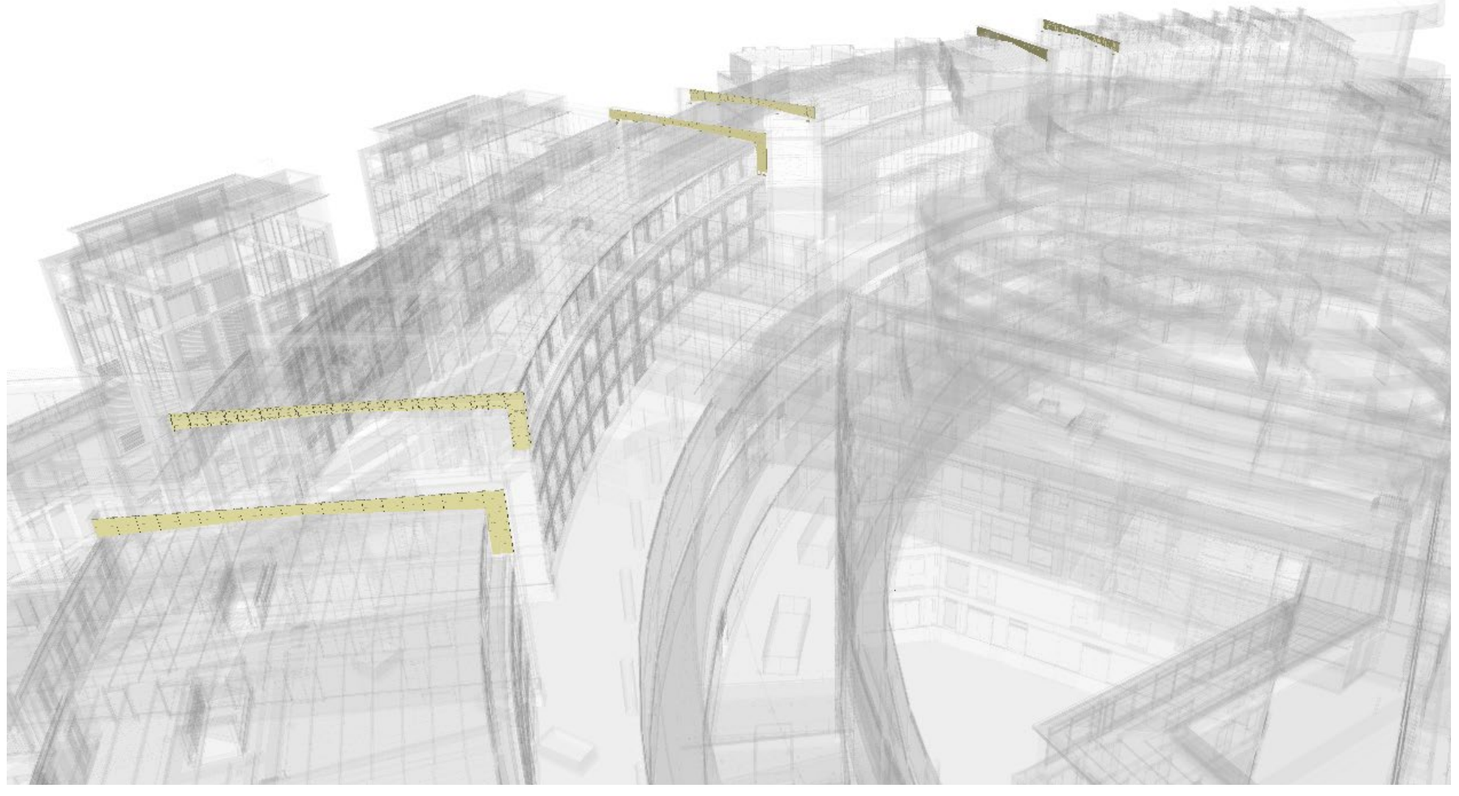
- BWT produced cutting schedules directly from a digital model, applying 4D BIM for works scheduling and 5D BIM for cost integration;
- GRC Gable Ends were optimised in terms of layout and structural behaviour to cover the maximum area with the less panels.

Optimised GRC Gable Ends

The landmark Edinburgh St James Centre demonstrates BWT's capability in providing specialist facade design and detailing services. This is a live project which also uses a natural stone facade. BWT are providing structural engineering design for all precast panels including the design of bracket connections as well as all stone design and detailing (partly handset and partly panelised).

The gable end locations consist of 1m wide panels with various angle on their lower edges to align with the sloped roof. Panels are separated by 20mm vertical shadow gaps, with dummy 20mm shadow gaps running horizontal.

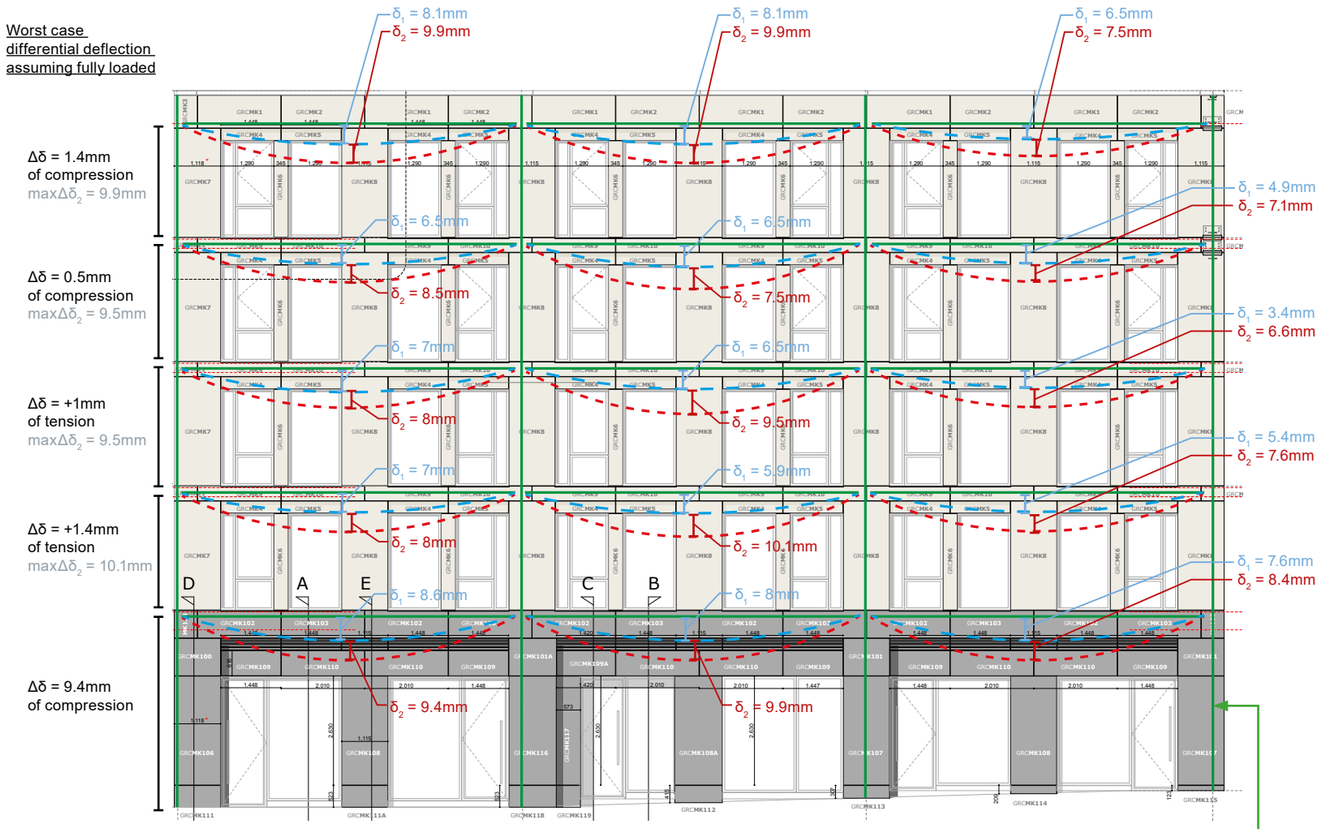


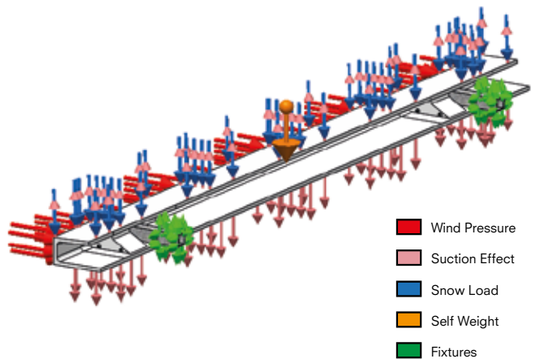


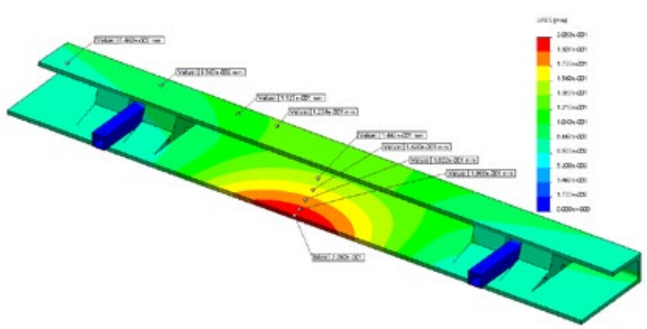
2.7 GRC Remedial Works Analysis

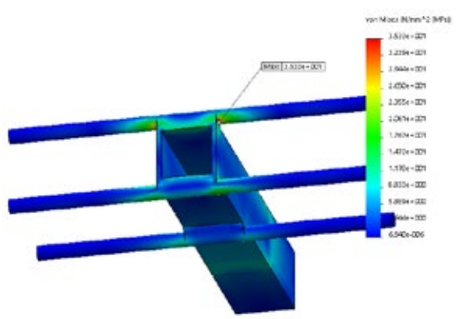
Bryden Wood has conducted structural reviews of projects potentially requiring remedial works to assess structral non-compliance and to identify and develop solutions.

- Review of design documentation
- Structural assessment for Reliability and Availability of Details, Compliance, and Risk for GRC panels
- Visual Inspection
- Identification of panels that for testing to gain additional insight into the structural integrity of the GRC and general workmanship
- Structural Assessment of test results and recommendation based on the review of evidence
- Design of replacement panels
- Development of other remediation solutions









3.0 Other relevant Case Studies

3.1 Google Headquarters - Precast Concrete Cladding and Structure

Project Summary

Client: Google
Our Partners: Laing O' Rourke, Expanded/ExpLORe
Construction Value: £1 billion
Status: Under Construction
Disciplines: Structural | Architectural

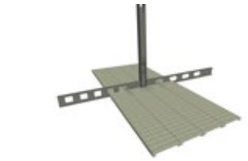
How we added Value:

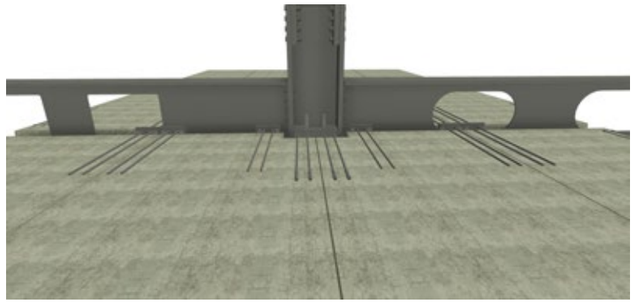
- Rationalisation of the design to afford maximum repeatability and quality within the factory.
- Load testing for full optimisation in design.

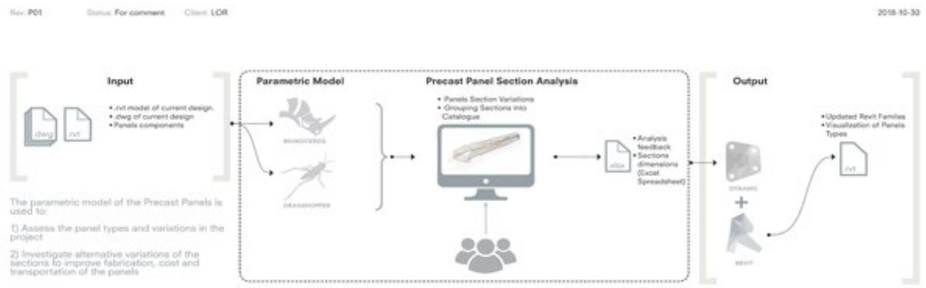
Precast Concrete Cladding System

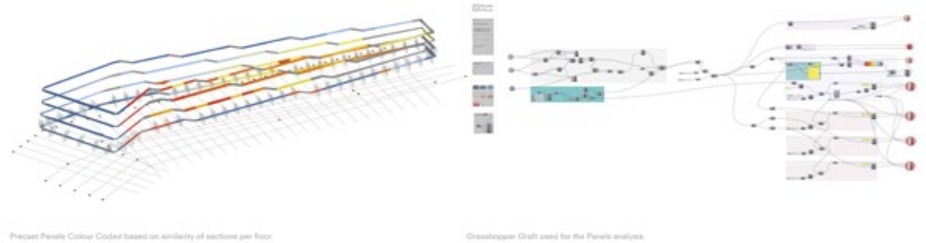
BWT is working on the Google Headquarters London project, a flagship development for the King's Cross area and the first wholly owned and designed Google building outside the US. The building will comprise more than 1 million square feet and was designed by Heatherwick Studio and Bjarke Ingels Group (BIG). Together with the current Google building at 6 Pancras Square and an upcoming third building, will provide office accommodation for up to 7,000 Google employees. The development is set to become a key feature of the emerging King's Cross Knowledge Quarter and a new economic driver for London.

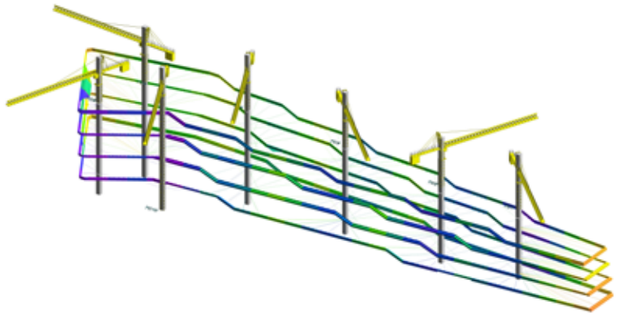
BWT are currently working with Expanded and Explore Manufacturing on the Google Headquarters. We are the engineers for an extremely challenging precast package including exposed and bespoke shape planks, feature stairs, feature elements such as the "Cockpit" and other special areas. Some elements are load tested for full optimisation and we are also developing interface details from precast to other packages; in addition to the precast cladding package under a separate contract.











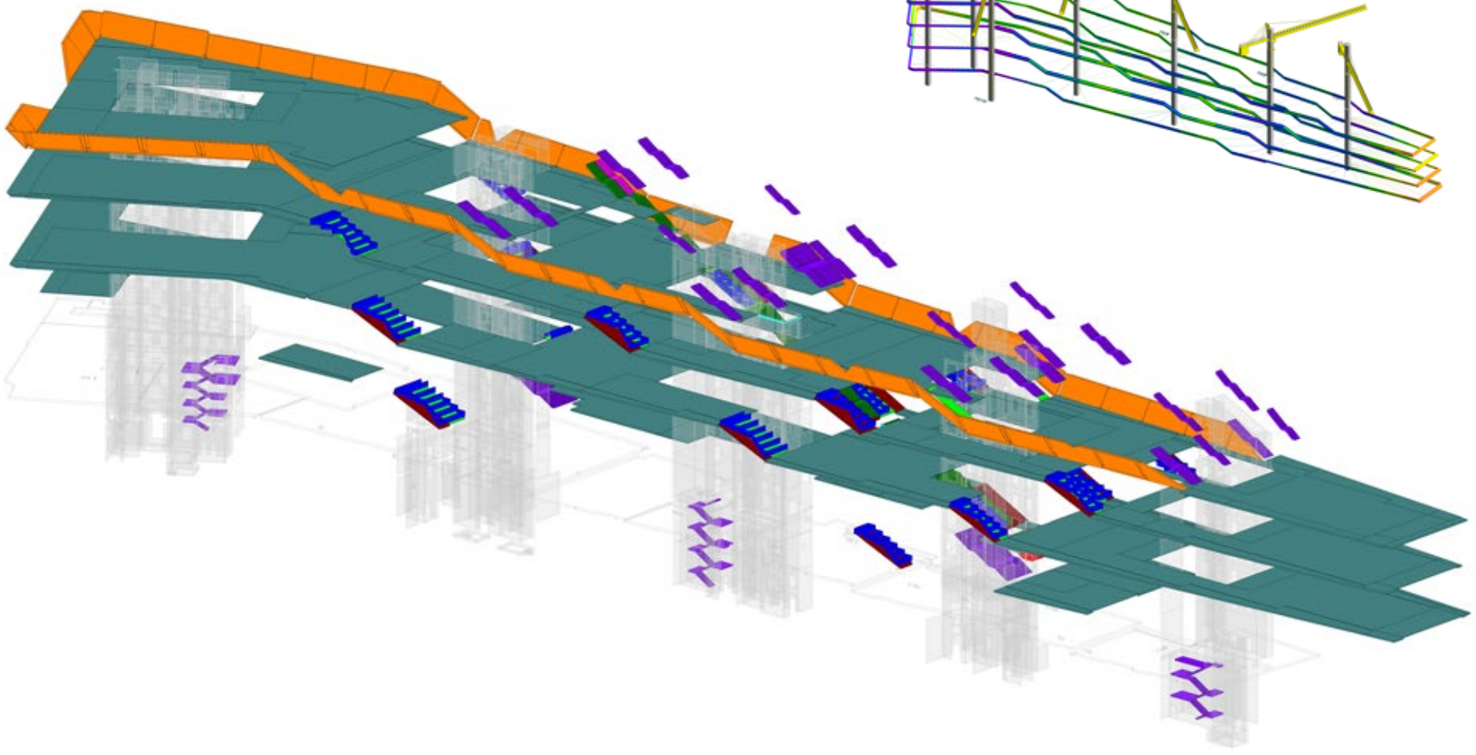
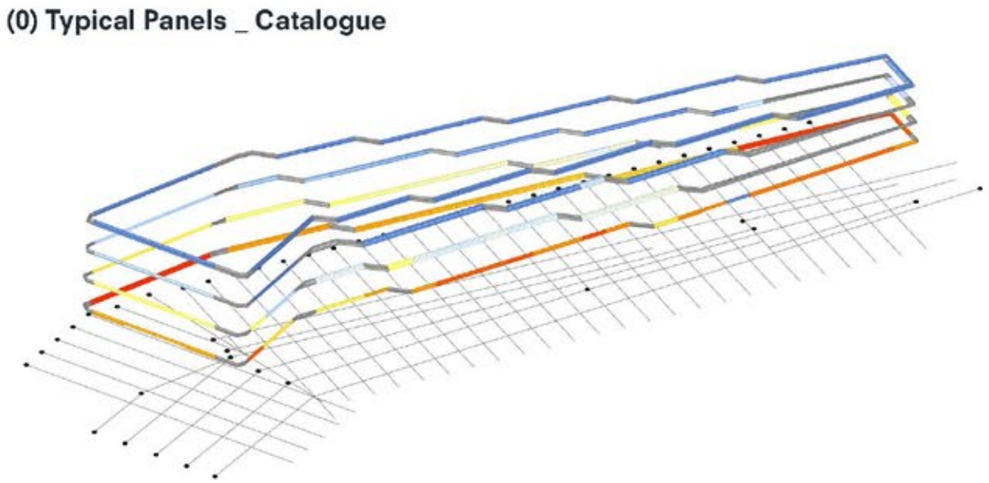
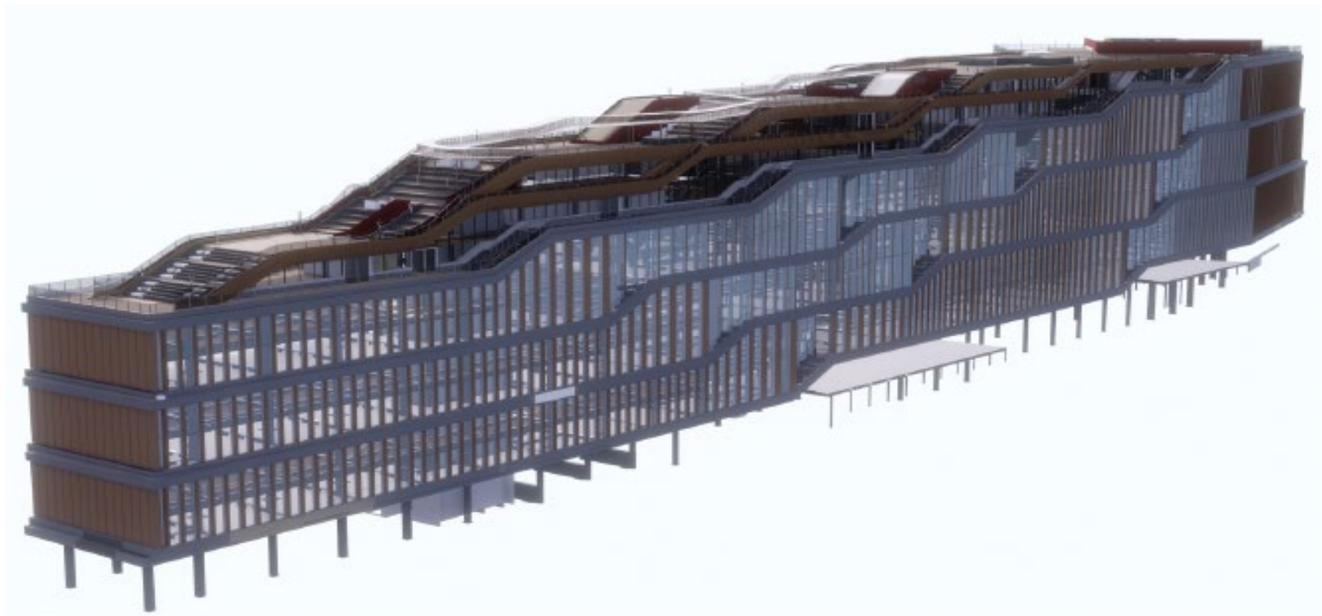
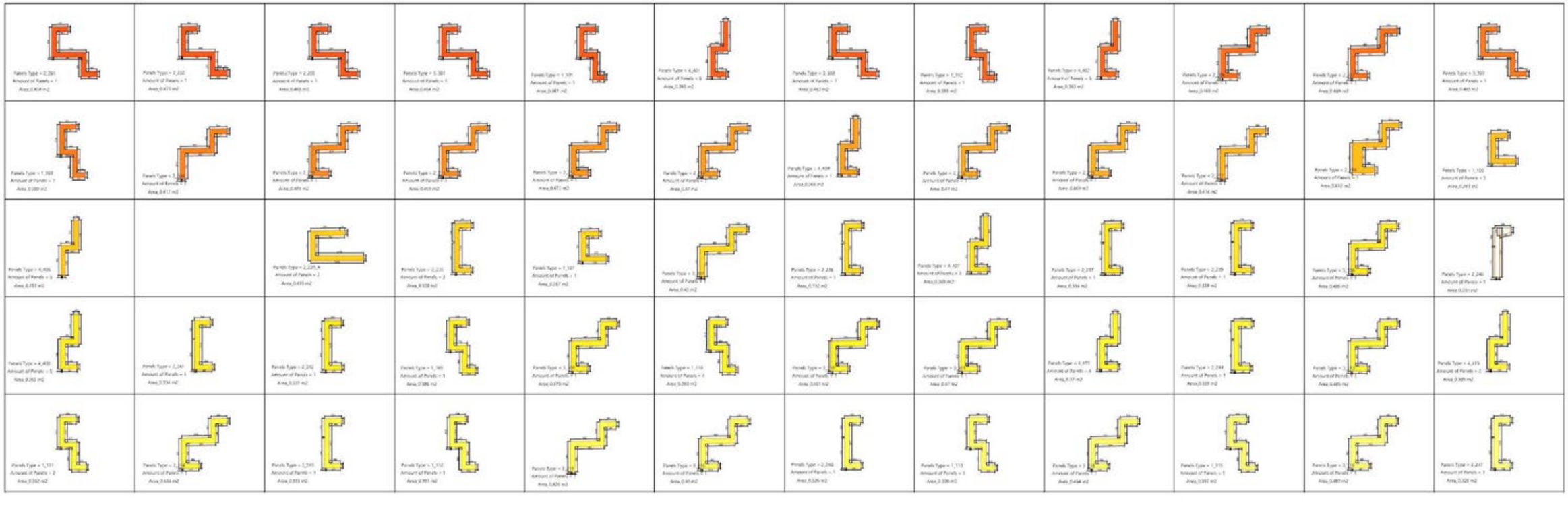


Image taken from Google or alternative source

3.1 Google Headquarters - Precast Concrete Cladding and Structure







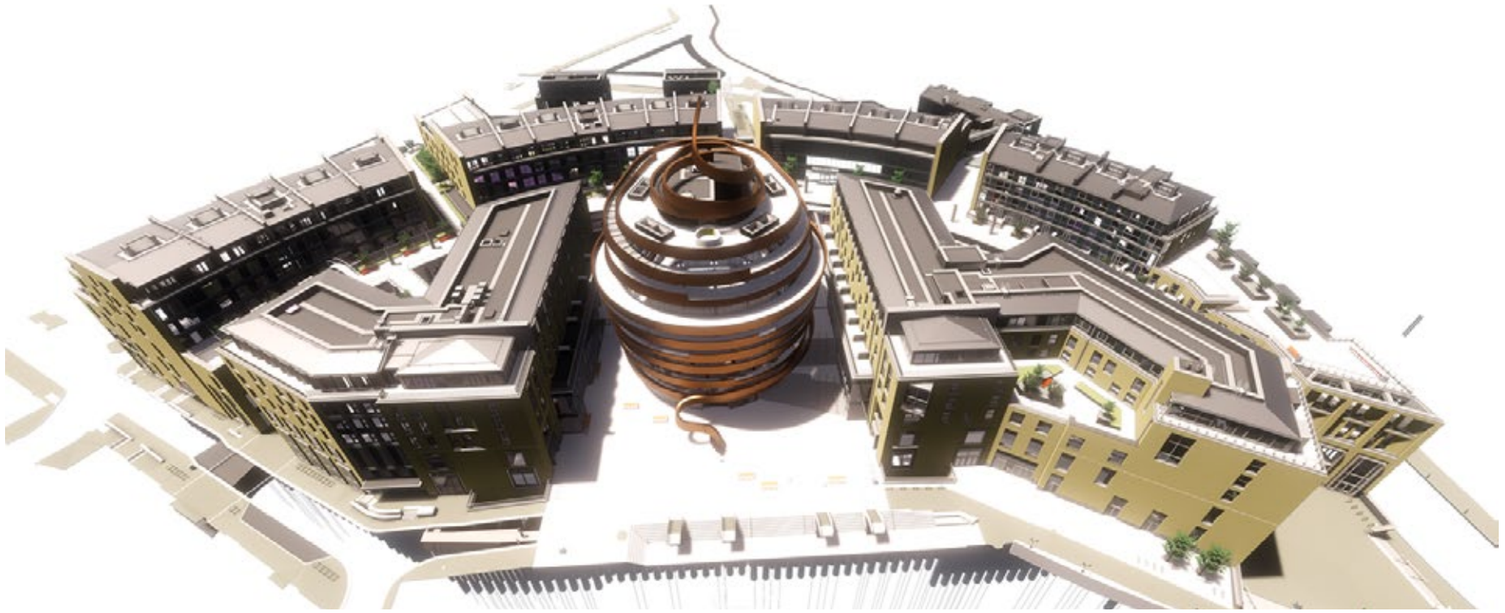
3.2 Edinburgh St James Centre - Handset Stone Cladding and Façade Engineering

Project Summary

Client: Nuveen Real Estate
Our Partners: Laing O' Rourke, Expanded/ExpLORe
Construction Value: £1bn
Status: Complete

How we added Value:

- BWT produced cutting schedules directly from a digital model, applying 4D BIM for works scheduling and 5D BIM for cost integration;
- All façade panels were modelled to a fabrication level of detail and information, fully coordinated with our project partners and scheduled directly from the model for procurement
- BWT used bespoke Dynamo scripting to automate the modelling process for stones, placing 19,000 individual stone pieces using predefined rules based on the architectural concept



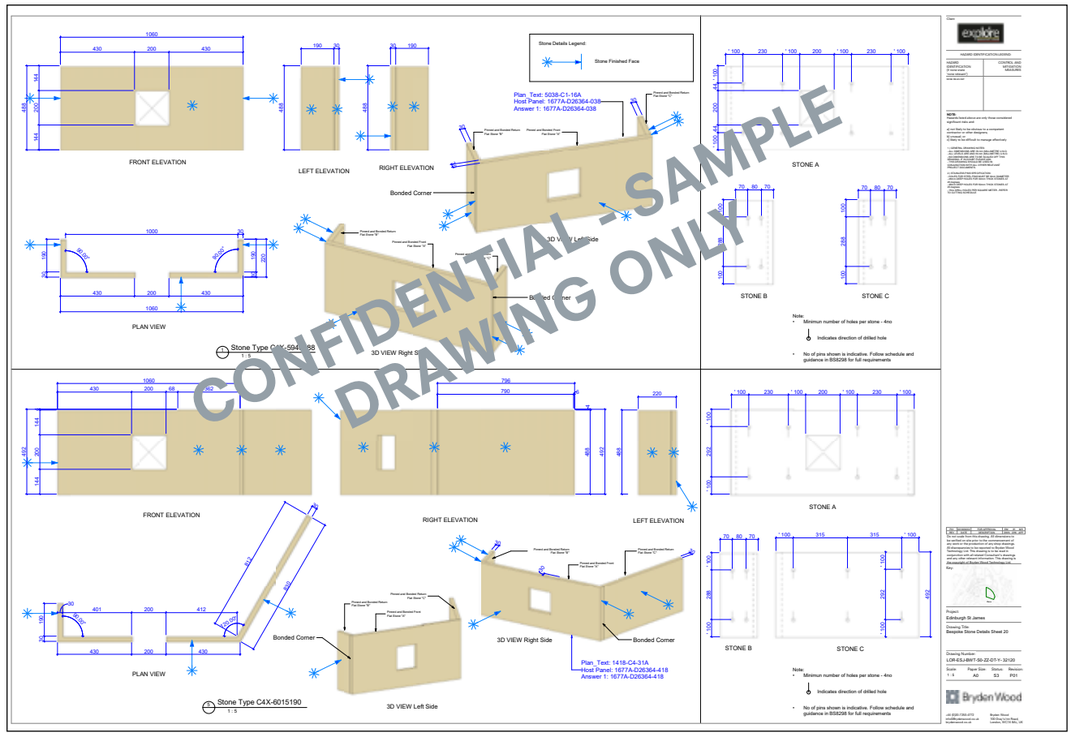
Advanced digital workflows for façade panel fabrication and installation

The landmark Edinburgh St James Centre demonstrates BWT's capability in providing specialist facade design and detailing services. This is a live project which also uses a natural stone facade. BWT are providing structural engineering design for all precast panels including the design of bracket connections as well as all stone design and detailing (partly handset and partly panelised).

The stone cladding is quarried in Petersbuch Quarry, Germany and a digital model is used to create the stone cutting schedules. Bryden Wood have modelled and produced quantities with sizes for all the stones that sit in the handset and precast stone finished panels. Stone is used to comply with the planning aspiration to complement the surrounding buildings. Designed by Allan Murray Architects, the 1.7 million sqft Edinburgh St James scheme will see the 1970s shopping centre replaced with 850,000 sqft of retail space, anchored by John Lewis, Edinburgh's first Everyman cinema, the UK's second W Hotel and 150 new homes.

BWT led the interface detailing between the different facade packages and have done all the facade performance engineering and detailing:

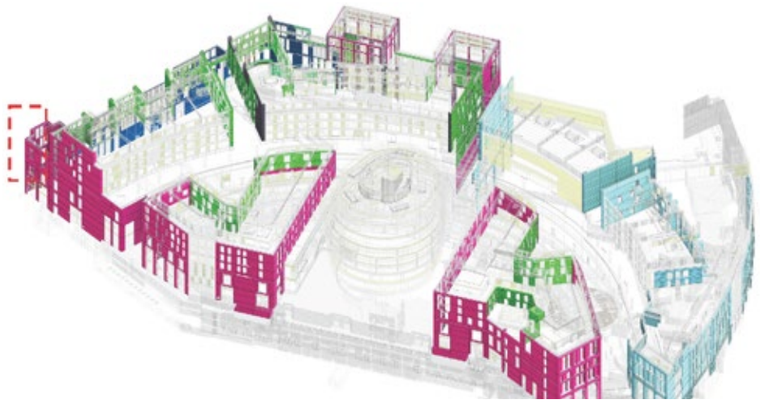
- Structural
- Thermal and Condensation Risk
- Waterproofing
- Air Tightness
- Fire
- Acoustics
- etc.

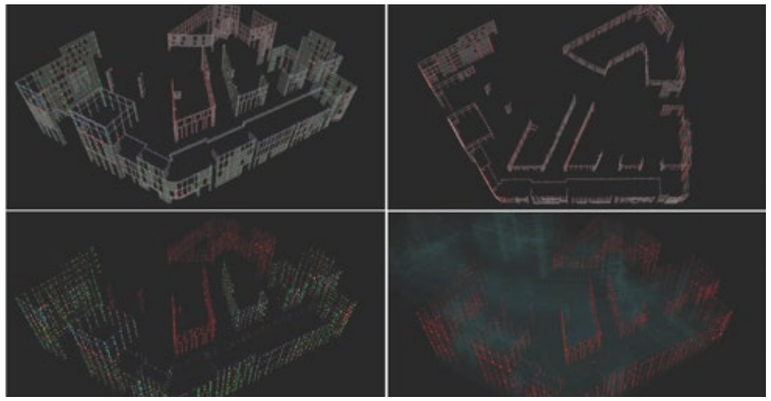


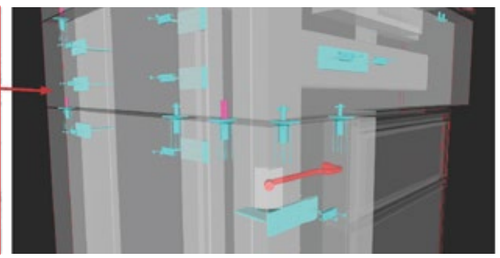
Stone Detailing - Panelised and Handset Stone

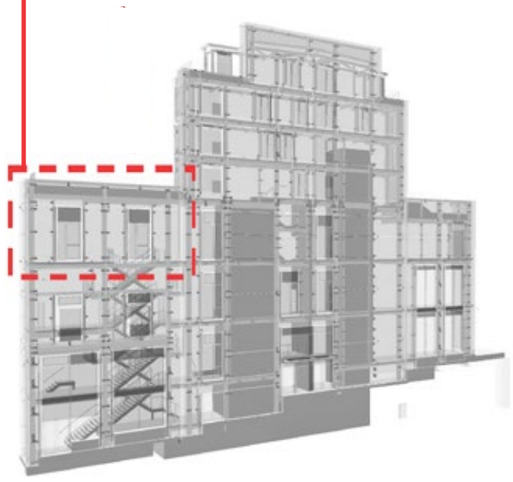
3.2 Edinburgh St James Centre - Handset Stone Cladding and Façade Engineering

Revit / Dynamo super workflow

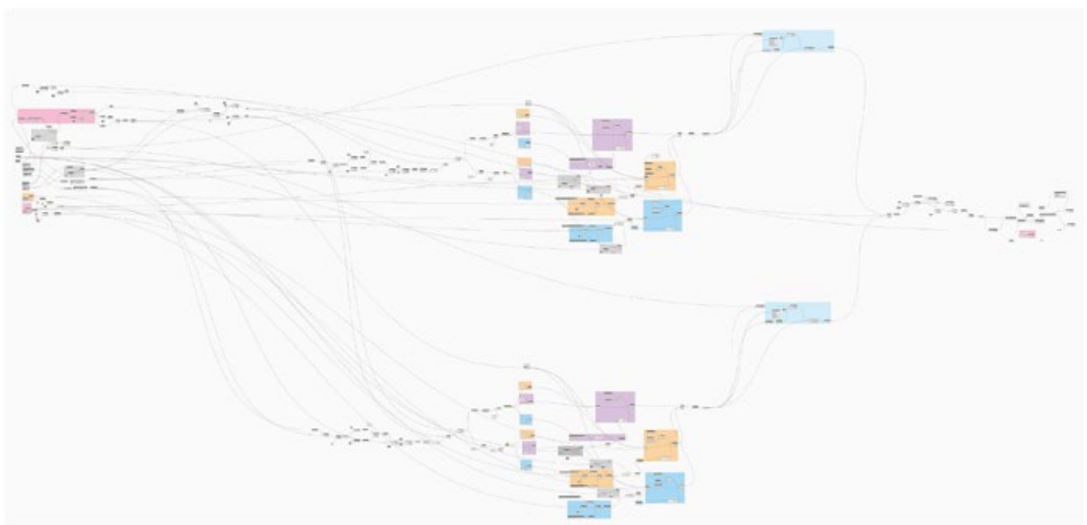






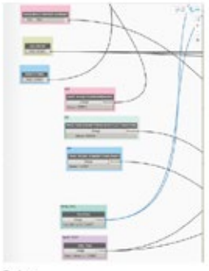


Bespoke Dynamo scripts

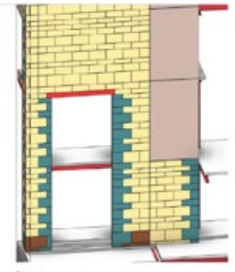


Complex Dynamo Script

1,144	Precast Concrete Panels with Stone
966	Reconstructed Precast Panels
19,000	Pieces of stone in precast panels
540	Tonnes of stone

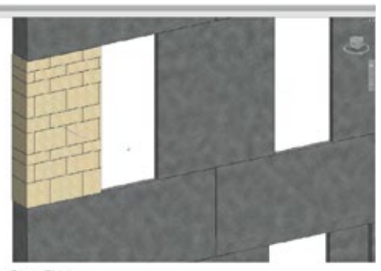


Script



Stones

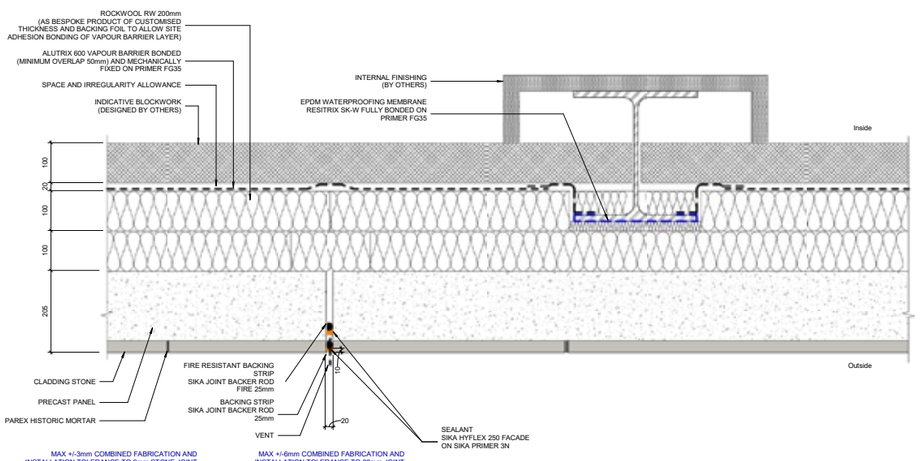
Script

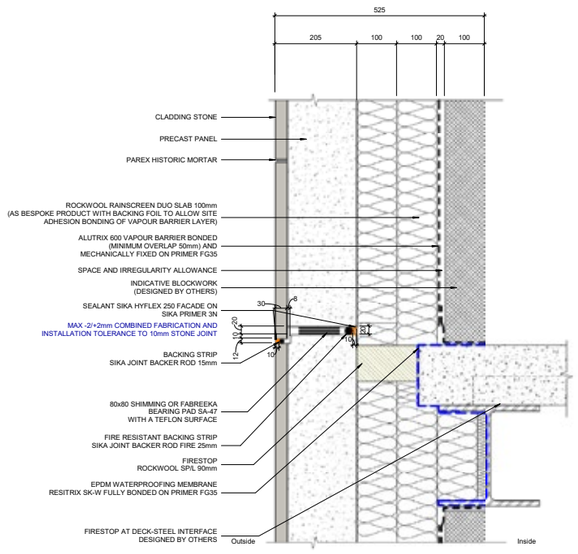


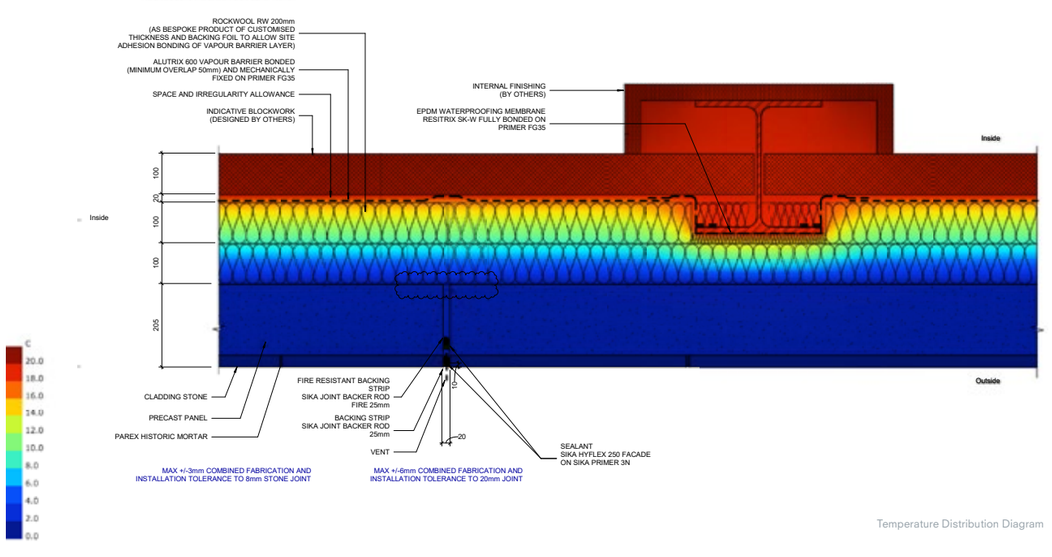
Stones Division

3.2 Edinburgh St James Centre - Handset Stone Cladding and Façade Engineering

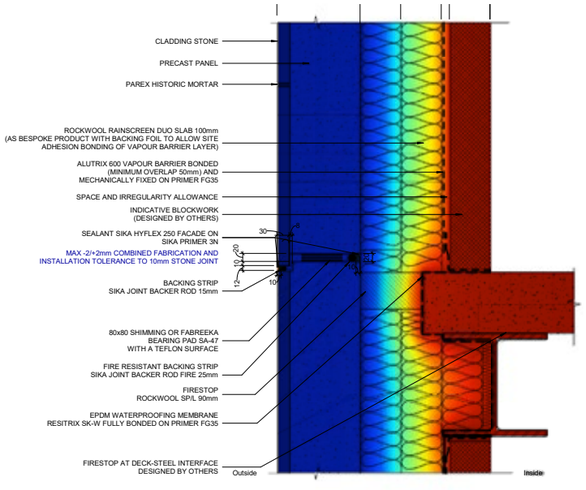
Sample Design Excerpt for details and thermal diagrams







Temperature Distribution Diagram



3.3 Brighton 3Ts Hospital Redevelopment - Precast Concrete Façade

Project Summary

Client: Brighton and Sussex University Hospitals, NHS Trust
Our Partners: Laing O'Rourke
Construction Value: £485m
Status: Under Construction

How we added Value:

- Detailed design, modelling and analysis to ensure feasibility of achieving required façade performance while complying with application standards
- Colour coded and referenced process for following each interface joint line resulted in a more complete and easy-to-reference detail package

Façade engineering for major hospital upgrade

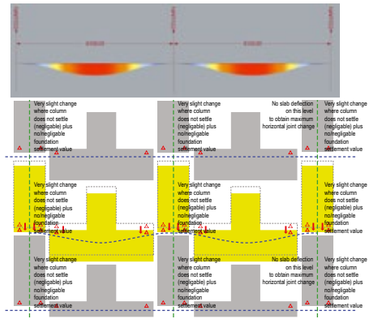
Bryden Wood is involved in the £485 million development of Royal Sussex County Hospital in Brighton to replace all the buildings on the front of the main hospital site. More specifically, Bryden Wood is involved not only in the precast concrete façade's performance in terms of weather tightness, thermal comfort, fire safety, acoustic integrity, end-user wellbeing, and movement tolerances but also the solar and coastal environmental effects.

Through working with LOR, Expanded, and GRC UK, Bryden Wood's role has provided a vital link in ensuring that the performance of the precast façade is not just theoretically upheld by international and national standards but also pragmatically feasible on-site by using both finite element analysis and construction level interface detailing with the other work packages (curtain walling, windows, doors, internal lining, roofing).

As part of this project Bryden Wood developed a process of following each individual interface joint line through panels, glazing etc. These were then colour coded and referenced to provide all precast and interface details on site.

3.3 Brighton 3Ts Hospital Redevelopment - Precast Concrete Façade

Scenario 1: Slab Deflection Only

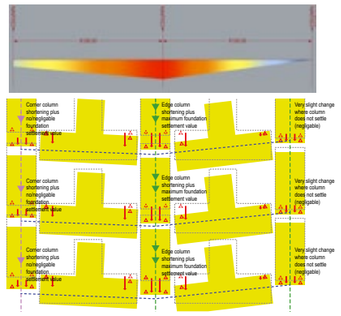


In this scenario, all columns have very slight shortening and is deemed negligable.

Max. joint expansion: 20mm to 23.4mm (17%) ie. 3.4mm expansion

Max. joint compression: 20mm to 16.6mm (17%) ie. 3.4mm compression

Scenario 2: Column + Pile Settlement Only



In this scenario:
Left column uses a corner column shortening value plus no foundation settlement differential value.
Middle column uses an edge column shortening value plus maximum foundation settlement differential value.
Right column has very little shortening/negligable value plus no foundation settlement differential value (to allow for a worst case scenario).

The scenario is categorized into left and right situations:
Left: Max. corner column shortening with no foundation settlement compared to max. edge column shortening with max. foundation settlement differential value
Right: Edge column max. shortening with max. foundation settlement differential value compared to column with very slight/negligable shortening with no foundation settlement differential value

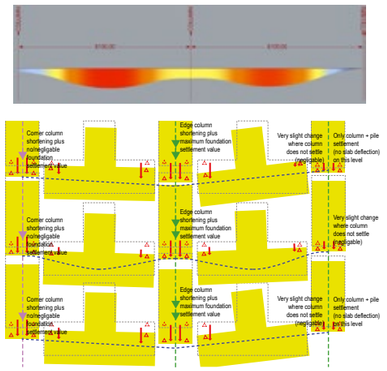
Left side:
Max. joint expansion on the left side:
20mm to 21.1mm (5.5%) ie. 1.1mm expansion

Max. joint compression on the left side:
20mm to 18.9mm (5.5%) ie. 1.1mm compression.

Right side:
Max. joint expansion on the right side:
20mm to 21.7mm (8.5%) ie. 1.7mm

Max. joint compression on the right side:
20mm to 18.3mm (8.5%) ie. 1.7mm compression

Scenario 3: Column plus pile settlement together with slab deflection



In this scenario:
Left column uses a corner column shortening value plus no foundation settlement differential value.
Middle column uses an edge column shortening value plus maximum foundation settlement differential value.
Right column has very little shortening/negligable value plus no foundation settlement differential value (to allow for a worst case scenario).
Slabs at the middle level incorporate max. slab deflection value.
Slabs at the level above and below the middle level have very little/negligable slab deflection value.

The scenario is categorized into left and right situations:
Left: Max. corner column shortening with no foundation settlement compared to max. edge column shortening with max. foundation settlement differential value
Right: Edge column max. shortening with max. foundation settlement differential value compared to column with very slight/negligable shortening with no foundation settlement differential value

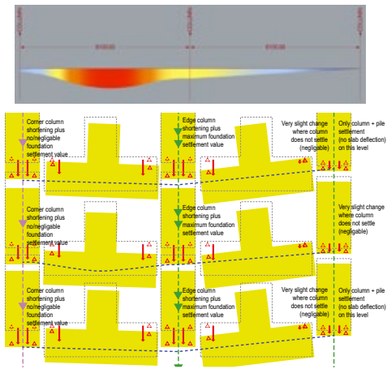
Left side:
Max. joint expansion on the left side:
20mm to 22.2mm (11%) ie. 2.2mm expansion

Max. joint compression on the left side:
20mm to 17.8mm (11%) ie. 2.2mm compression.

Right side:
Max. joint expansion on the right side:
20mm to 22.8mm (14%) ie. 2.8mm

Max. joint compression on the right side:
20mm to 17.2mm (14%) ie. 2.8mm compression

Scenario 4: Column plus pile settlement together with slab deflection isolated to one side



In this scenario:
Left column uses a corner column shortening value plus no foundation settlement differential value.
Middle column uses an edge column shortening value plus maximum foundation settlement differential value.
Right column has very little shortening/negligable value plus no foundation settlement differential value (to allow for a worst case scenario).
Slabs at the middle level incorporate max. slab deflection value on the left side only.
Slabs at the level above and below the middle level have very little/negligable slab deflection value.

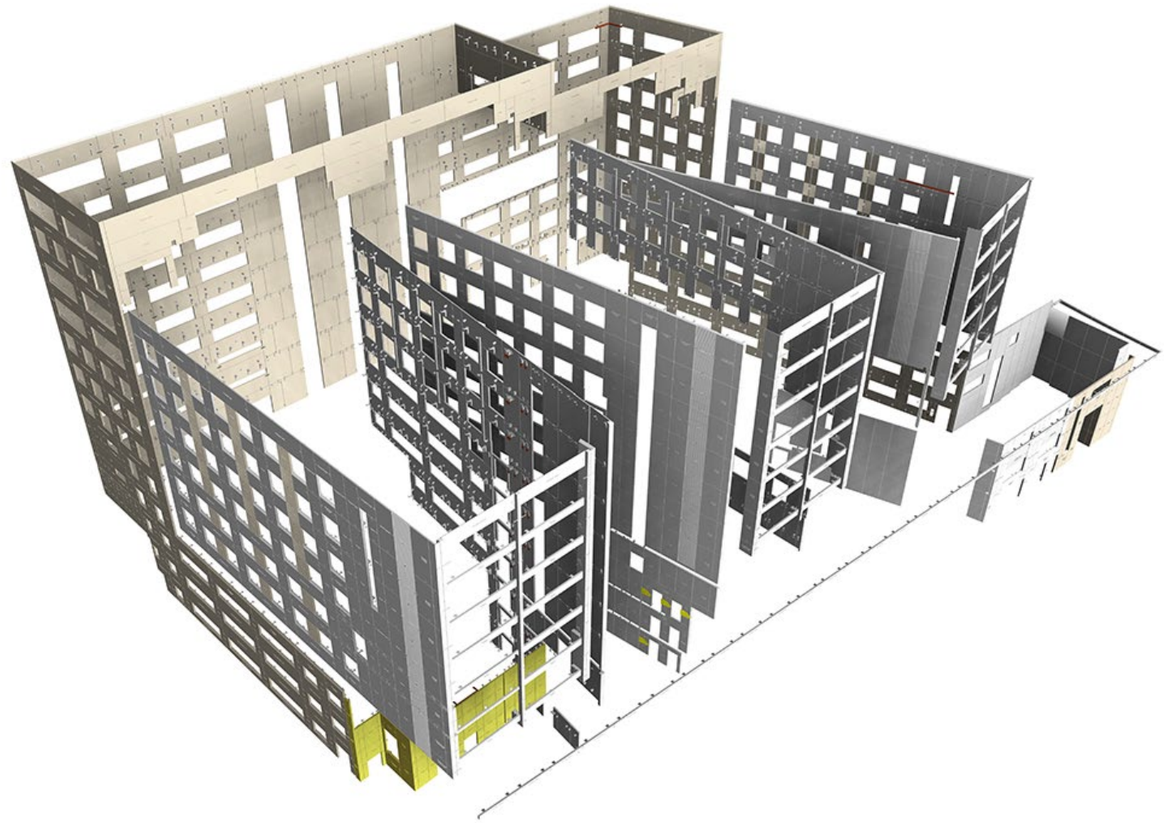
The scenario is categorized into left and right situations:
Left: Max. corner column shortening with no foundation settlement compared to max. edge column shortening with max. foundation settlement differential value
Right: Edge column max. shortening with max. foundation settlement differential value compared to column with very slight/negligable shortening with no foundation settlement differential value

Left side:
Max. joint expansion on the left side:
20mm to 22.2mm (11%) ie. 2.2mm expansion

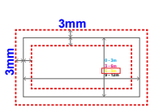
Max. joint compression on the left side:
20mm to 17.8mm (11%) ie. 2.2mm compression.

Right side:
Max. joint expansion on the right side:
20mm to 21.7mm (8.5%) ie. 1.7mm

Max. joint compression on the right side:
20mm to 18.3mm (8.5%) ie. 1.7mm compression

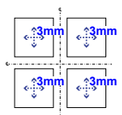


AS DESIGNED JOINT WIDTH



Maximum panel length taken **~8000mm** which has a **reduced 3mm** fabrication tolerance

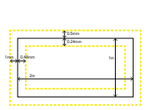
Ⓐ 20 + Ⓑ +3 = 23 − Ⓒ -3 = 17



Reduced installation tolerance of **3mm**

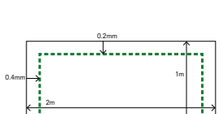
+ Ⓓ +3 = 26 − Ⓔ -3 = 14

Sealant applied here



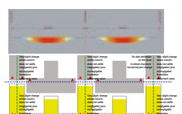
External temperature influences (SW facing - worst case scenario) precast concrete expansion of **0.5mm/m** and contraction of **0.24mm/m**

+ Ⓕ +(0.5 x 8) = +4 − Ⓖ - (0.24 x 8) = -1.92



Precast concrete drying strain which contracts **0.2mm/m**. Do note this is only applied to situations involving panel contraction and not panel expansion as the drying strain occurs over a period of several years.

+ Ⓗ +N/A = +0 − Ⓘ - (0.2 x 8) = -1.6



Structural movment scenario 1 (slab deflection only - worst case scenario) of **3.4mm** for both joint expansion and contraction

+ Ⓙ +3.4 − Ⓚ - 3.4

The above influences brings about the following key scenarios relating to sealant compatibility:

1. Joint of **14mm reduced** to **7.1mm** ie. by **6.9mm** or **49%**

Ⓐ + Ⓒ + Ⓔ + Ⓖ + Ⓘ + Ⓚ
20 -3 -3 -1.92 -1.6 -3.4

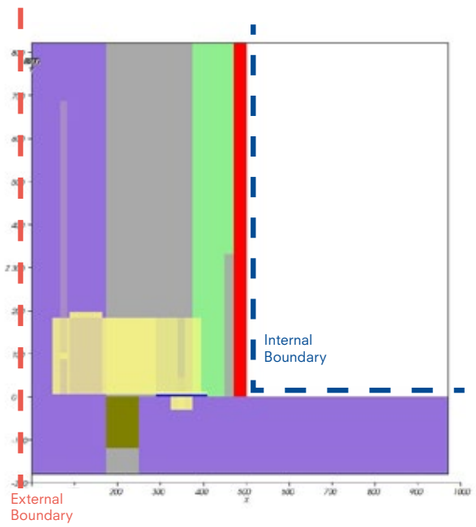
2. Joint of **14mm increased** to **21.4mm** ie. by **7.4mm** or **53%**

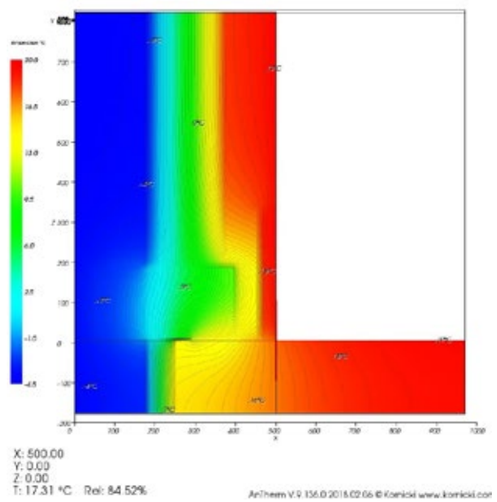
Ⓐ + Ⓒ + Ⓔ + Ⓕ + Ⓗ + Ⓙ
20 -3 -3 +4 +0 +3.4

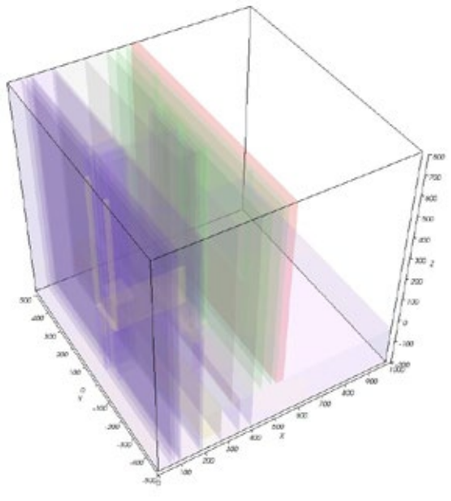
3. Normally not governing but explained here for better understanding: Joint of **26mm increased** to **33.4mm** ie. by **7.4mm** or **~28%**

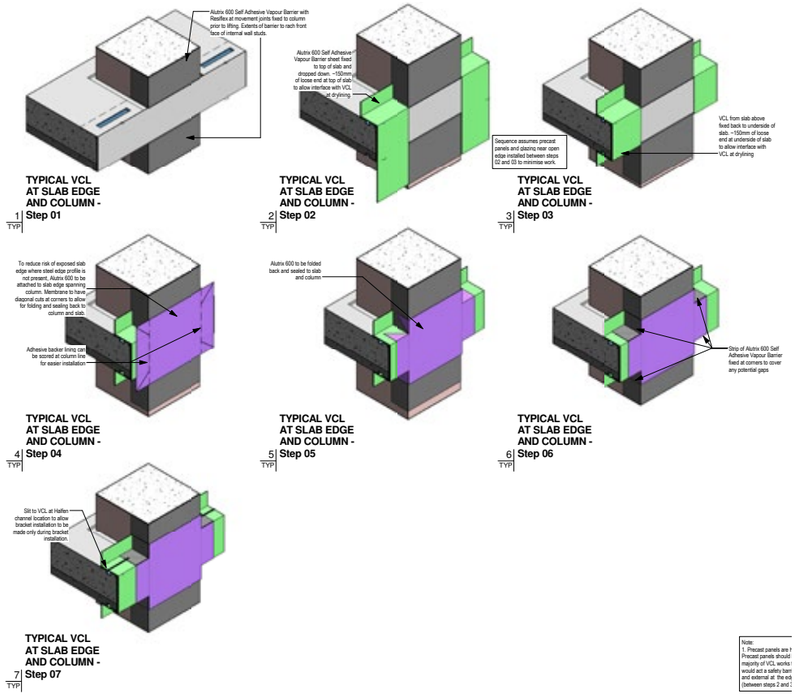
Ⓐ + Ⓑ + Ⓓ + Ⓕ + Ⓗ + Ⓙ
20 +3 +3 +4 +0 +3.4

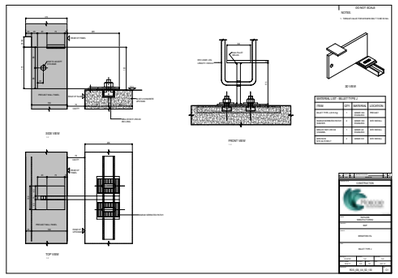
3.3 Brighton 3Ts Hospital Redevelopment - Precast Concrete Façade











Materials

C	Name	λ [W/(m·K)]
	Cavity Horizontal d=95 w=1000	0.5007
	dT=5	
	Concrete	2.5
	Fire Stop Siderise	0.039
	Gypsum Board	0.24
	Rockwool RW	0.035
	Steel	17

Used Heat Transfer Coefficients

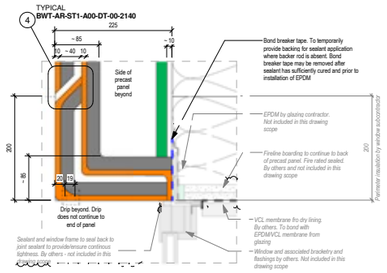
Room	Rs(H)	Rs(T)	Description
External	Rs=0.04 m²K/W	Rs=0.04 m²K/W	External
Internal	Rs=0.13 m²K/W	Rs=0.13 m²K/W	Internal

Thermal Coupling Coefficient with Bracket penetration = 0,315811 W/K

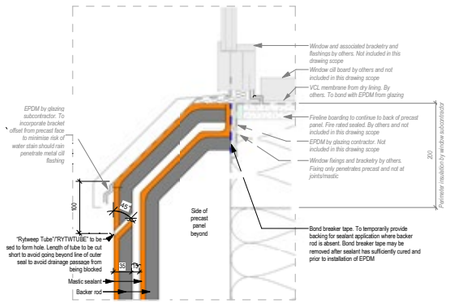
Thermal Coupling Coefficient without Bracket penetration = 0,21782 W/K

Temperature difference: ΔT = 24.5 K

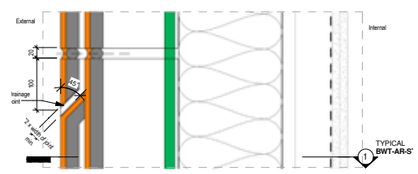
Point thermal transmittance of dead load restraint bracket = 0.097991 W/K



2 Typical Vertical Joint Detail at Window Head Option A
TYP 1 : 5

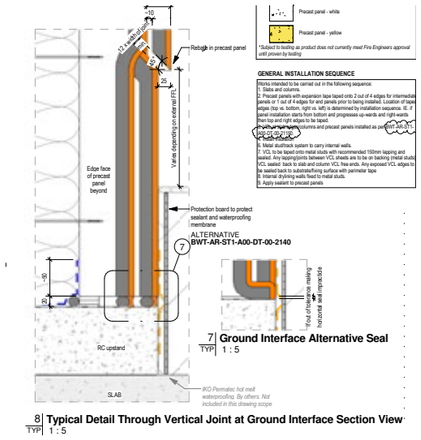


4 Typical Vertical Joint Detail at Window Cill_Vent
TYP 1 : 5



4 Typical Detail Through Vertical Joint Section View
TYP 1 : 5

Rev. P03 note:



7 Ground Interface Alternative Seal
TYP 1 : 5

8 Typical Detail Through Vertical Joint at Ground Interface Section View
TYP 1 : 5

3.4 Hong Kong Lyric Theatre - DfMA Optimisation Studies

Project Summary

Client: Gammon Construction Limited

Construction Value: HK$ 5.5bn

Status: Under Construction

How we added Value:

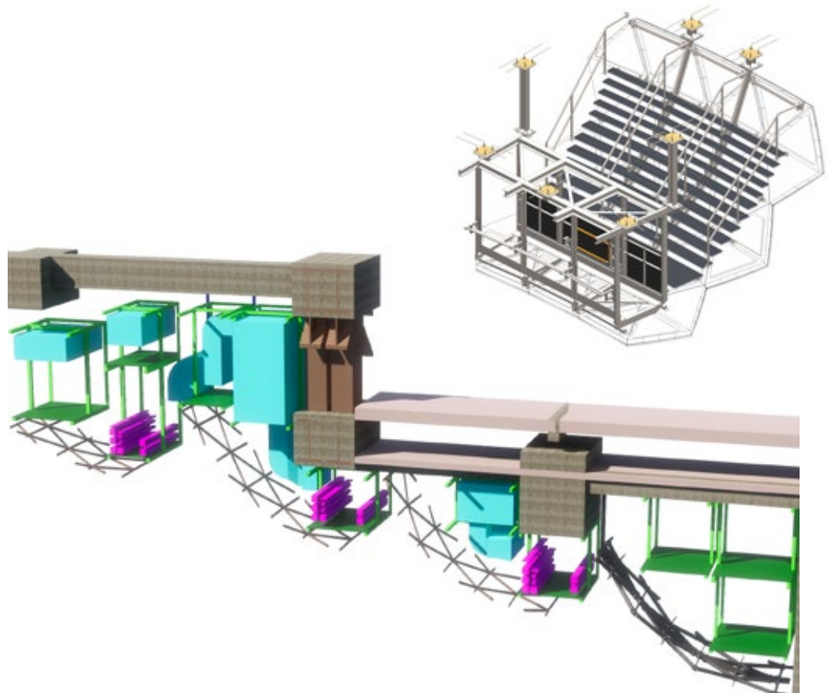
- Developed design proposals for efficient and constructable solutions to achieve highly complex geometric forms in an efficient way
- Standardisation opportunities investigated to increase value without compromise to the design intent
- Introduced prefabrication strategies for key components to move fabrication off the critical path for site operations on this complex project

DfMA opportunities review

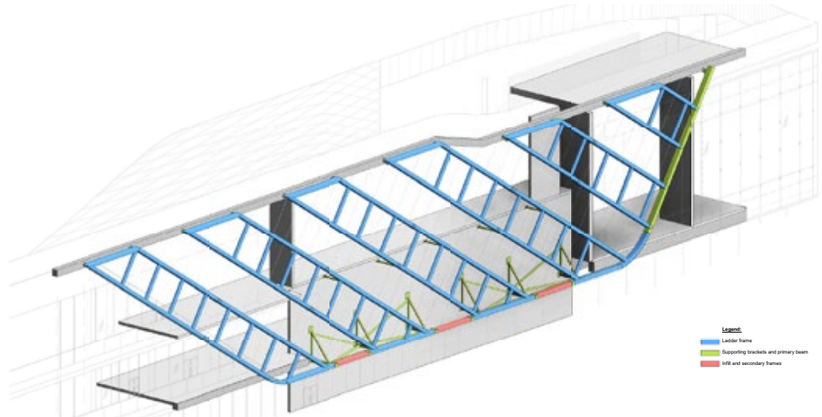
Bryden Wood were appointed by Gammon to support their successful tender for the construction of the Lyric Theatre complex in the West Kowloon Cultural District of Hong Kong. The Lyric Theatre complex is scheduled to be completed in 2023 and will be a world-class cultural facility incorporating a 1,450 seat lyric theatre, a 600 seat medium theatre and a 270 seat studio theatre, as well as rehearsal spaces and a collaboration hub for dance companies and artists. The complex is situated on the Kowloon waterfront and will be an iconic venue for Hong Kong.

The project's status as an iconic and landmark development for Hong Kong affords an opportunity to set a strong example in adoption of the Hong Kong Government's "Construction 2.0" report that sets out a vision for the transformation of Hong Kong's construction sector.

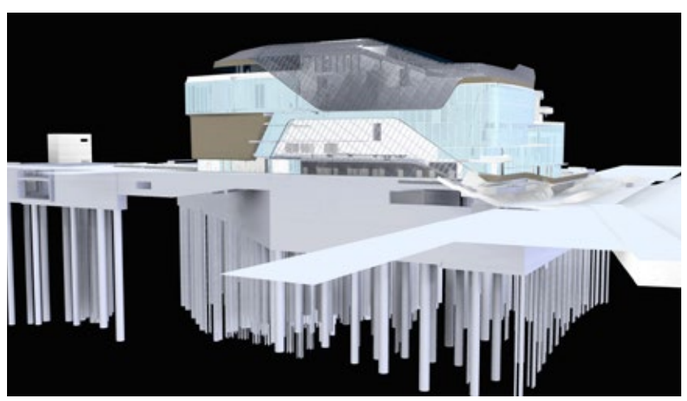
Bryden Wood provided a number of specialist engineering studies focused on identifying opportunities for optimised DfMA solutions for the delivery of the façade elements, very complex theatre ceilings and M&E prefabrication and specialist in-situ and precast concrete elements (e.g. curved seating areas).

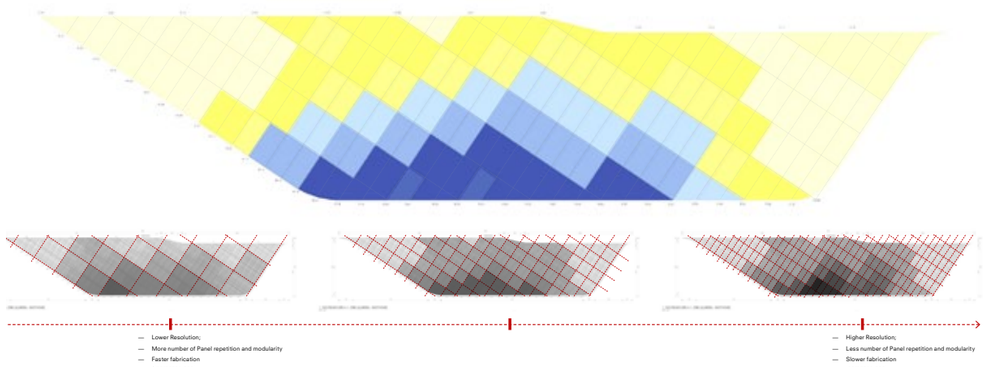


Preliminary study of theatre ceiling support structure.



3D view of proposed ladder frame and cladding support structure.





Preliminary study of mesh vertical facade and pixelation strategy.

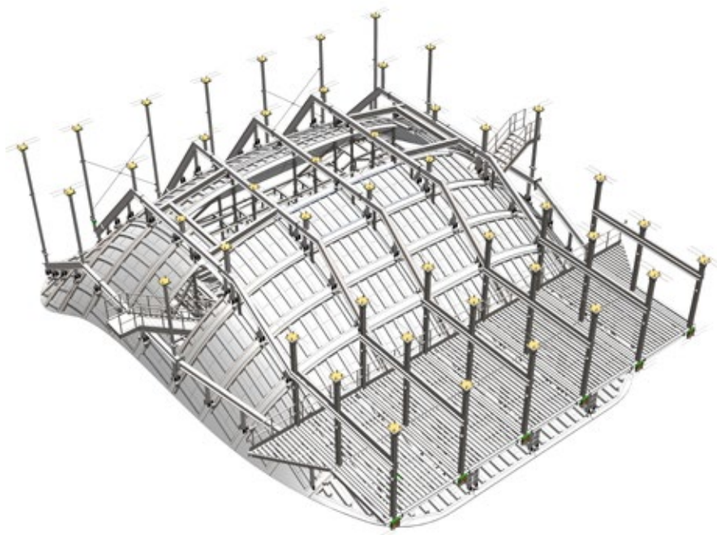
3.4 Hong Kong Lyric Theatre - Fabrication Design of GRG Feature Ceilings

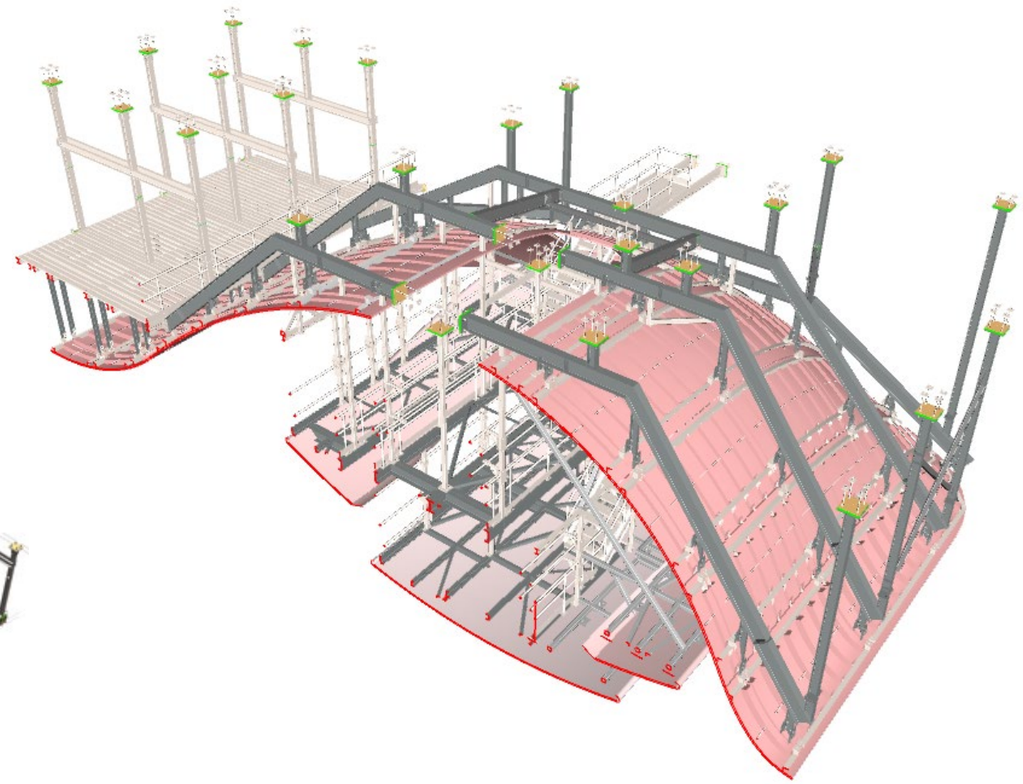
DfMA solutions for theatre feature ceilings

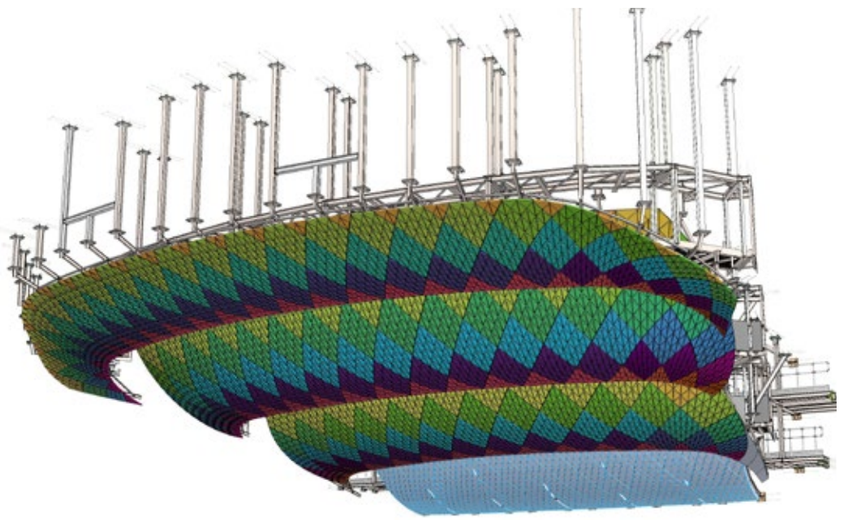
Subsequently to Gammon's successful tender for the project, Bryden Wood were appointed by Gammon to further develop the design of DfMA elements including GRG Ceilings in the Large and Medium Theatres, including the hanging modular support structure (for walkways, lighting and M&E distribution), the secondary framing structure for the feature ceiling elements, and the feature ceilings themselves.

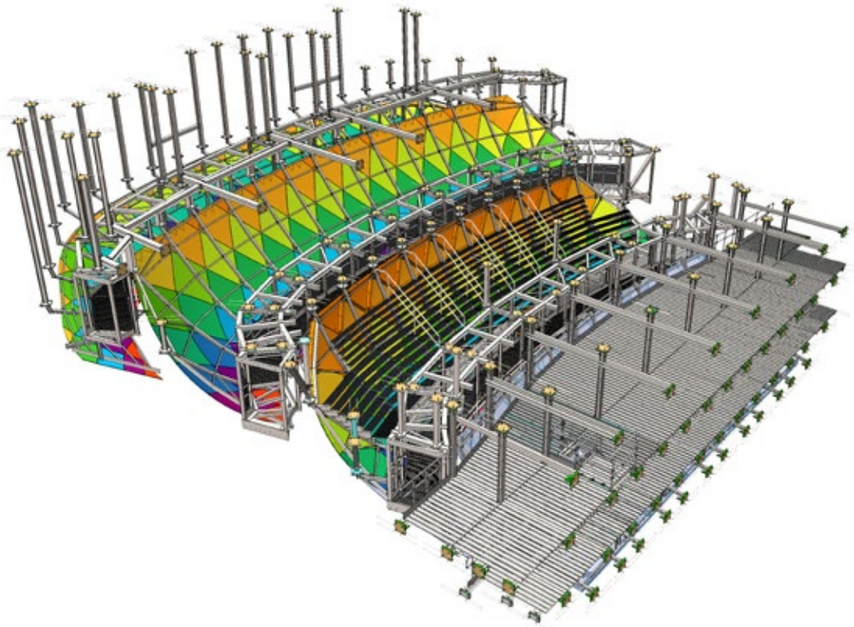
Bryden Wood are providing a comprehensive design service for these specialist packages including:

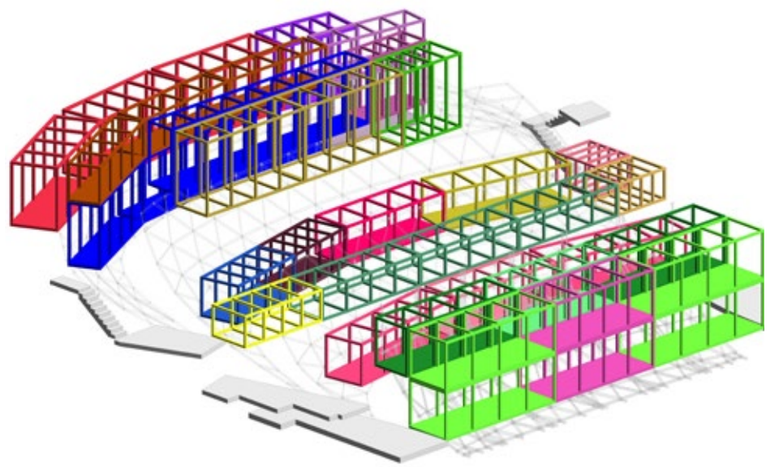
- Development of a modularisation strategy adopting a DfMA approach to the package;
- Initial high level consideration of possible fabrication and transportation routes and issues;
- Development of installation strategies for the ceiling elements;
- Consideration of the integration of access galleries, E&M, theatre systems etc. with the ceilings.
- Detailed fabrication documentation.









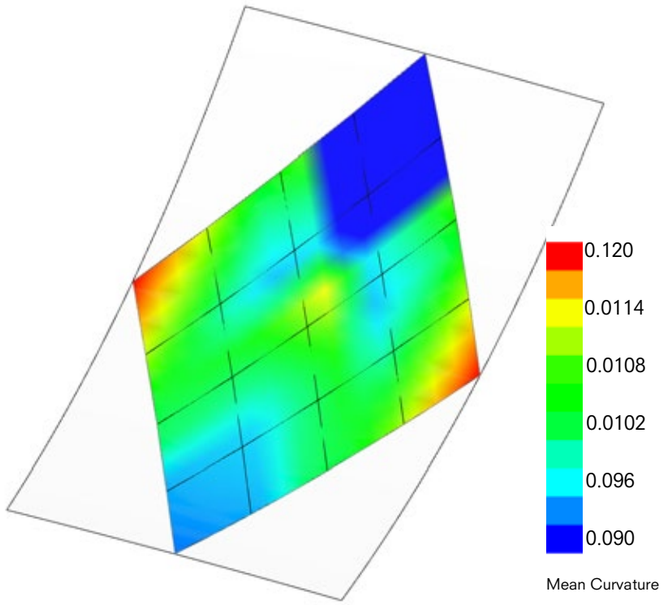


3.4 Hong Kong Lyric Theatre

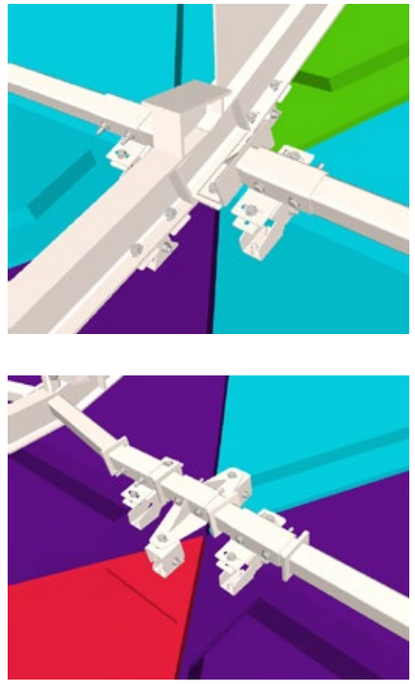
Analysis and rationalisation

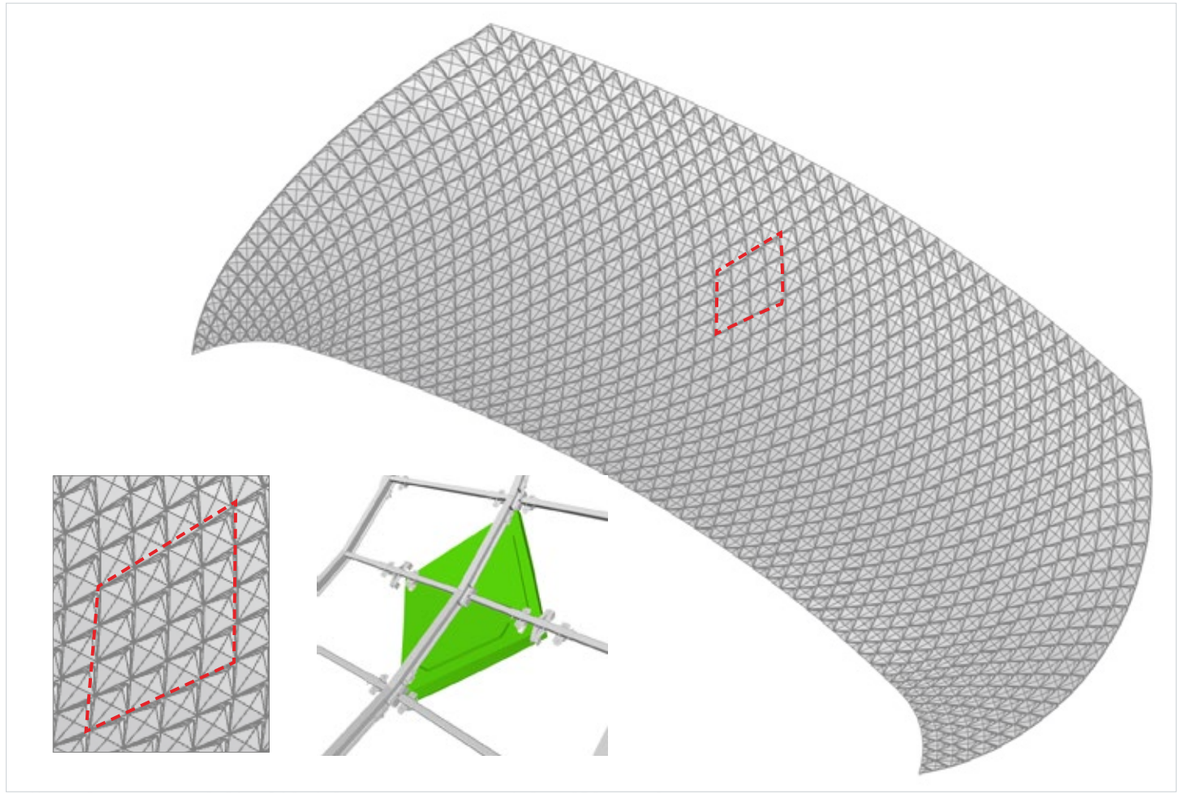
Bryden Wood developed automated workflows to investigate and analyse the complex curvature elements of the feature ceilings in order to propose opportunities to improve the modularity of the design and therefore increase manufacturing efficiency while decreasing costs.

The analysis and rationalisation exercise resulted in a series of possible design interventions with a quantified benefit in terms of lower cost and faster fabrication as well as a defined impact on the overall ceiling geometry.

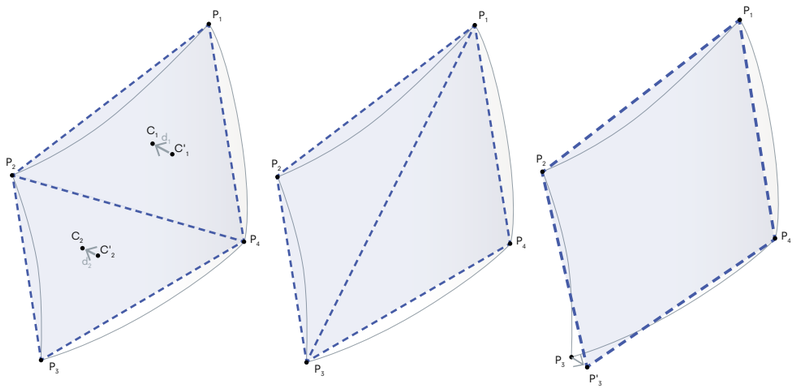


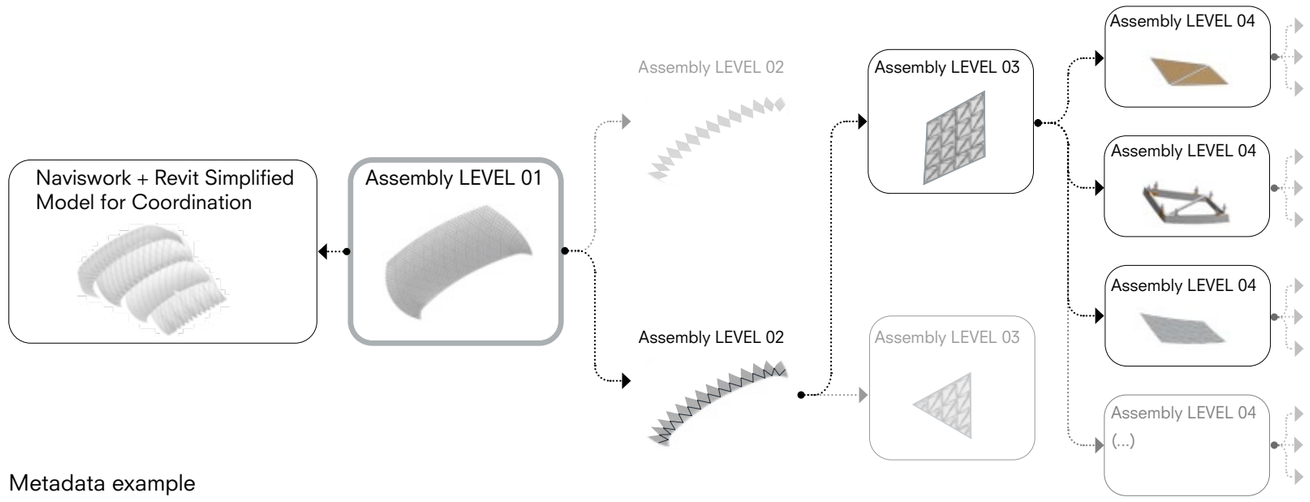
Mean Curvature of the current base Surface.





Mean Curvature of Simplified Geometry proposed for GRG panels.





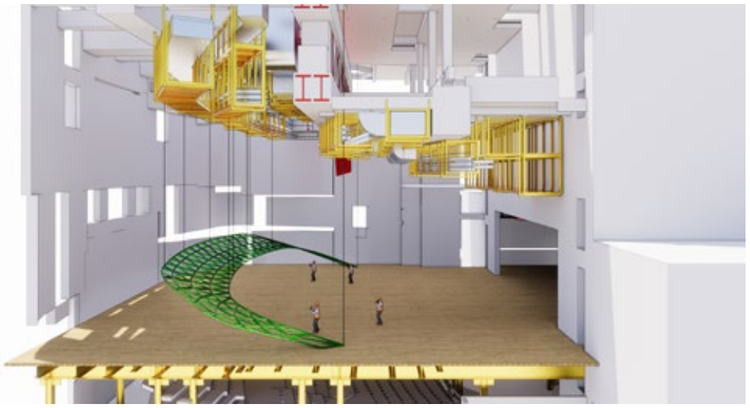
Metadata example

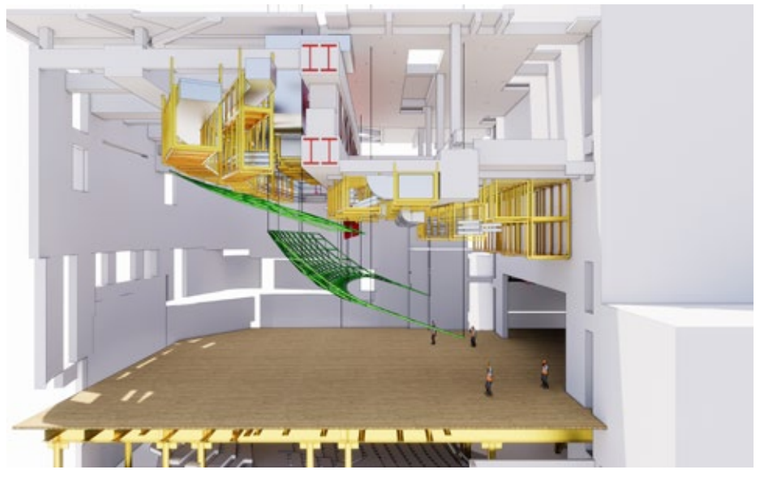
- A - LT Location
- B - MT Location
- S1 - Ceiling Strip 01
- S2 - Ceiling Strip 02
- R1 - Row 01
- R2 - Row 02
- F - Flat Geom.
- D - Double Curved Geom
- G - GRC
- CS - Carbon Steel

3.4 Hong Kong Lyric Theatre

Installation strategy

Bryden Wood have developed a range of possible delivery and installation strategies for the feature ceilings to both theatres. These strategies were reviewed together with Gammon's logistics team to identify the preferred construction approach.





3.5 Kings Cross S5 - Precast Concrete Cladding with Factory Installed Brickwork

Project Summary

Client: Laing O'Rourke
Construction Value: Confidential
Status: Pre-Construction

How we added Value:

- Advanced digital workflows and scripting used to accelerate the design process, calculating panel quantities and rapidly model panel and brick geometries across the whole project
- A holistic approach to façade documentation including key drawings, technical reports and assessments

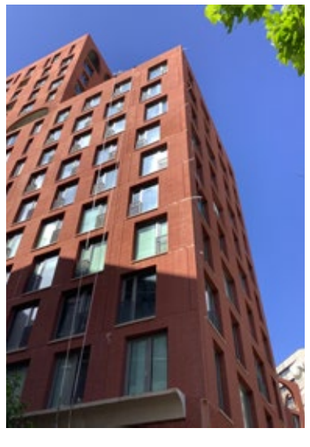
Precast façade project in central London based on integrated panels

Bryden Wood have been appointed by Laing O'Rourke to provide façade performance and precast engineering to the upcoming Kings Cross S5 residential development in London.

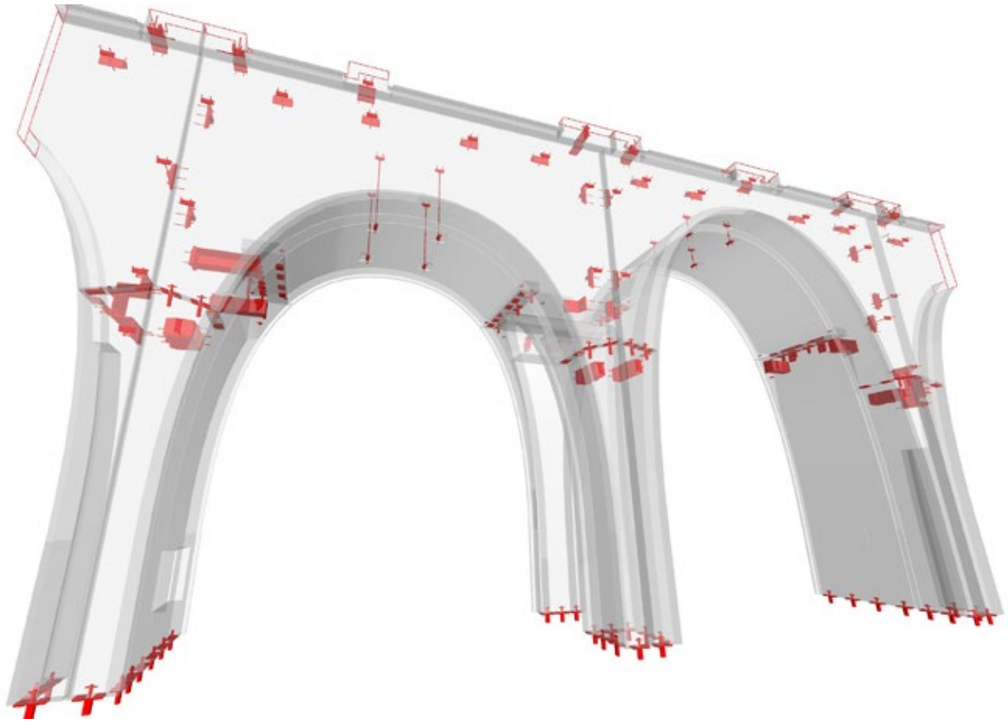
Bryden Wood's appointment encompasses overall façade performance and precast engineering and BIM. Bryden Wood have utilised advanced digital workflows and scripting to calculate panel quantities and rapidly model required precast panel and brick geometries across the entire project.

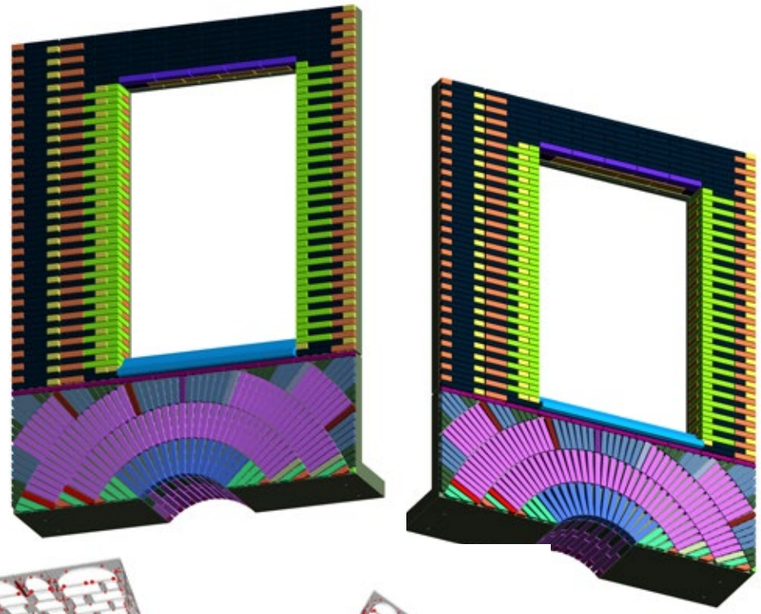
The fabrication design being completed by Bryden Wood is based on RIBA Stage 4 information produced by the project's main design team. Bryden Wood's holistic approach to the façade documentation includes key interface and setting out drawings as well as technical reports and assessments.

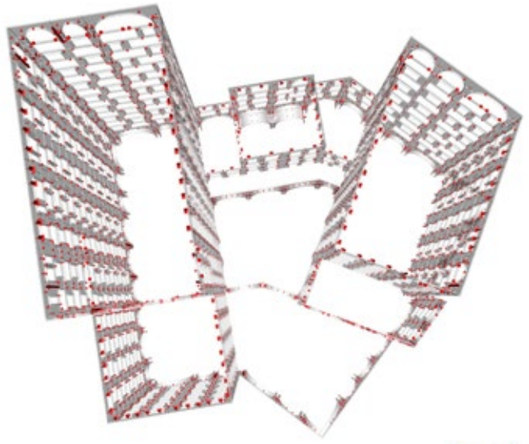
The Kings Cross S5 development will add 158 new dwellings to the vibrant Kings Cross neighbourhood in London with a strategic position at the junction of York Way and Canal Reach. The scheme comprises a six-sided perimeter block with masses of varying height up to fifteen storeys grouped around a central courtyard.

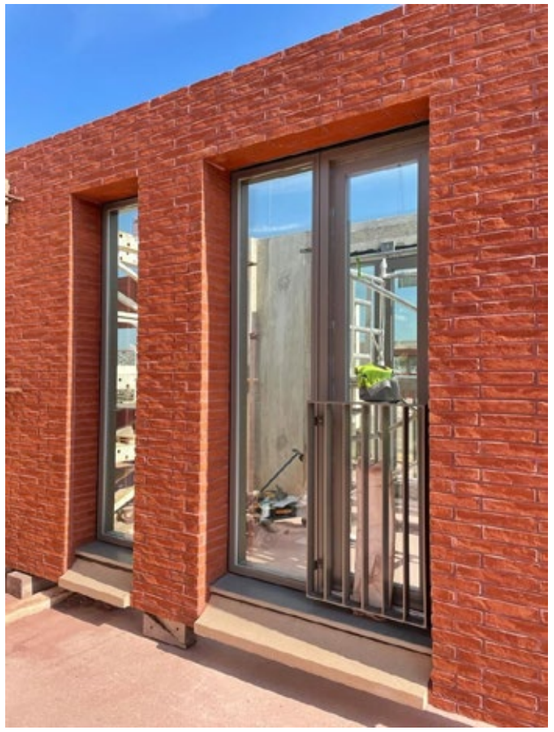


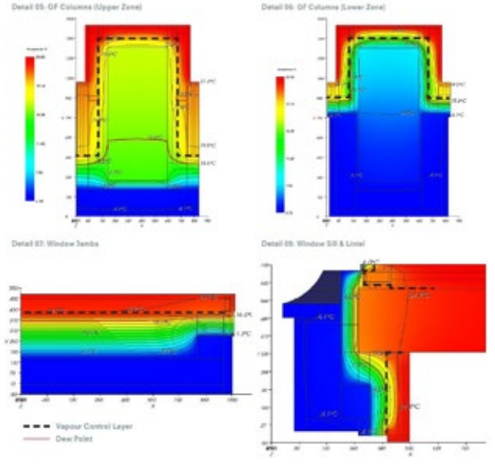
3.5 Kings Cross S5 - Precast Concrete Cladding with Factory Installed Brickwork

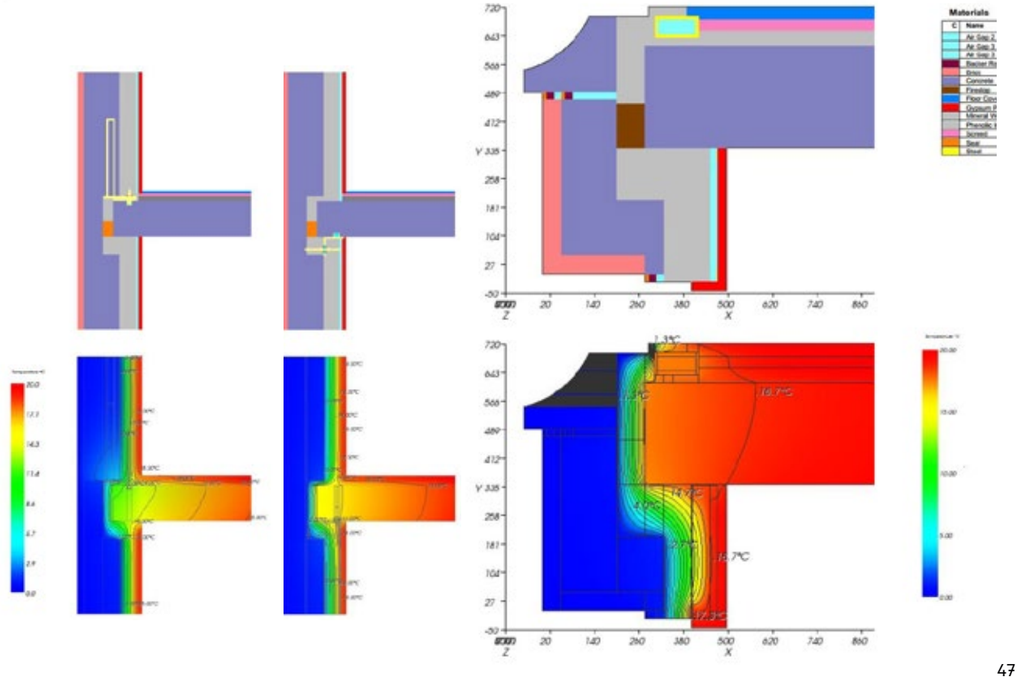












3.6 St Michaels - Curtain Wall Façade Optimisation

Project Summary

Client: Domis Construction
Construction Value: 200 million
Status: Ongoing

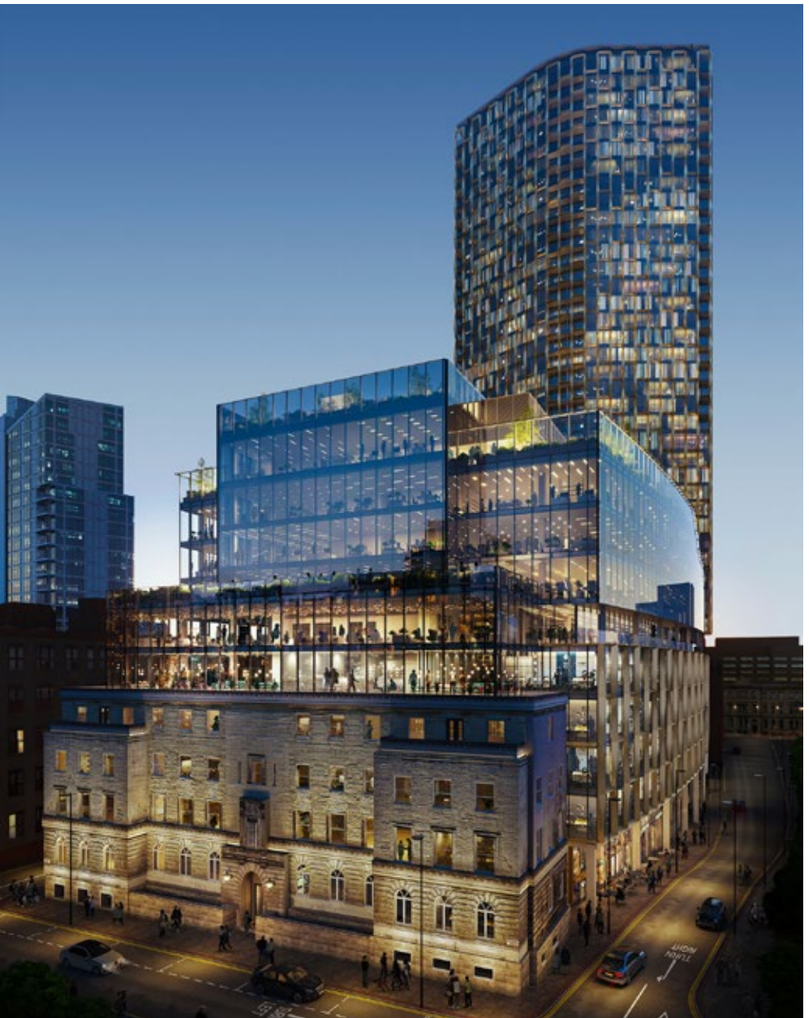
How we added Value:

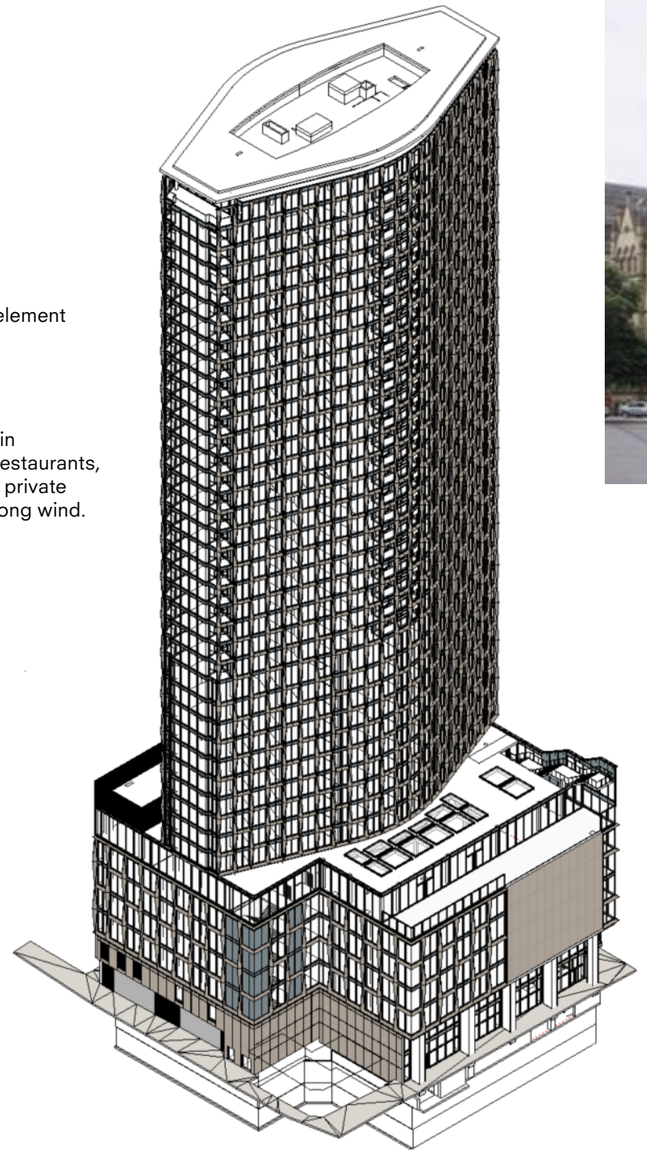
- Facade design optimization halving mullion use in corners
- Eliminating risks of curtain wall condensation
- Elimination of whictling and aberration risks by quality control of facade element design and fabrication

Project Summary

St Michael's Tower is a high rise, mixed development and new city landmark in Manchester comprising recreational area in the podiums with shopping and restaurants, and a hotel and luxury apartments in the tower. The design proposals include private balconies over 150 meters height from ground floor in an area exposed to strong wind.

Architectural visualization of St. Michael's Tower. Courtesy of Manchester Evening News





3d model. St Michael's Tower

BWT scope in this project is to oversee the design optimization of bespoke unitised curtain wall featuring large three dimensional decorative elements manufactured from anodized aluminium elements.
BWT is constantly performing Value Engineering exercise from the concept phase to guarantee the lowest possible construction price without compromising quality and facade performance
We are also acting as advisory to the General Contractor about the best supply chain alternatives for the project, both in the domestic and global market.

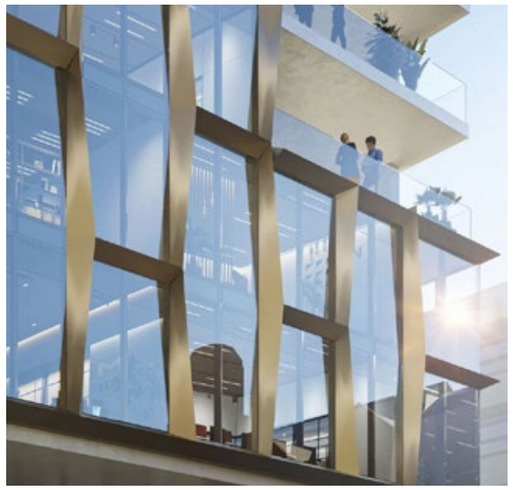
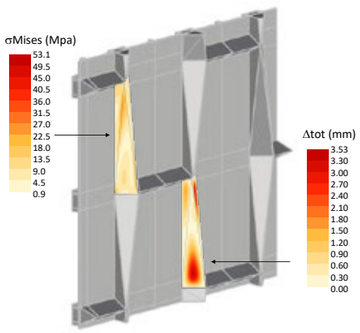


Image showing Facade anodized aluminium facade fins. St. Michaels Tower

Facade elements. St. Michaels Tower

3d model of facade. St. Michaels Tower



Facade performance analysis.

3.7 Two Taikoo Place - Façade Optimisation

Project Summary

Client: Swire Properties

Construction Value: Confidential

Status: Pre-construction

How we added Value:

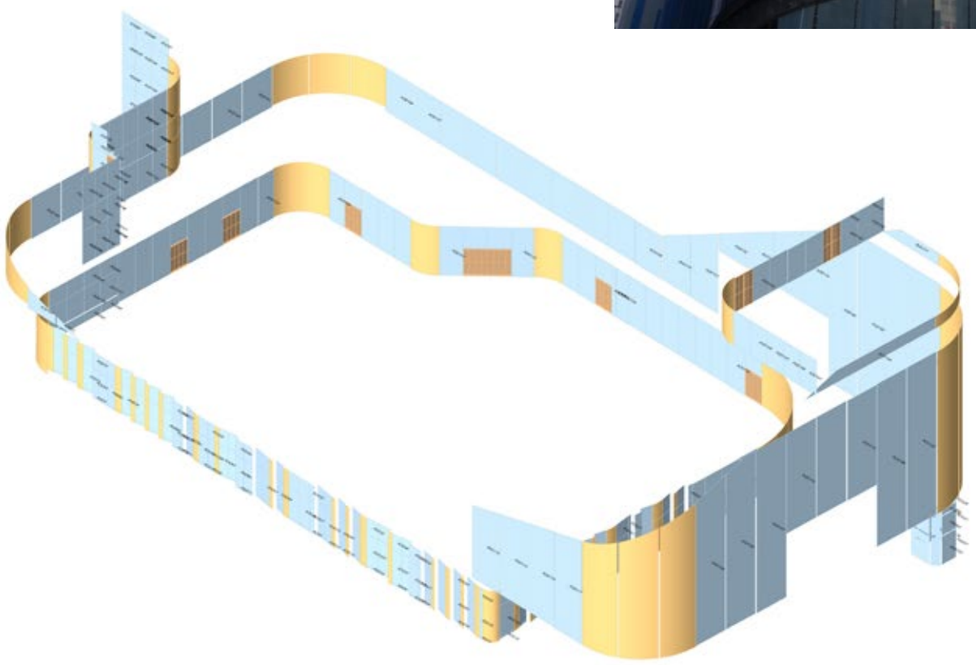
- Provided an optimised design that reduced the total number of unique glazed façade panels on the project while protecting the architectural intent.
- Provided an optimised design for the mullions that reduced the number of unique mullion types while protecting the architectural intent.
- Developed a suggested handling and installation sequence and explored possible scenarios to accelerate the installation process.

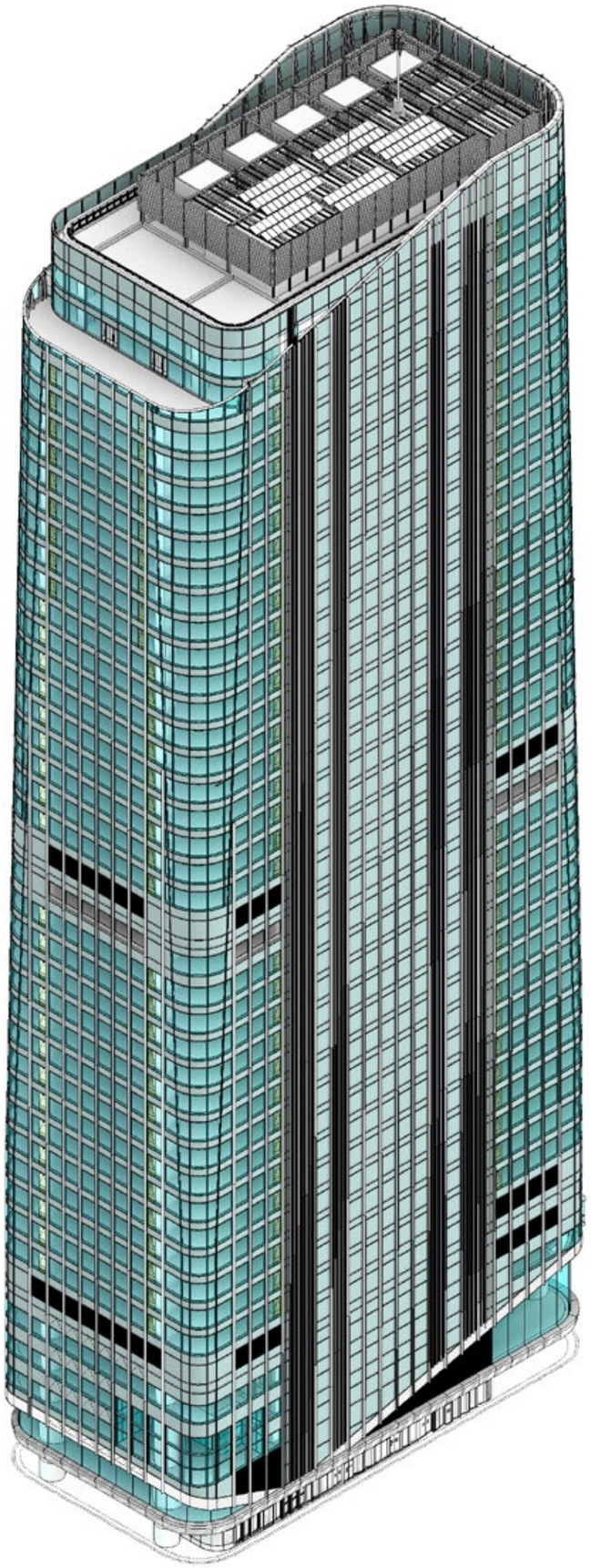
Façade optimisation for landmark Hong Kong development

Two Taikoo Place Tower is part of the redevelopment of one of the future best business hubs in Hong Kong. The tower is designed to reach a height of 203m and will host commercial space for local and multinational corporations. The project includes a sophisticated unitised curtain wall façade comprising a large quantity of both flat and curved glazed panels.

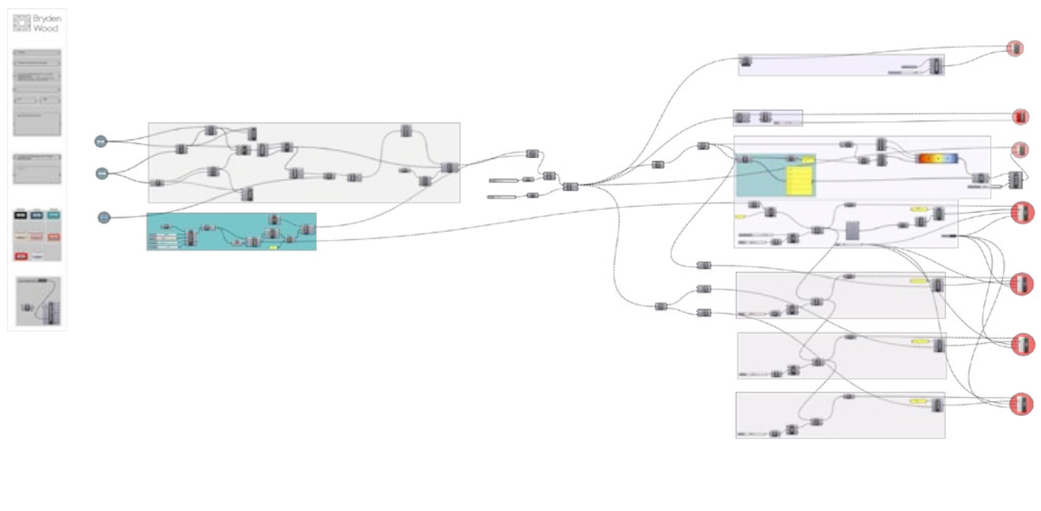
Bryden Wood was appointed by the developer, Swire Properties, to undertake an analysis and optimisation exercise on the façade to reduce the manufacturing and installation cost while protecting the architectural intent. We used algorithmic design and computational analysis tools to complete a panel count for the entire building and rationalise the design, reducing the overall number of unique panels and simplifying their geometry with no perceivable impact on the final built outcome.

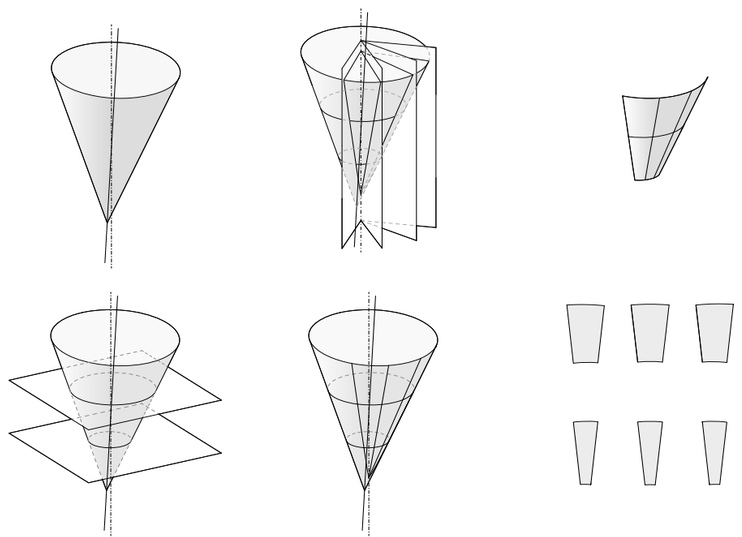
As part of the project Bryden Wood also undertook a design review of the façade details and developed a handling and installation strategy that was used to generate estimates of overall installation time requirements and identify scenarios to accelerate the installation process.

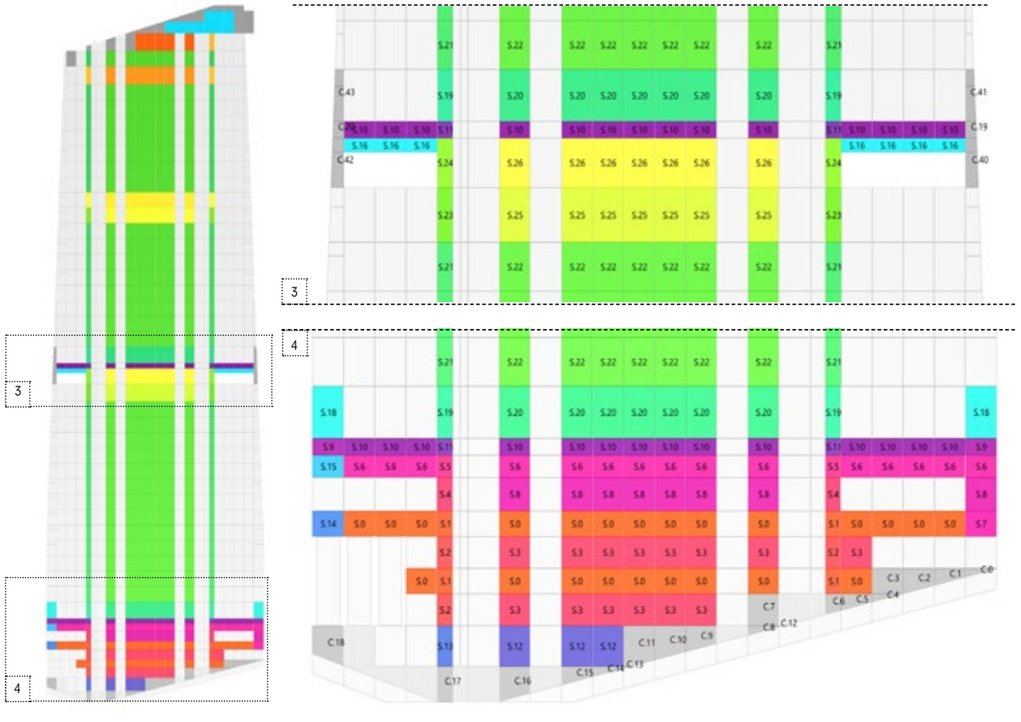


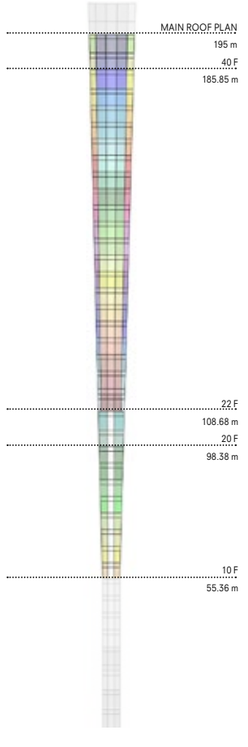


3.7 Two Taikoo Place - Façade Optimisation









Note: grey panels are all unique.

Note: The panel quantity for each panel has to be multipled by four to obtain the total number of panels required along the tower.

3.8 Circle Reading Hospital - Architectural, Structural, Mechanical Design

Project Summary

Client: Circle Health Properties Ltd
Construction Value: £25m
Status: Completed 2012

How we added Value:

- Highly standardised and prefabricated building system was built in only 18 months with a 25% cost reduction per square metre compared to the previous Circle hospital.
- Precast concrete planks all had the same cross section but varied in length and location of services penetrations.
- A standardised simple bolted connection detail to the steel columns was developed for the corners of the planks.
- Modular offsite construction resulted in accelerated on site programme.
- The full structure was erected without topping or wet trades.
- The precast planks were integrated with other platform elements including chilled beams (heating/cooling), lighting, bathroom pods and bedhead services.
- The quality of the precast was sufficiently high that the painted underside of the planks became the exposed ceiling finish in the bedrooms, thereby providing a high quality architectural shape and finish as well as fully eliminating further finishing works and providing additional room height.

Prescast planks partially supported by structural beams.

Precast slab to steel column connection detail.

Bespoke precast DfMA system for flagship hospital

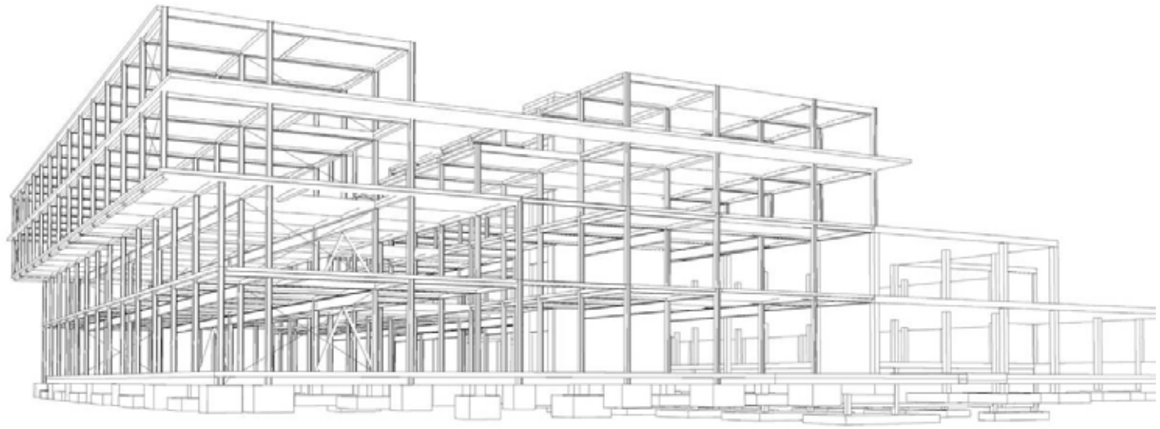
Circle Reading used highly standardised precast planks: all planks were standardised in cross section (3.9m span) with a plank length up to 9m. Plank types were defined by the positions of penetrations for M&E services. Simple bolted connections were used between the precast planks and steel columns.

The connection details were simple and highly standardised (2, 3 or 4 planks) which ensured rapid construction. Note the full structure was erected without topping or wet trade. The precast planks were integrated with other platform elements including chilled beams (heating/cooling), lighting, bathroom pods and bedhead services.

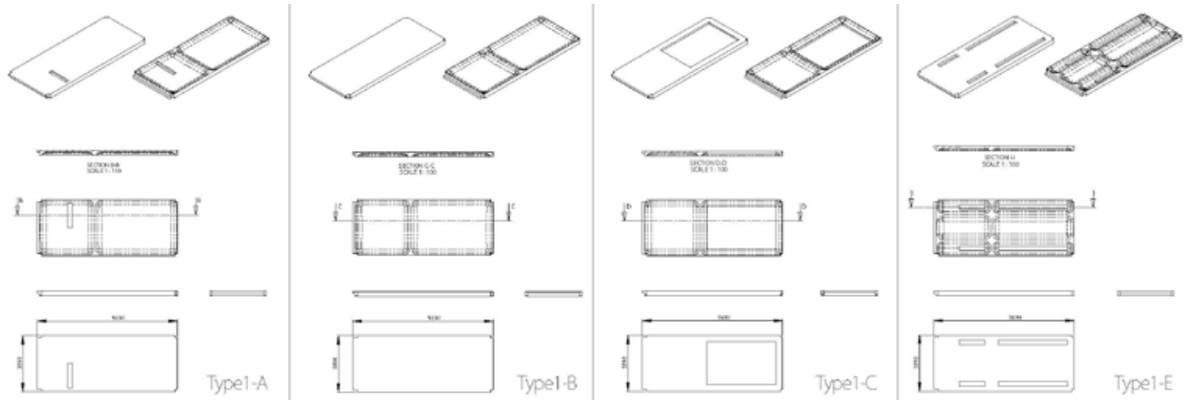
Precast planks and steel columns adjacent to atrium space.

Painted underside of the planks became the exposed ceiling finish in corridor, bedroom and atrium spaces.

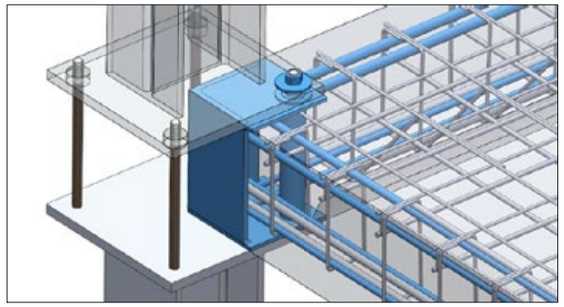
3.8 Circle Reading Hospital - Architectural, Structural, Mechanical Design



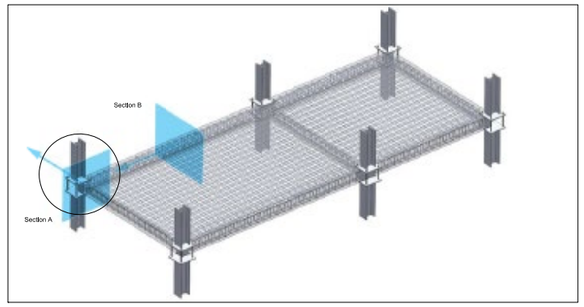
3D model view of concrete plank and steel superstructure.



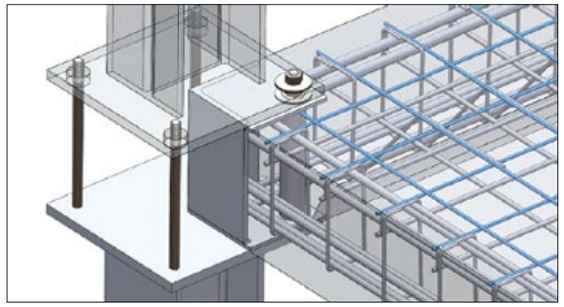
Sample of concrete plank types. All planks were standardised in cross section (3.9m span) with a planks length up to 9m. Plank types were defined by the positions of penetrations for M&E services.



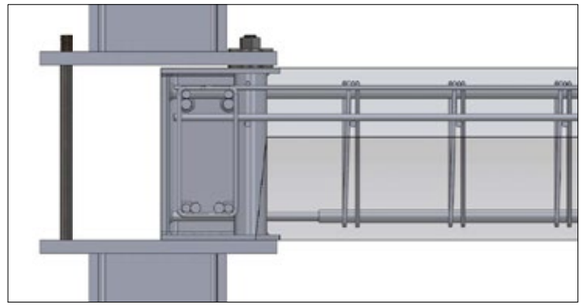
3D Image: perimeter downstand starter bars highlighted



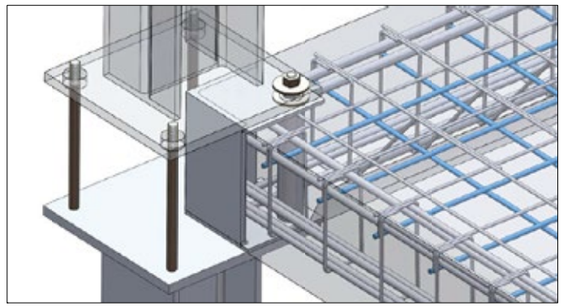
3D Image: detail and section location key



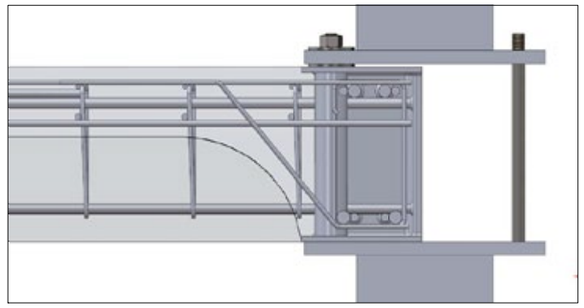
3D Image: top reinforcement highlighted



Section A: transverse perimeter downstand in corner



3D Image: bottom reinforcement highlighted



Section B: longitudinal perimeter downstand in corner

Circle Reading concrete plank design details. Simple bolted connections were used between the precast planks and steel columns.

3.9 Modular Construction

Project Summary

Client: Multiple
Construction Value: Various
Status: Rollout of 35 projects to date

How we added Value:

- Rapid superstructure assembly; flat pack components are designed to be rapidly assembled on site in a range of configurations to suit site-specific internal and external space requirements.
- A range of configurations of components is possible.
- A variety of internal spaces can be achieved, with a clear internal span of over 8m. Floor to ceiling heights can vary to suit the function of the room or hall.
- Single or double storey buildings are possible.
- Sustainable materials used.

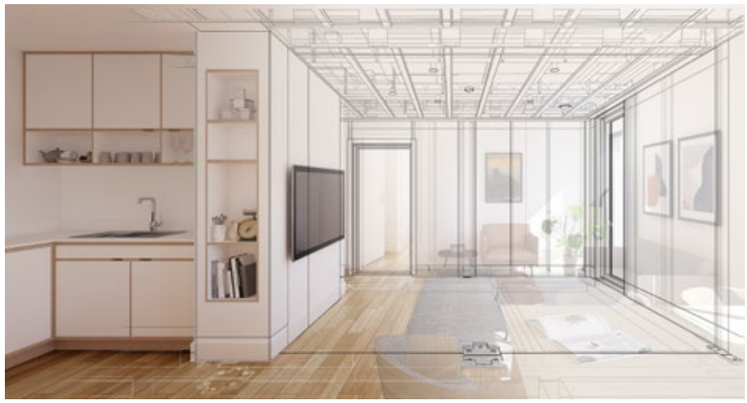
Modular house

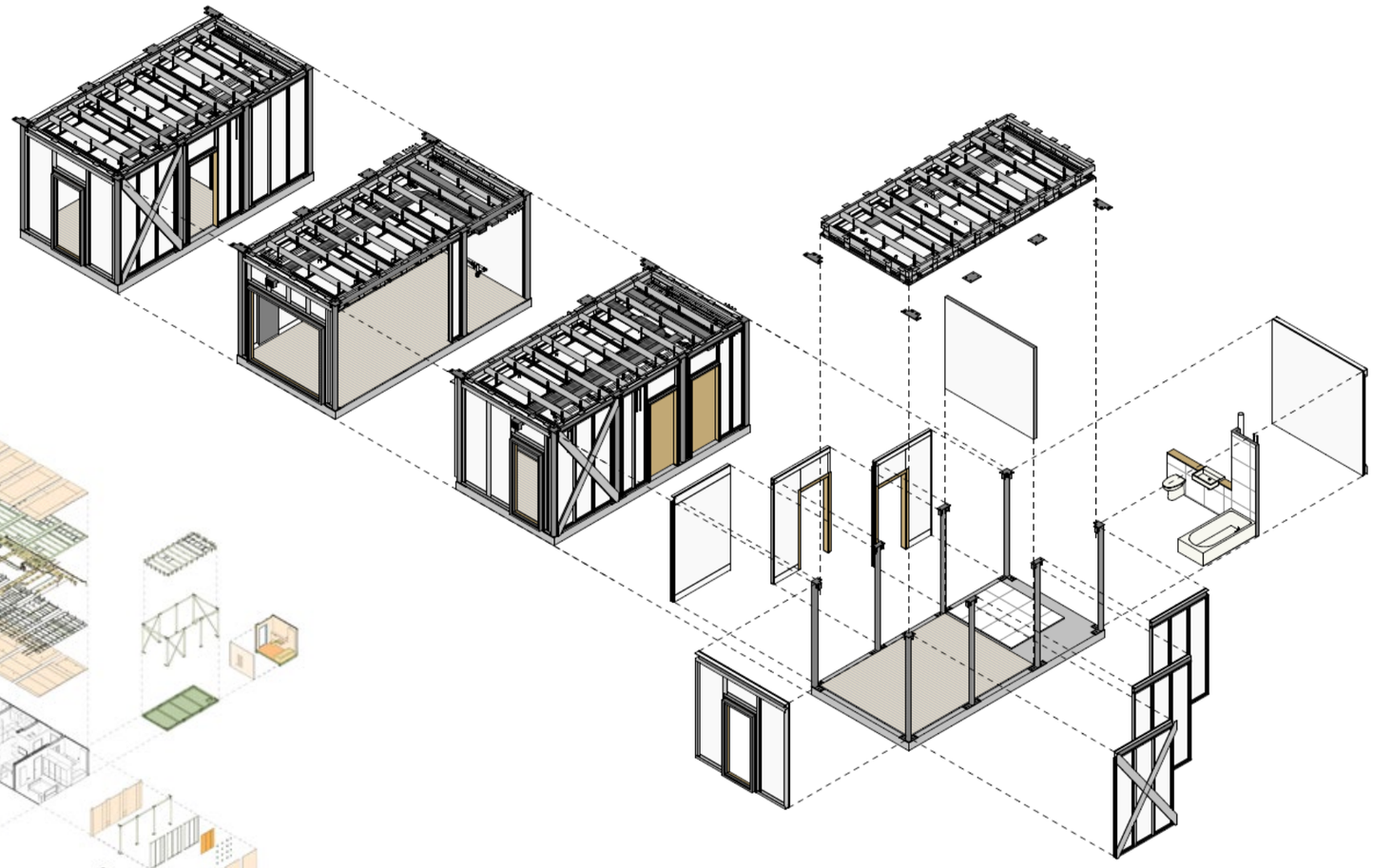
In 2018 BWT started work with a large UK modular house construction company. Our scope is to provide DfMA services, integrated design - Architecture and Engineering, as well as Master planning of sites. We are supporting the companies commitment to developing sustainable communities. This is achieved through early engagement with their customers. Great people and great places are at the heart of the approach and form key aspects of the strategy.

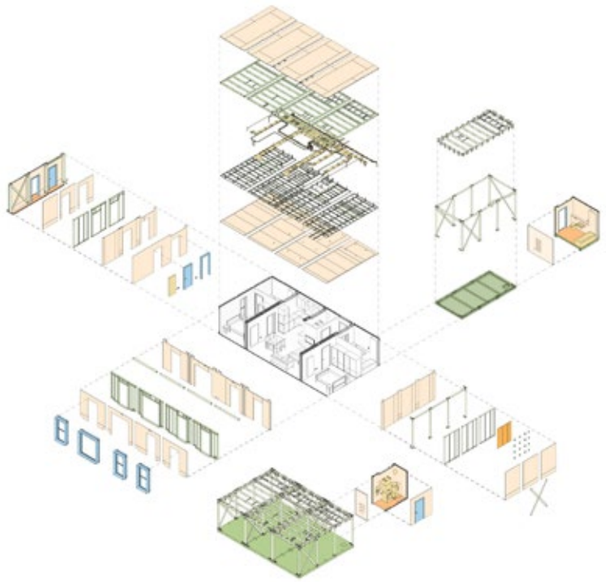
Through early engagement we developing a detailed analysis of community requirements which in turn informs the master plan process, which not only provides affordable, high-quality homes but communities where people want and aspire to live.

Investment in Europe's largest modular homes factory demonstrates the companies ambition to inject capital into the Housing sector alongside the creation of the Build to Rent, Later Living and Housebuilding businesses.

With BWT's experience of over 20 years in offsite and DfMA, we have assisted to develop manufacture precision engineered modular homes in a factory environment, ensuring accuracy of build, in dry controlled conditions, using state of the art methods and materials with a series of quality assurance checks carried out before it leaves the factory. BWT are currently working on the design of 6 housing typologies and the first 3 sites which will deploy the first Bryden Wood designed modules.







3.9 Modular Construction

Pre-cast slab off-loaded

Slab has skates mounted

Slab ready for assembly

Sub-assemblies made and stored

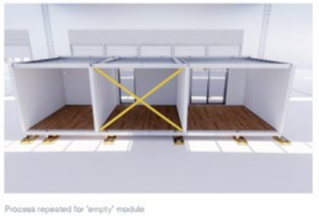
Sub-assemblies mounted on 'Tea Tray'

Assembly continues in sequence

Ceiling cassettes added

Handrails and weatherproofing added

Completed module moved to dock loaders



Dock slides lower unit onto lorry bed

Skates are removed and re-used

Process repeated for 'empty' module

3.9 Modular Construction

3.10 The Forge Platform Construction System

The Forge, at 105 Sumner Street in central London, is a landmark moment in construction.

Designed for development by Landsec, it will be the first major building completed using our Platform Design for Manufacture and Assembly (P-DfMA) approach, from building design to delivery. The Platform approach has been adopted by the Government and is the focus of the Construction Innovation Hub.

It is designed to a 'zero carbon in use' strategy, and is already achieving gains in:

- efficiency: a predicted 9.5% reduction in capital cost, 13% reduction in programme, 40% reduction in steel used and 50% reduction in site operatives for superstructure and facade
- sustainability: a forecast 19.4% reduction in embodied carbon per square metre, a 36.4% carbon reduction in the substructure and 20.2% in the superstructure and façade.

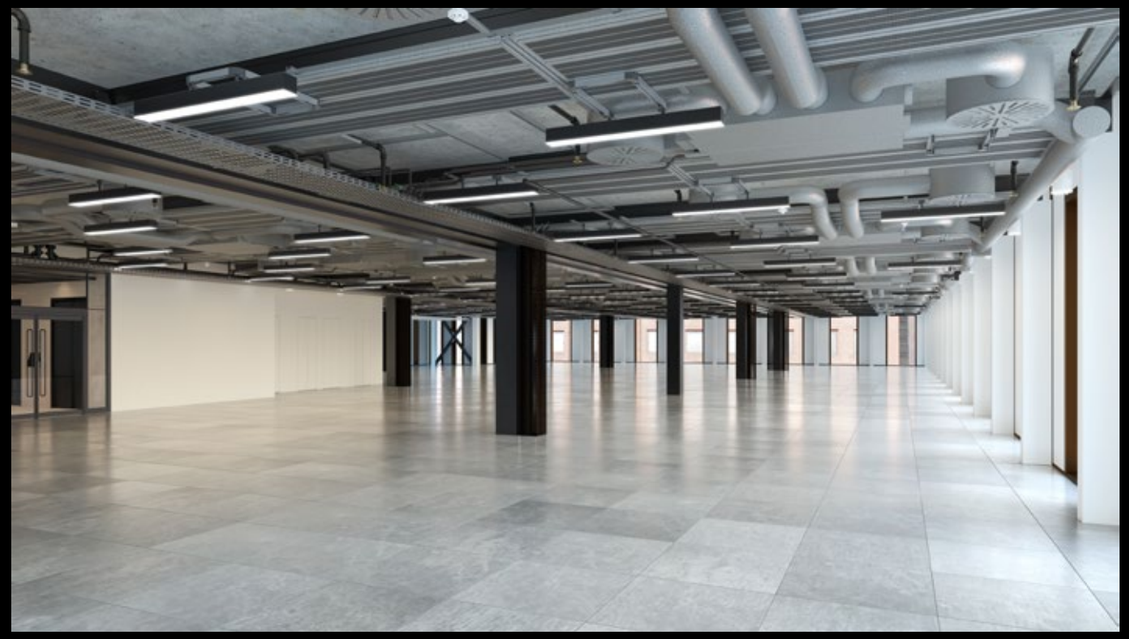
The Forge is two new-build commercial office buildings, built around a publicly accessible internal courtyard, in total comprising c. 135,000 sq ft. It will be nine storeys high with reception and basement areas. The development will be a high quality and sustainable building with a vastly improved streetscape and public realm. It will use a hybrid steel and concrete structural platform that was developed as part of an Innovate UK First Phase Challenge Fund research project on Automated Construction. The structural platform developed as part of the R&D project will provide the chassis for the office floor space and the project will include the development of cladding and building services components to create a reusable kit-of-parts-based solution for offices.

The project will validate and showcase the benefits that can be delivered using P-DfMA techniques, Modern Methods of Construction (MMC) and digital technologies on a large-scale new build commercial office development. The scale and ambition of the Forge will be a catalyst for change and a major step forward in proving the new business and financial metrics, whole life performance, and supply chain adoption needed – and deliverable – to accelerate the transformation of the construction sector.

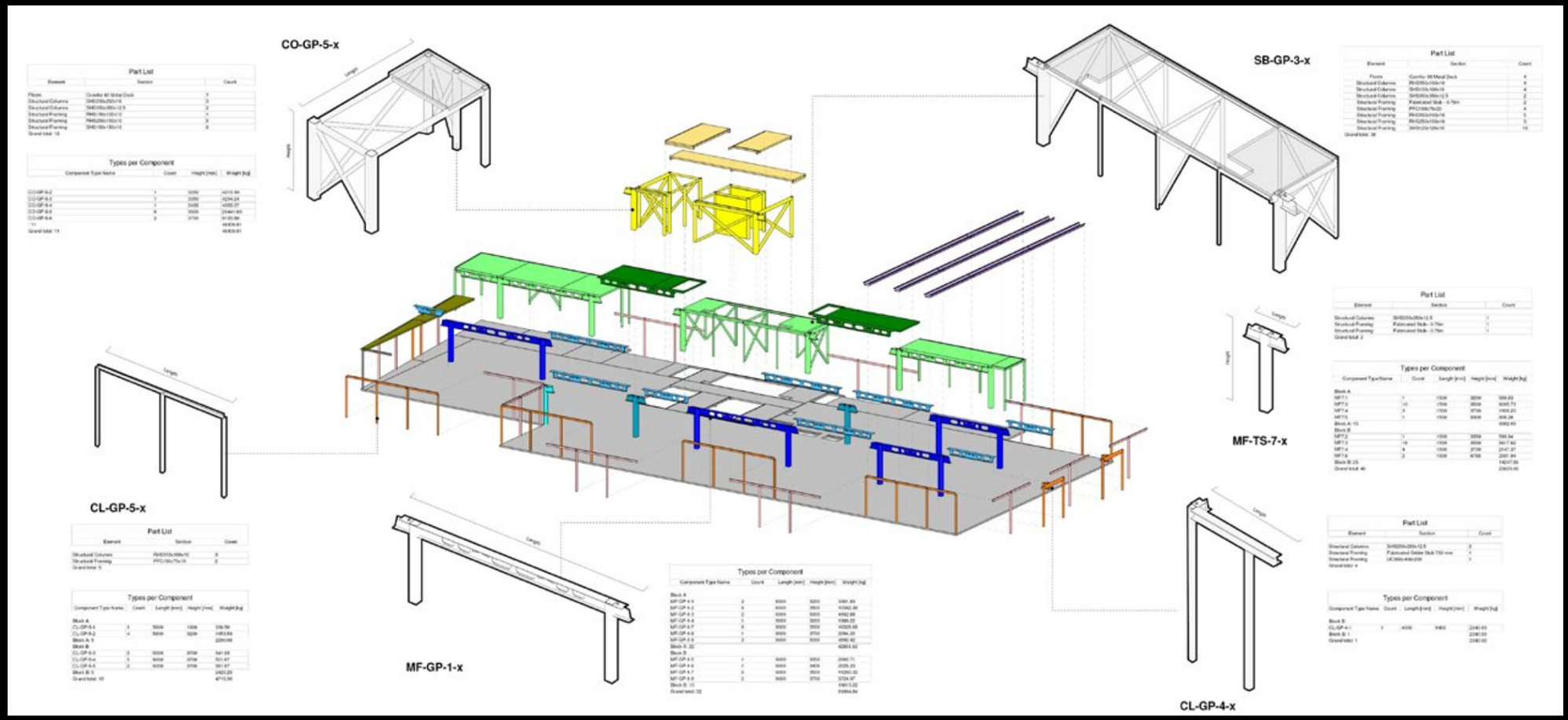
Bryden Wood developed the full design of the component kit of parts (structural and non-structural elements) including consideration of fabrication and installation methodologies. We produced fabrication drawings, component and module layouts and detailed assembly sequences and installation method statements.

Our scope included update of information for record drawings and engineering support throughout factory fabrication and on site installation.

The Forge



The Forge



Appointment:
Structural and Civil Engineering, Architecture, Building Services, DfMA

Programme:
Completion 2022

Client:
Landse

3.11 London College of Fashion (LCF) - Precast Concrete Structure and Façade Engineering

Project Summary

Client: Laing O'Rourke/Expanded
Construction Value: approx. £200million
Status: Under construction
Disciplines: Structural | Architectural

How we added Value:

- Undertook the design of precast elements and façade performance assessment. Converted previously in-situ elements into integrated efficient off-site solutions resulting in significant improvements in the construction time.

Precast and façade engineering for iconic education campus

BWT were appointed by Expanded to undertake design of precast elements and assess façade performance (including thermal behaviour and condensation risks) for the contractor designed portions of the new University of the Arts London College of Fashion (UAL-LCF), part of the Stratford Waterfront Development. The new UAL-LCF building is a riverside site in the Queen Elizabeth Olympic Park which will be part of a new innovation precinct with a focus on creativity, learning and collaboration between leading institutions including the BBC, UCL and V&A Museum in addition to the University of the Arts London.

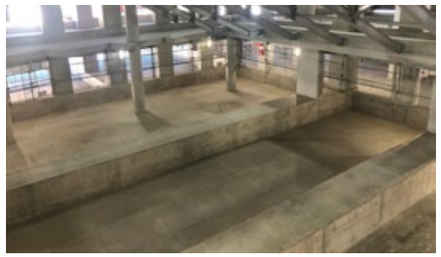
Numerous type of precast elements have been designed in this project. Some of them following the original design, and some others by the conversion from previous in-situ intent, integrating efficient off-site solutions into the live programme resulting in a significant improvement of the construction time.

Stability cores, shear walls, columns, beams, transfer shell beams, lattice planks, hollow core slabs, staircases and facades panels are the elements that form the massive off-site solution of this project.

LCF precast stair render

LCF precast stair Real

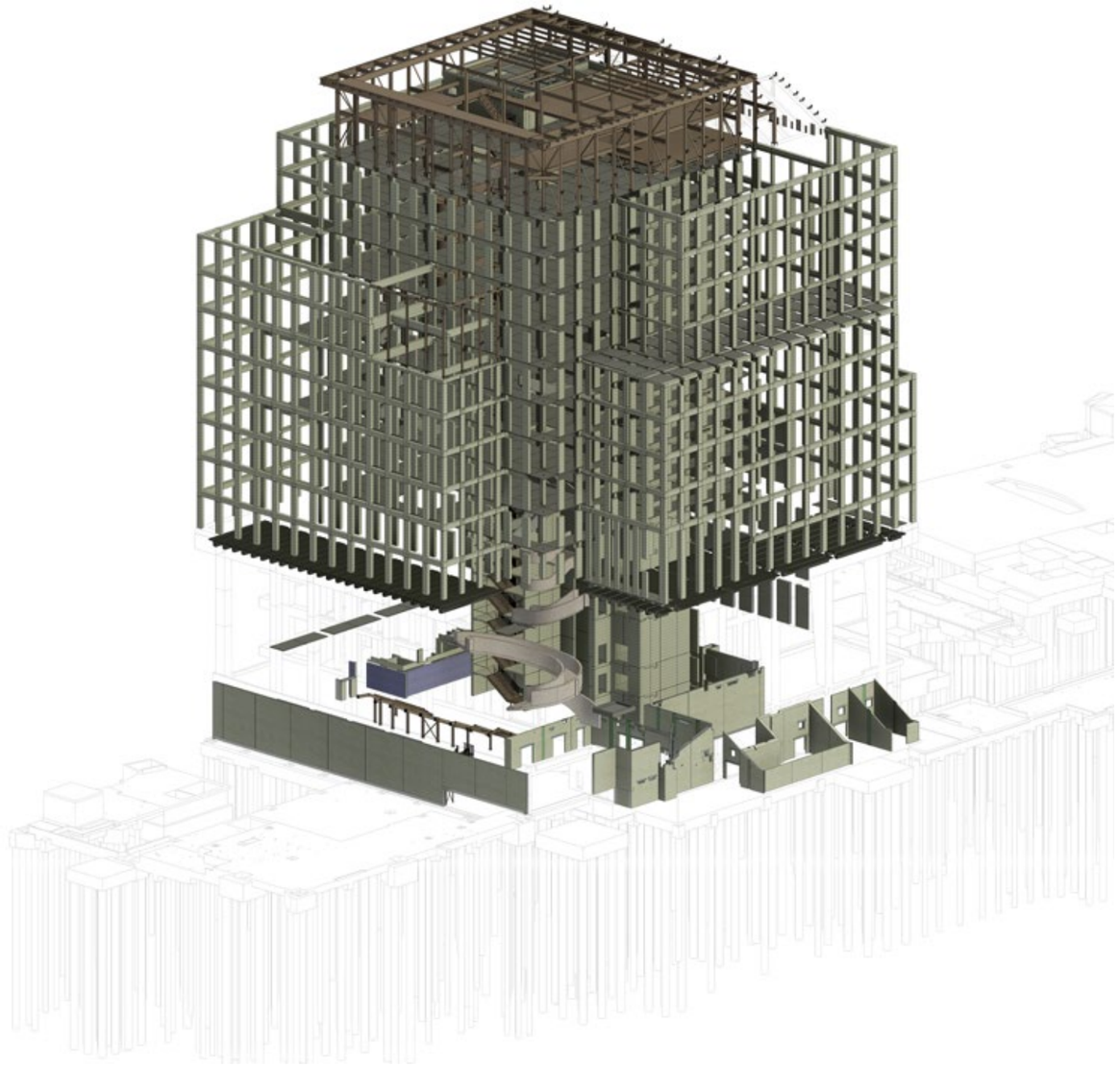
LCF theatre render



LCF theatre real

Site Photo

3.11 London College of Fashion (LCF) -
Precast Concrete Structure and Façade Engineering



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Igus GmbH
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Investec
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Kent Institute of Medicine
and Surgery
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Laing O'Rourke
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London Borough of Bromley
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and Chelsea
London Borough of Lewisham
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and Tropical Medicine
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Lufthansa

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Manchester Airport PLC
Metropolitan Police Service
Moorfields Eye Hospital
Mount Anvil
Ministry of Justice
Ministry of Defence

N
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North Manchester
General Hospital
Norstead

O
Oxfordshire County Council

P
PM Property Services

Q
Qatari Diar Delancey

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S
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SEEDA
SES
Serco
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Shepherd Group
Sir Robert McAlpine
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SnoozeBox
SPb Renovation
Spie Matthew Hall
Stanhope
Swire Properties

T
Tate Modern
Tesco Stores Ltd
The London Clinic
Three Valleys Water
TRE Global

U
University College London (UCL)
University of Southampton

V
Vastint
Vestfold Hospital
Trust - Norway
Vinci PLC

Y
Yotel

Thank You 谢谢你 감사합니다 Gracias Grazie ευχαριστώ Mulțumesc شكرك

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