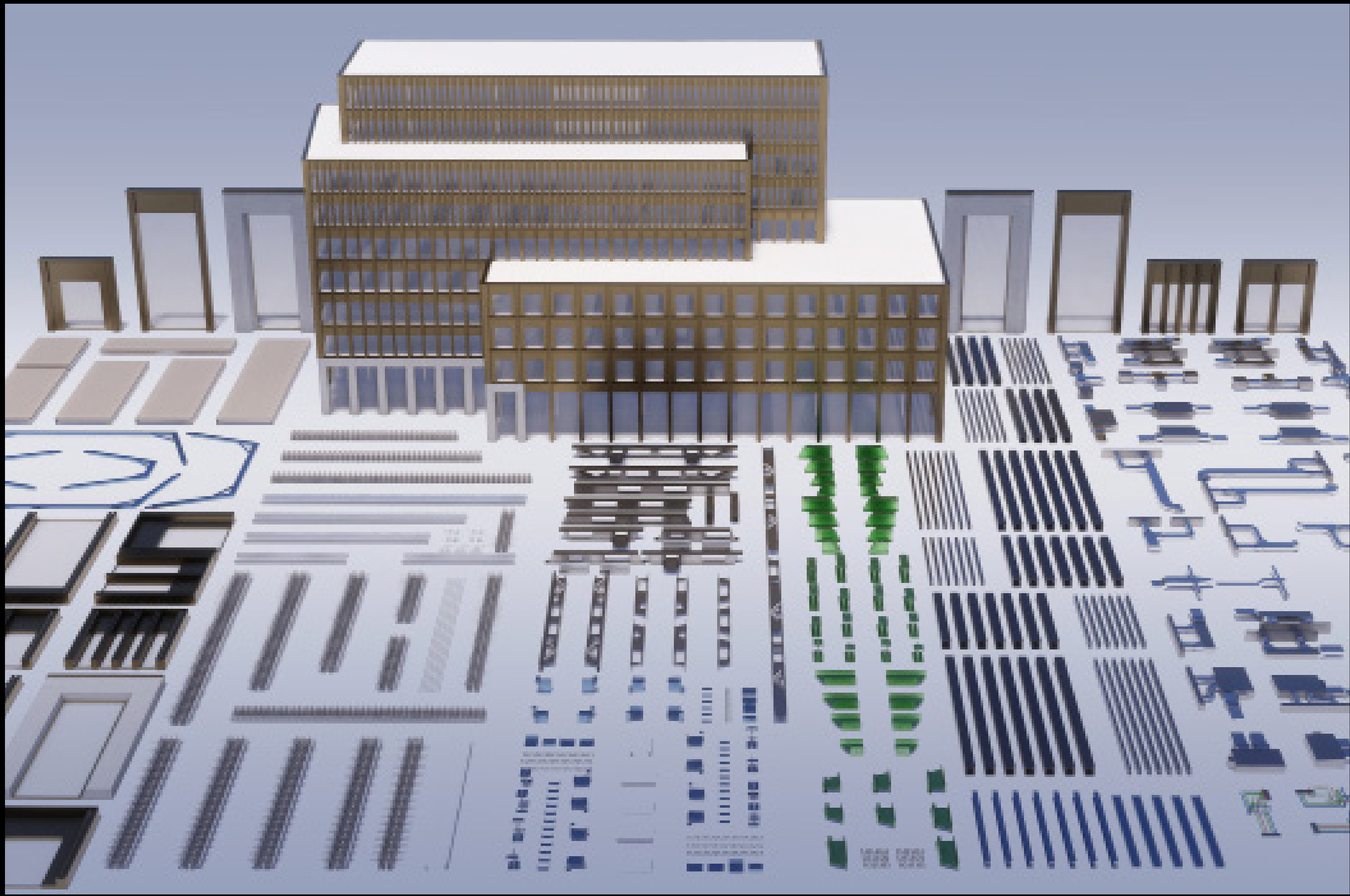
Systemisation and DfMA

Profile and Selected Projects

2022



Bryden Wood
London, Barcelona, Milan,
Singapore, St Albans

Tel. 020 7253 4772
Email info@brydenwood.co.uk
brydenwood.co.uk

Bryden Wood

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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.

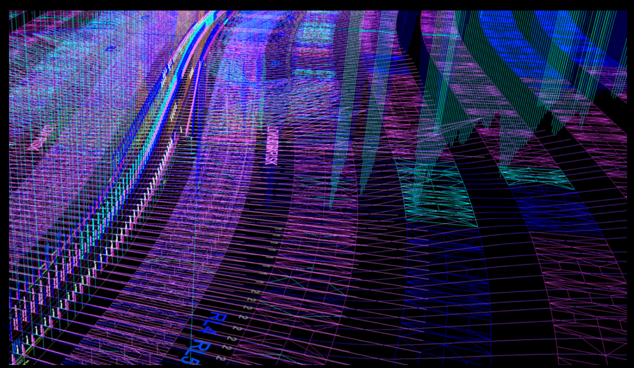
From strategy to delivery. Proven results

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 and Singapore 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

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.

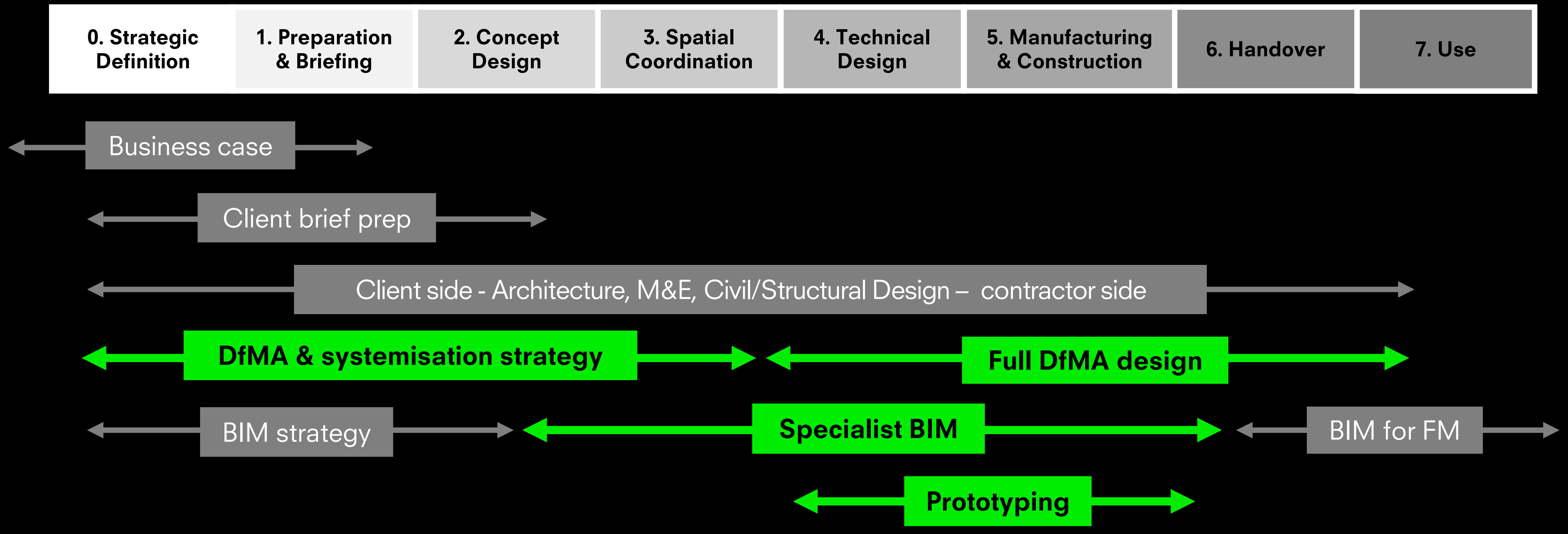
We maintain a clear design intent right the way through your project, to deliver the vision we set out at concept stage. Our team is growing constantly and currently has the following approximate percentage of people in each department:

- 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.



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.

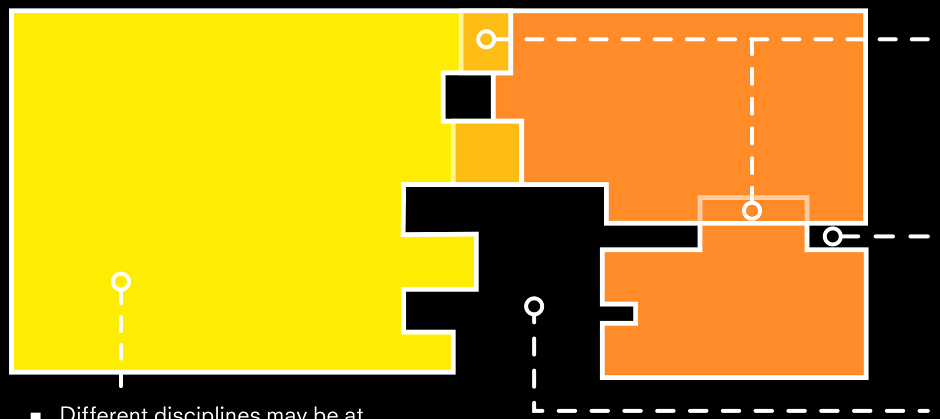
From design to delivery

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

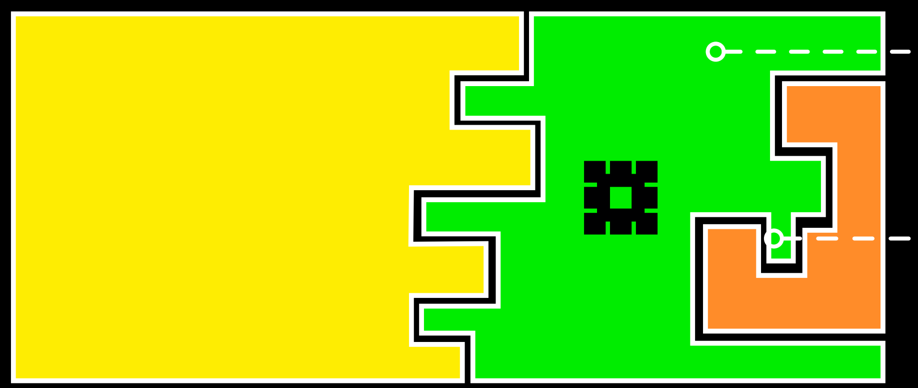
Conventional design scope interface at end of stage



- Different disciplines may be at different levels of resolution;
- Unlikely that disciplines are fully co-ordinated 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.

Design Team Stage 3/4
Specialist Contractor
Bryden Wood

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, eg 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.

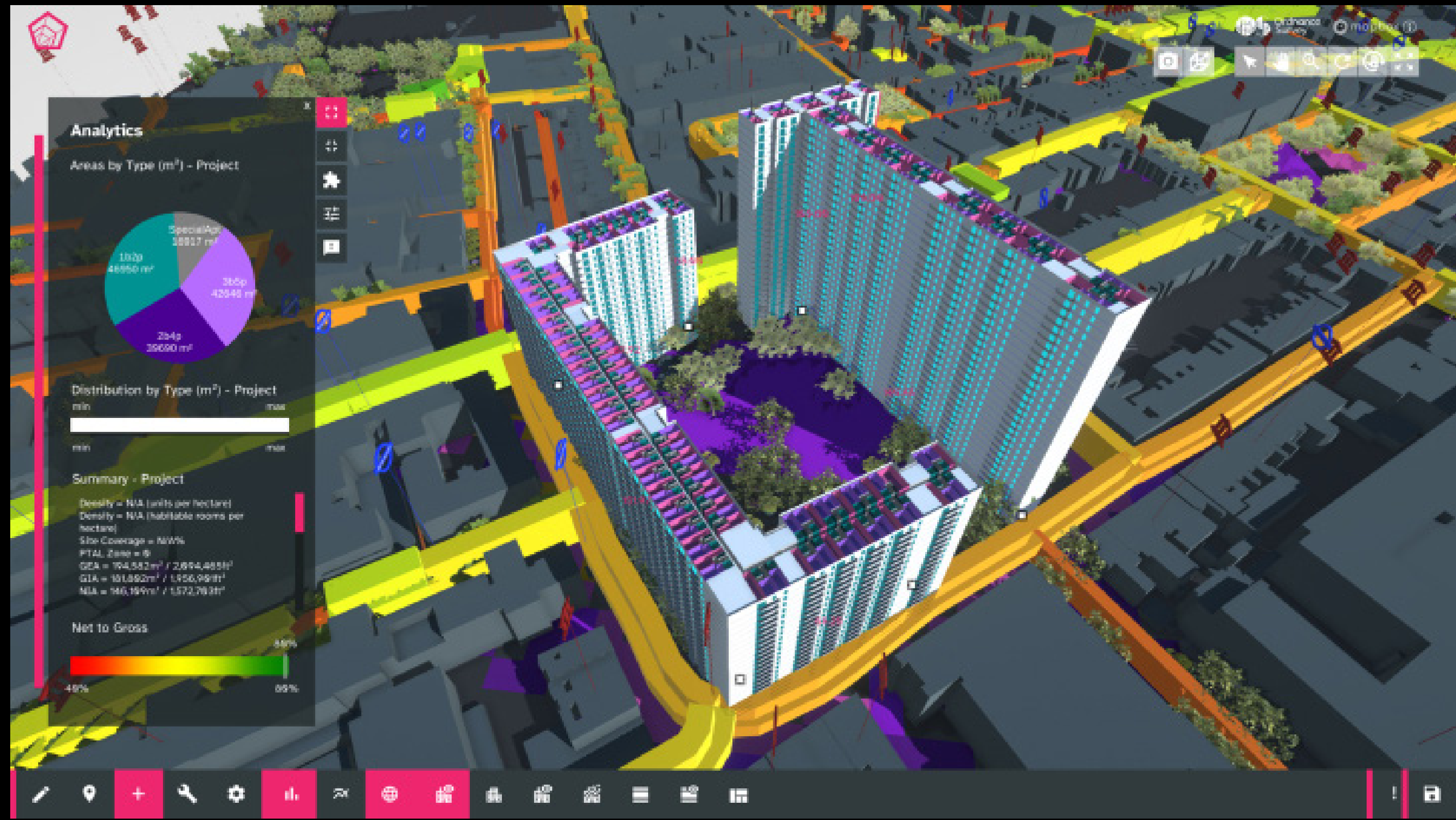
The role of configuration in construction technology

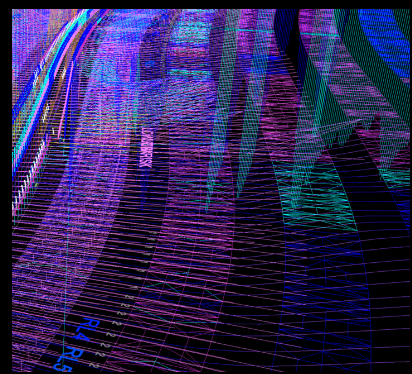
There is a common thread that runs through the wide range of computational design apps that we build: configuration.
We build configurator apps to give users the ability to configure a building in minutes – using pre-engineered components and according to pre-determined assembly rules – rather than design 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 technologues) to inform and evidence everything we do.

Technology in construction: learning, improvement and collaboration

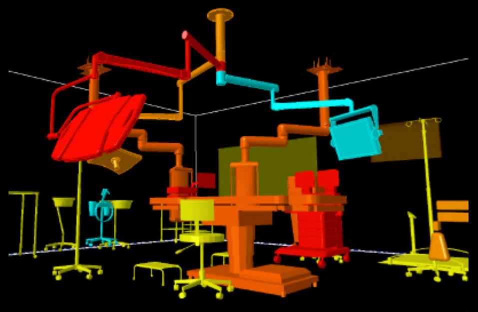
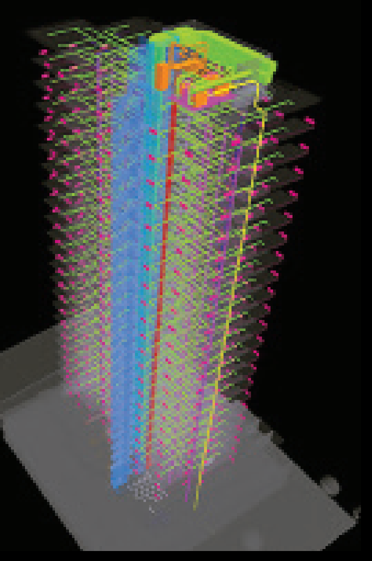
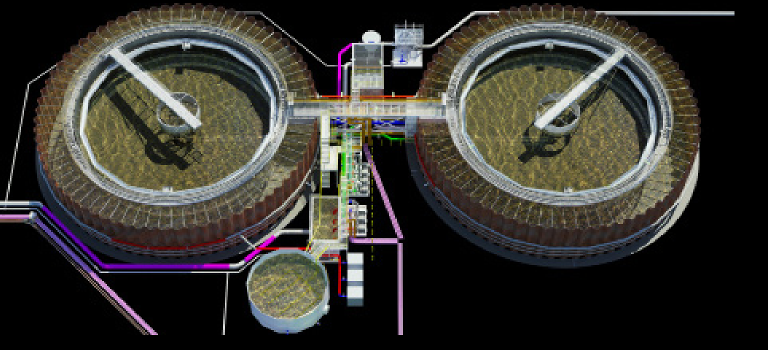
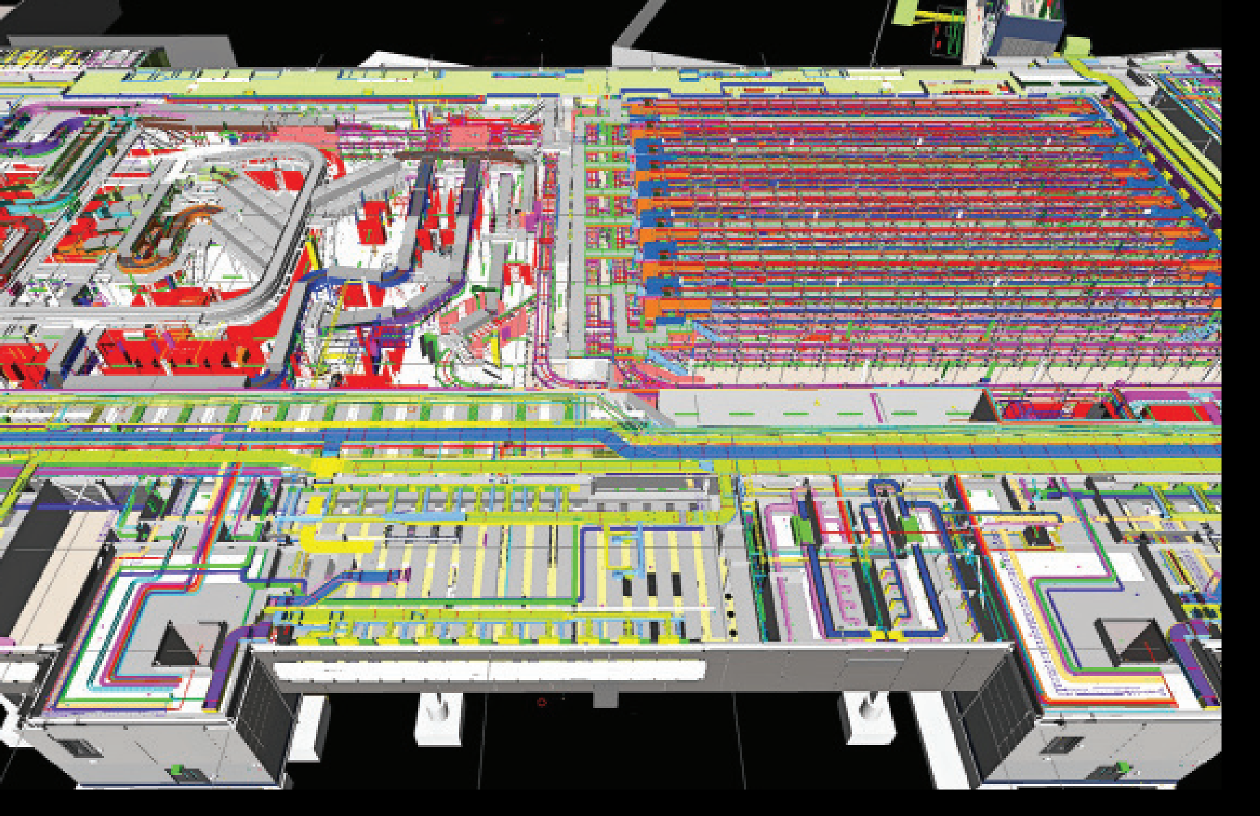
As with many other parts of our work, we have been keen to share and promote what we learn about effective new technologies inconstrcution, and new approaches. We were part of the UK government's efforts to produce BIM standards that could be applied across the whole construction industry. We have built 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.

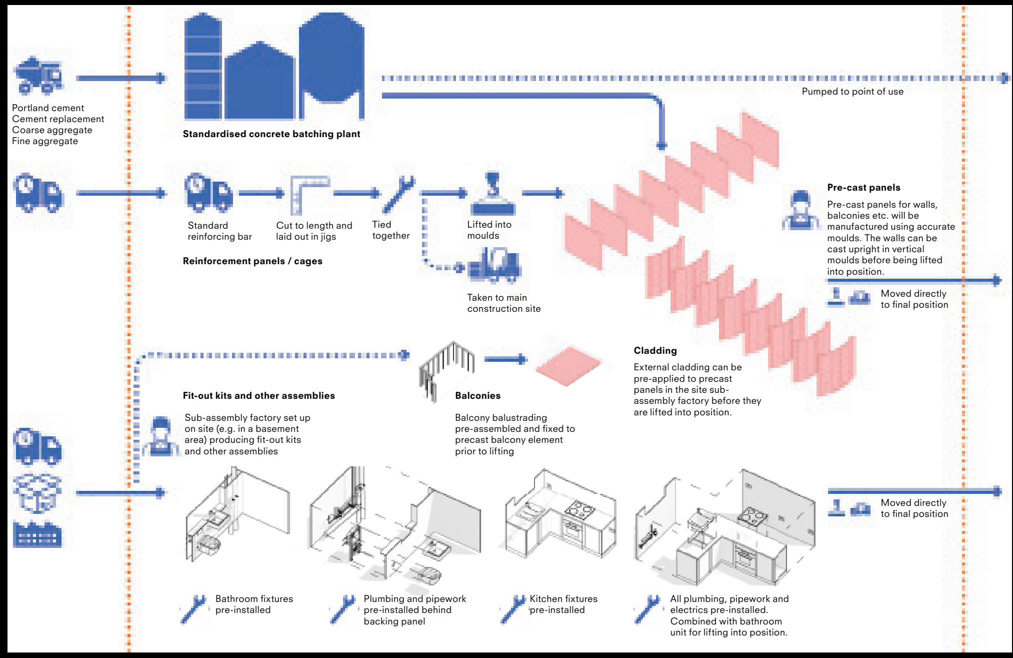
For example, individual components could be cost-effectively procured at scale from the existing specialised supply chain and delivered to a client-controlled consolidation centre. From this point, components would be grouped and transported to site on a just-in-time basis for installation according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

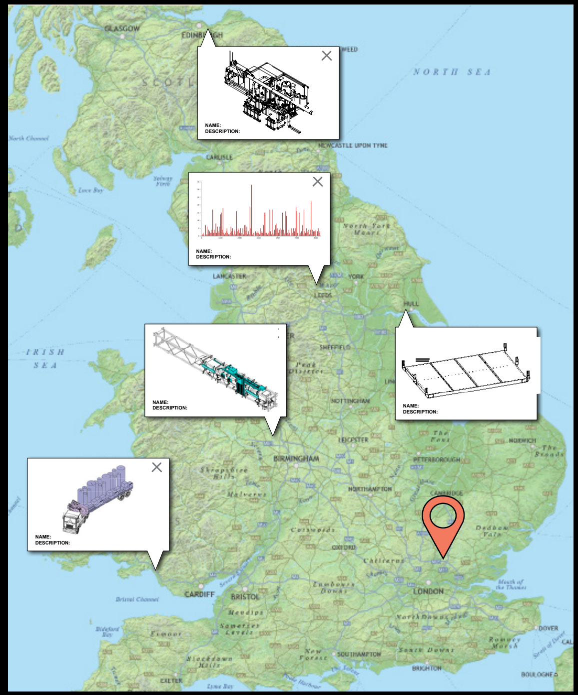
Logistics hubs

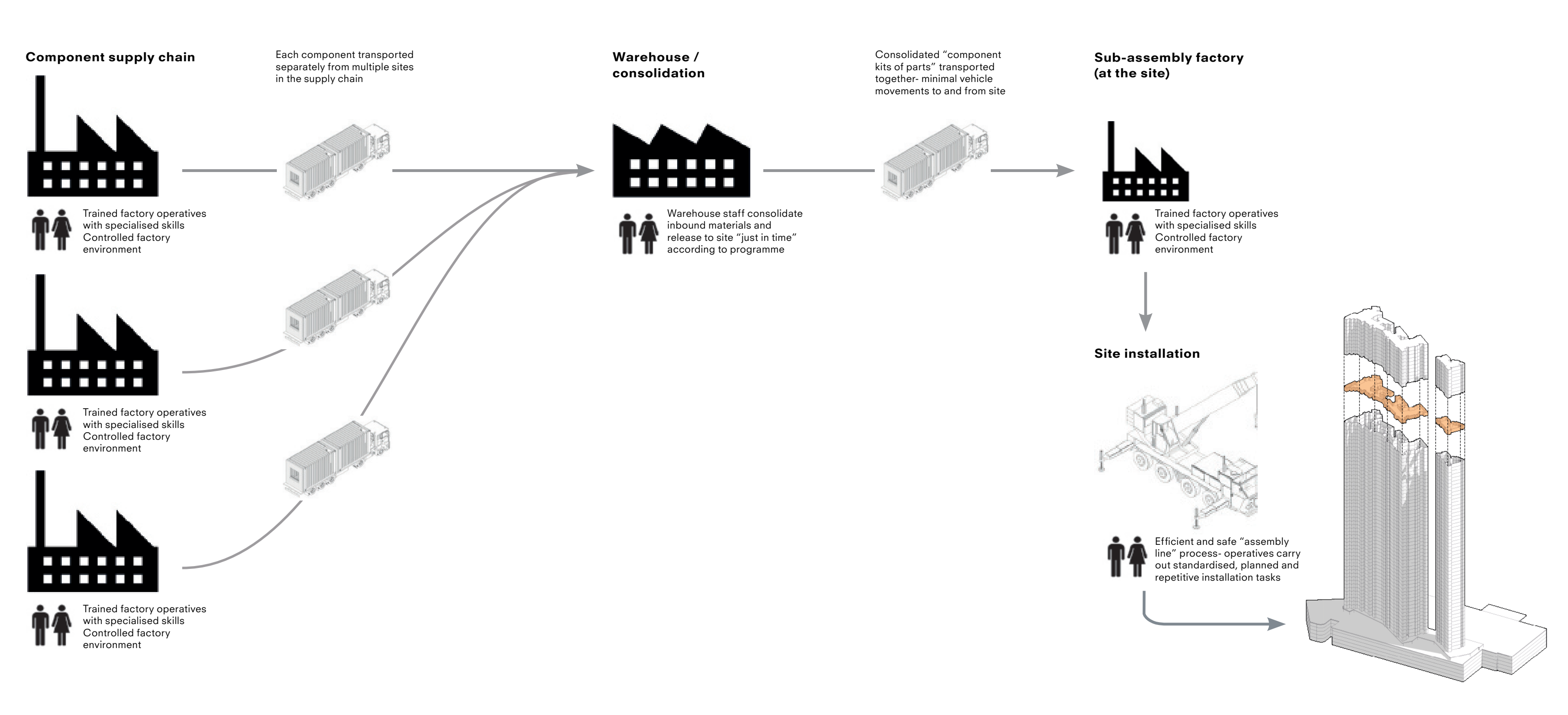
A DfMA-enabled production and assembly flow would allow more rigorous control of logistics, with loads of materials and sub-assemblies highly targeted to specific modes of transport, work areas and rates of flow production. Centralised consolidation centres or Logistics Hubs can carry out a range of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

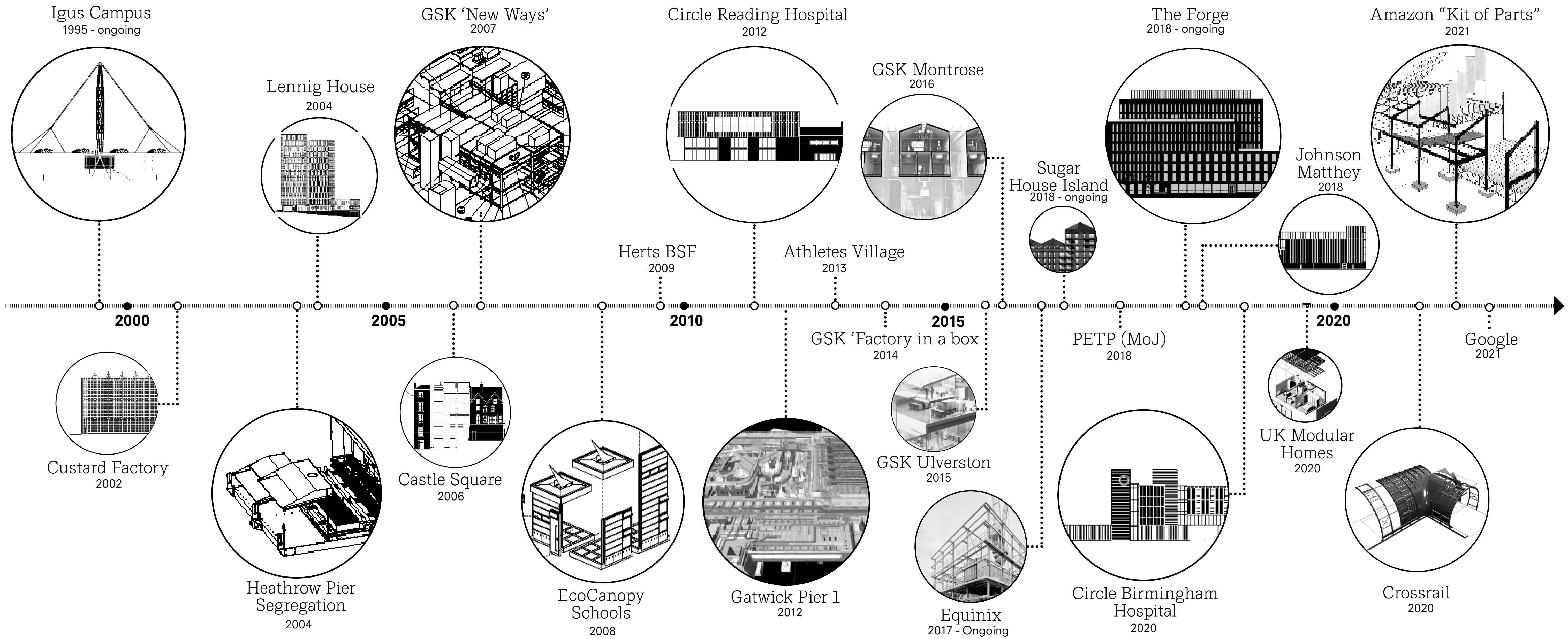






1.11 Methodology - Technology timeline
Delivering sustainable and MMC solutions

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

2.1 Edinburgh St James Centre

Project Summary

Client: Nuveen Real Estate

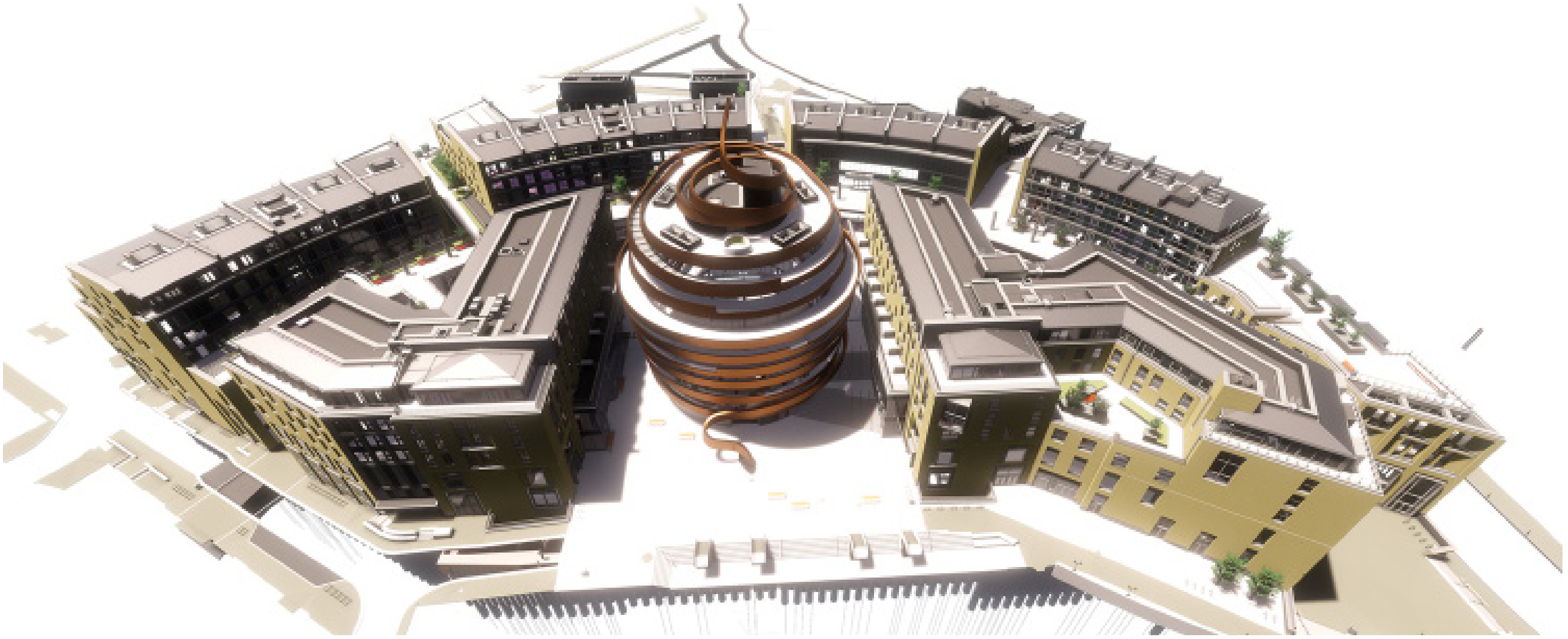
Our Partners: Laing O' Rourke, Expanded/ExpLORe

Construction Value: £1bn

Status: Under Construction

How we added Value:

- Bryden Wood 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
- Bryden Wood 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 Bryden Wood's capability in providing specialist facade design and detailing services. This is a live project which also uses a natural stone facade. Bryden Wood 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.

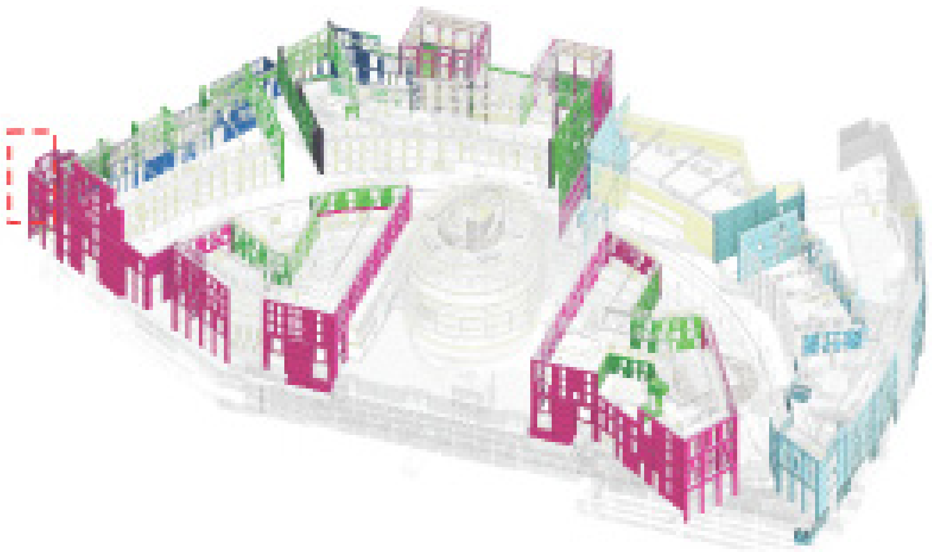
Designed by Allan Murray Architects, the 1.7 million sqft Edinburgh St James scheme will see the 1970s shopping centre replaced with 850,000 sqft of retail space, anchored by John Lewis, Edinburgh's first Everyman cinema, the UK's second W Hotel and 150 new homes.

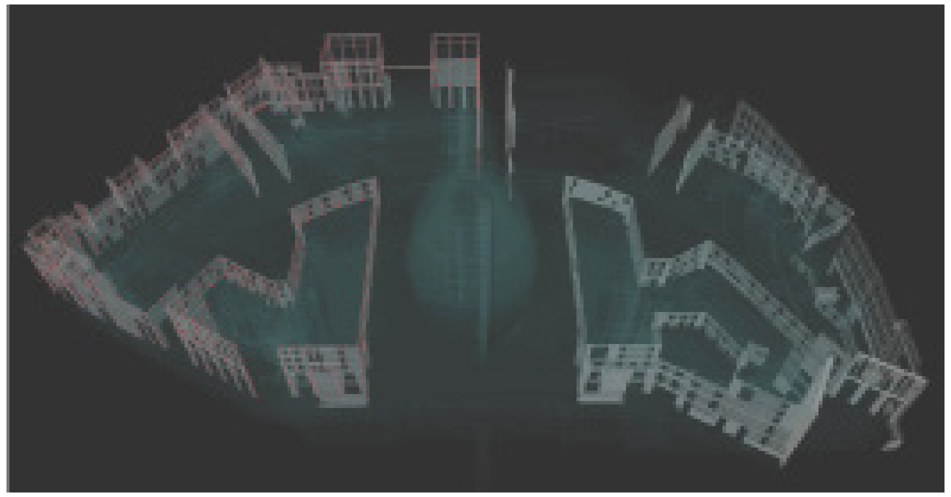
Bryden Wood led the interface detailing between the different facade packages and have done all the facade performance engineering and detailing:

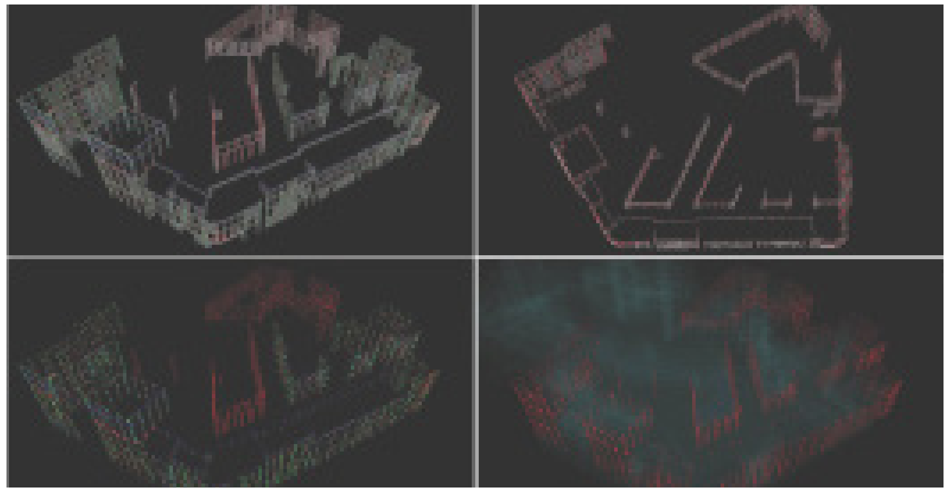
- Structural
- Thermal and Condensation Risk
- Waterproofing
- Air Tightness
- Fire
- Acoustics
- etc.

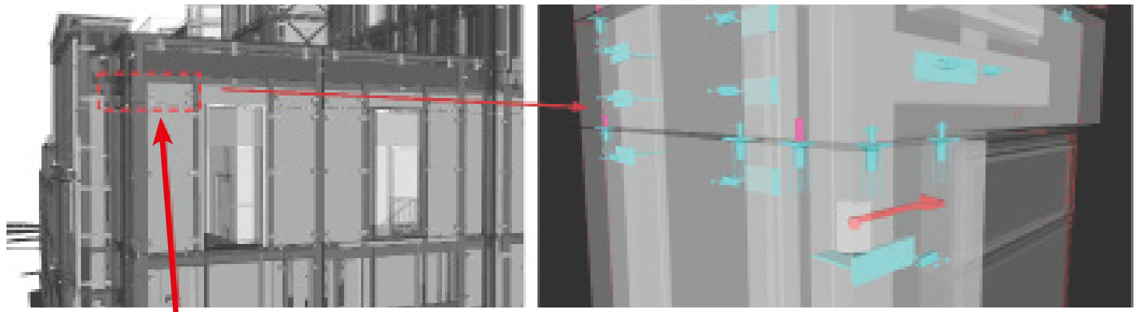
2.1 Edinburgh St James Centre

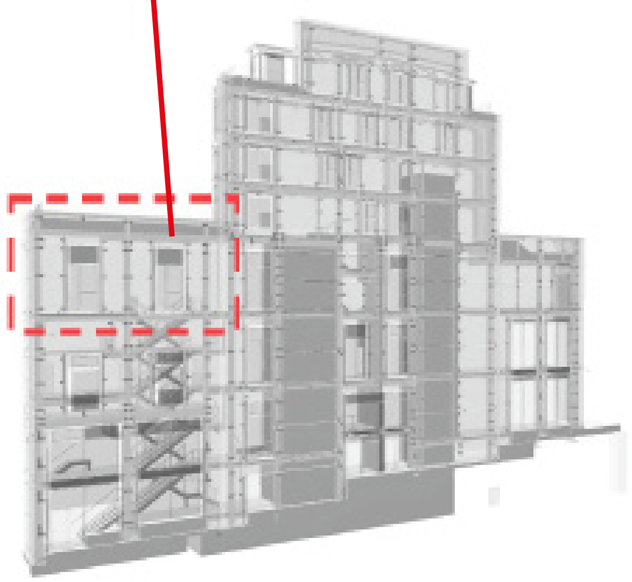
Revit / Dynamo super workflow

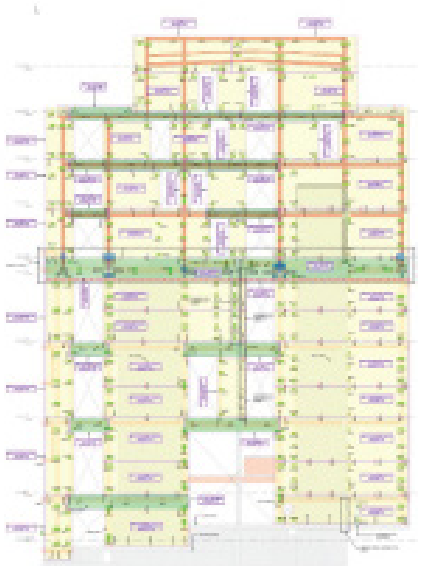




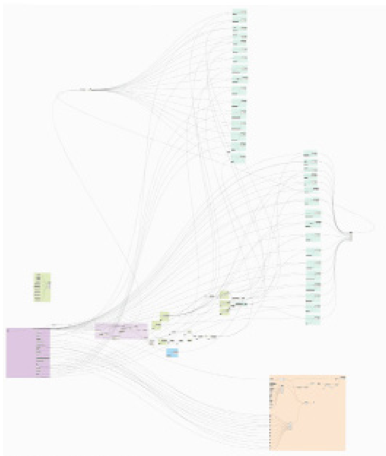


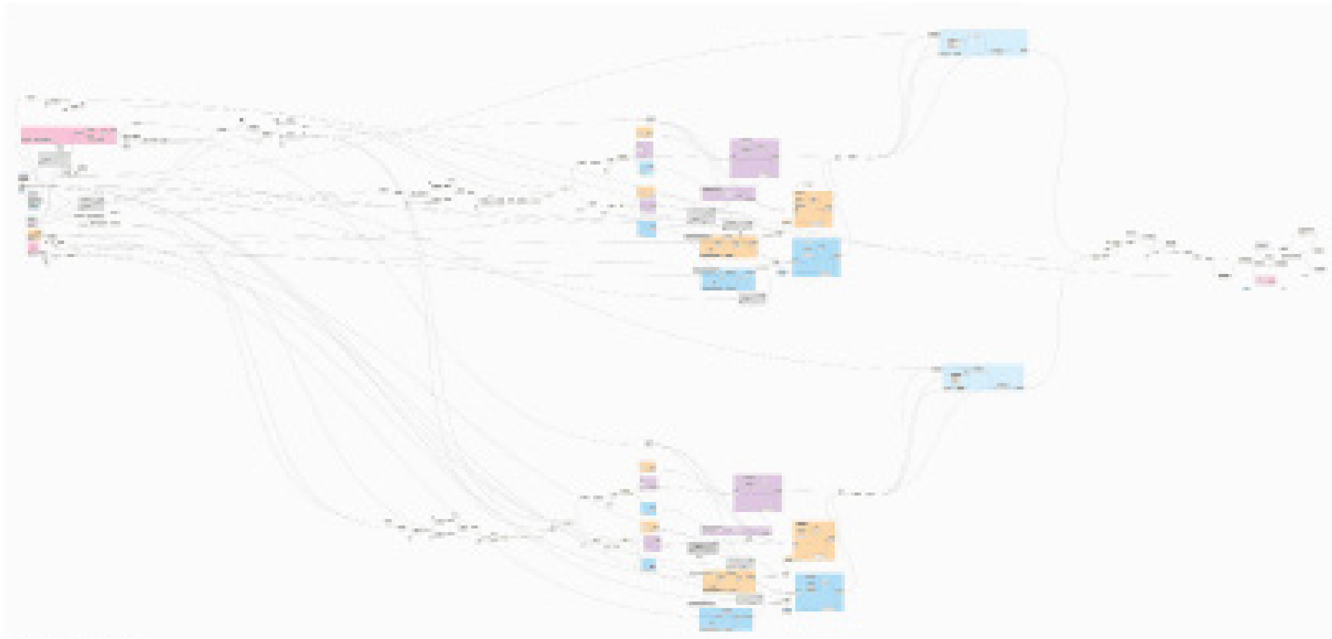


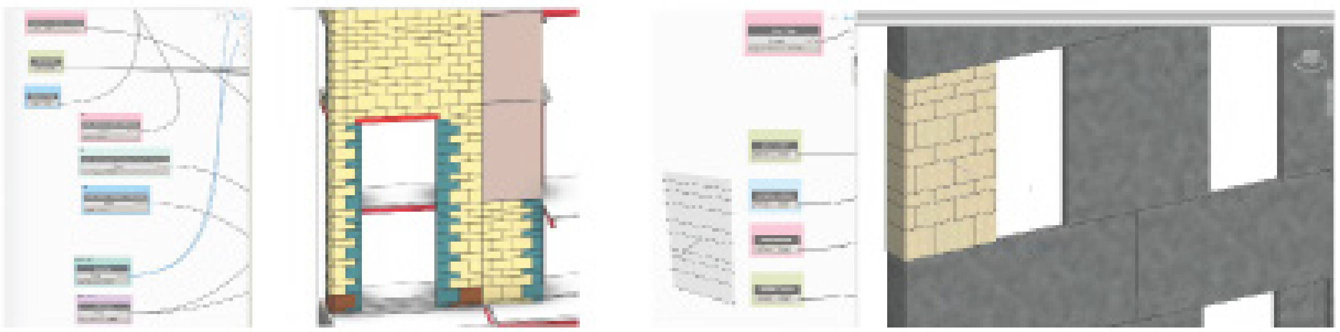




Bespoke Dynamo scripts



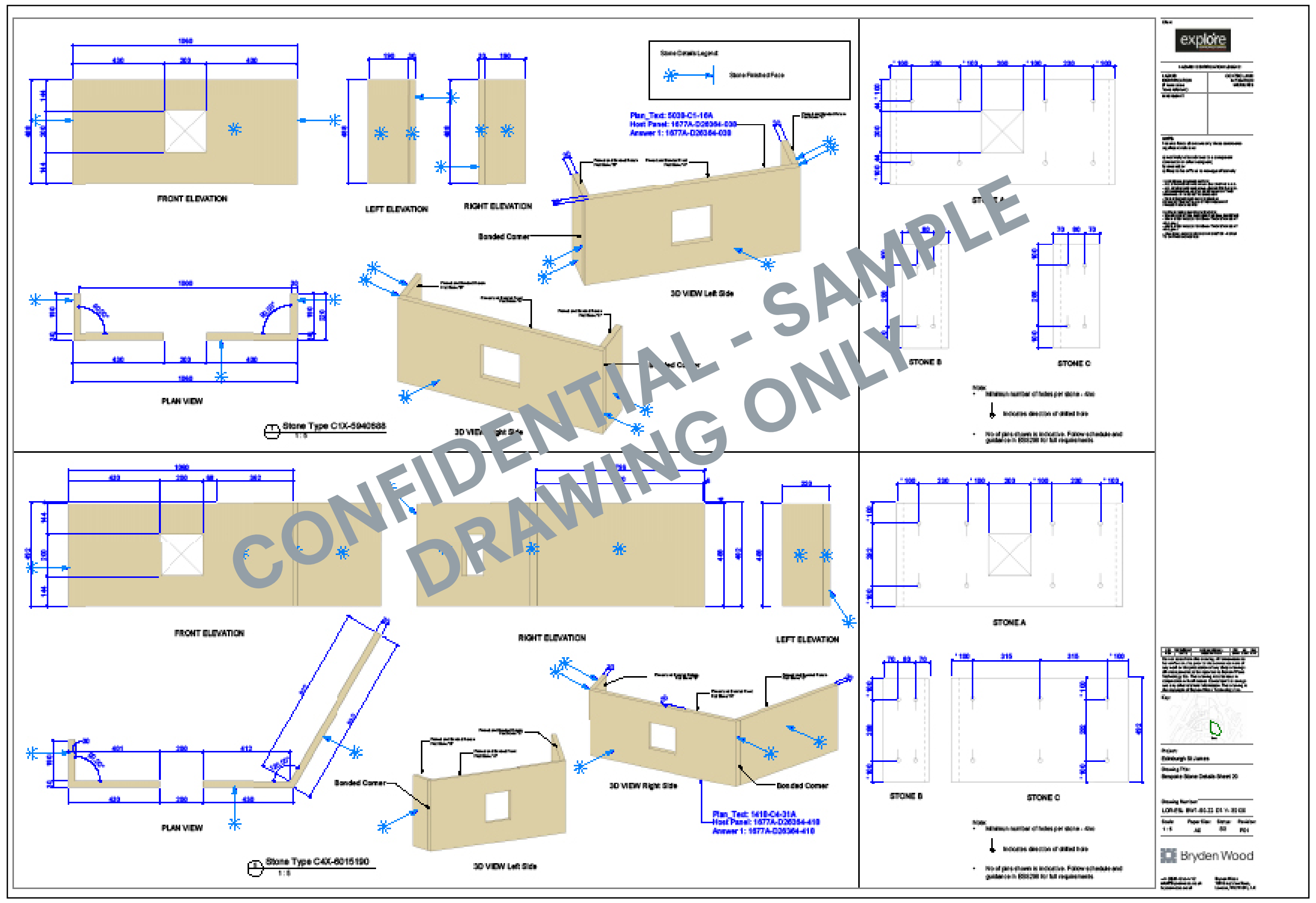




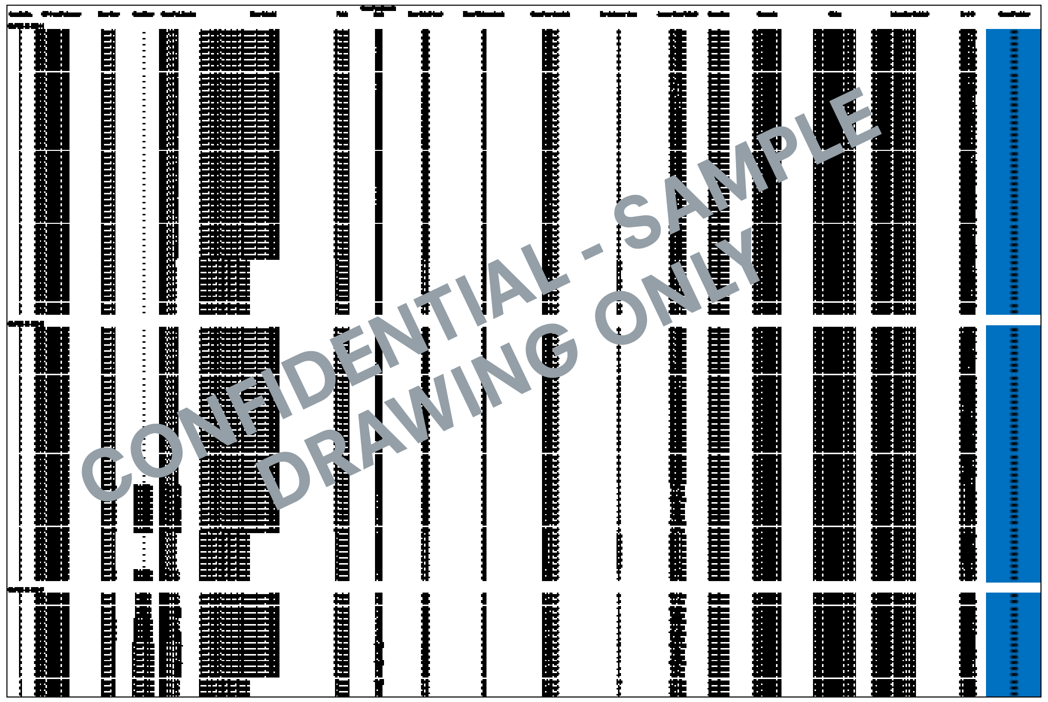
1,144 Precast Concrete Panels with Stone
568 Reconstructed Precast Panels
19,088 Pieces of stone in precast panels
540 Tonnes of stone

2.1 Edinburgh St James Centre

Stone facade - panelised and handset



Stone Detailing - Panelised and Handset Stone



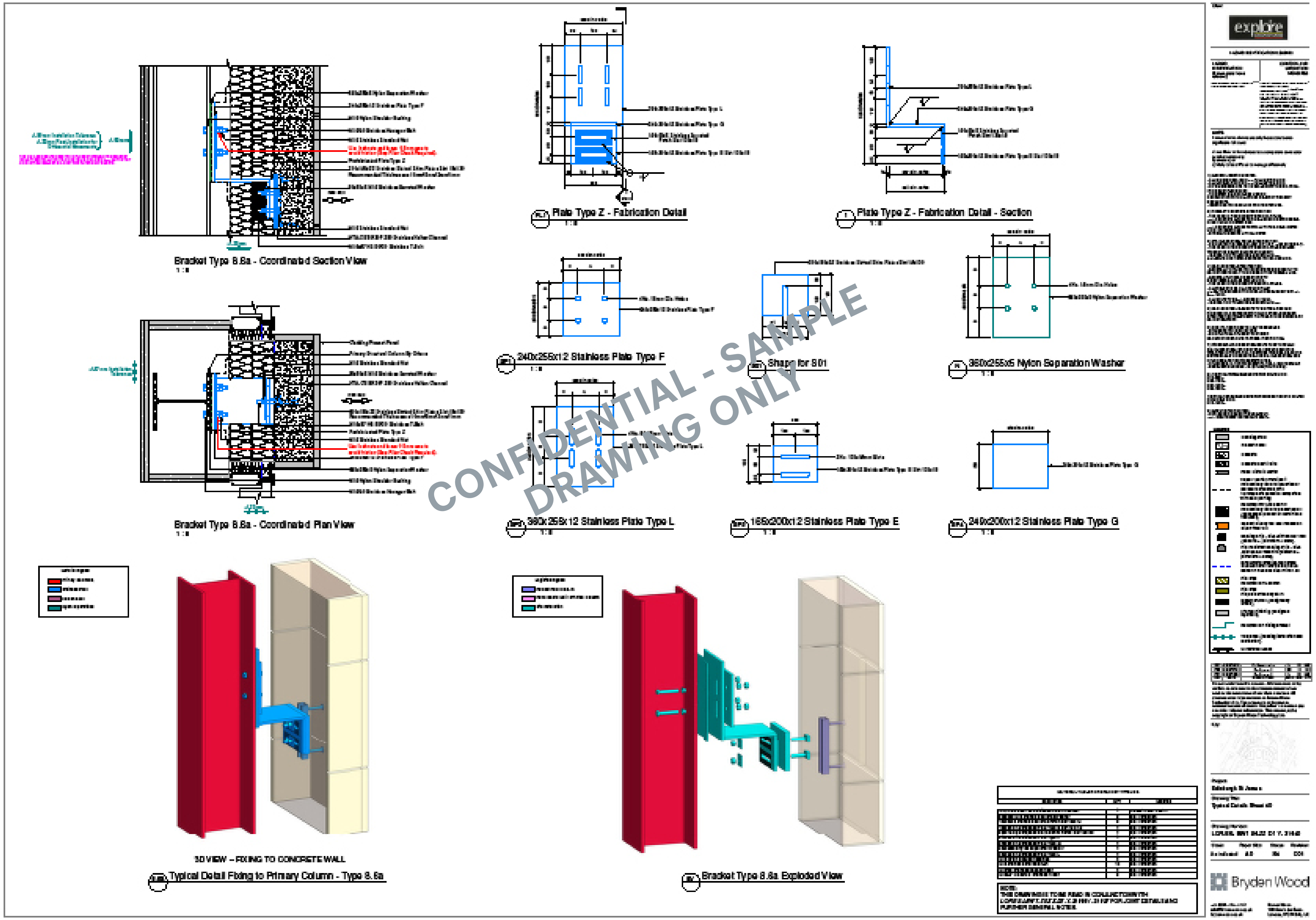
Stone Schedule

2.1 Edinburgh St James Centre

Site Photos from Explore

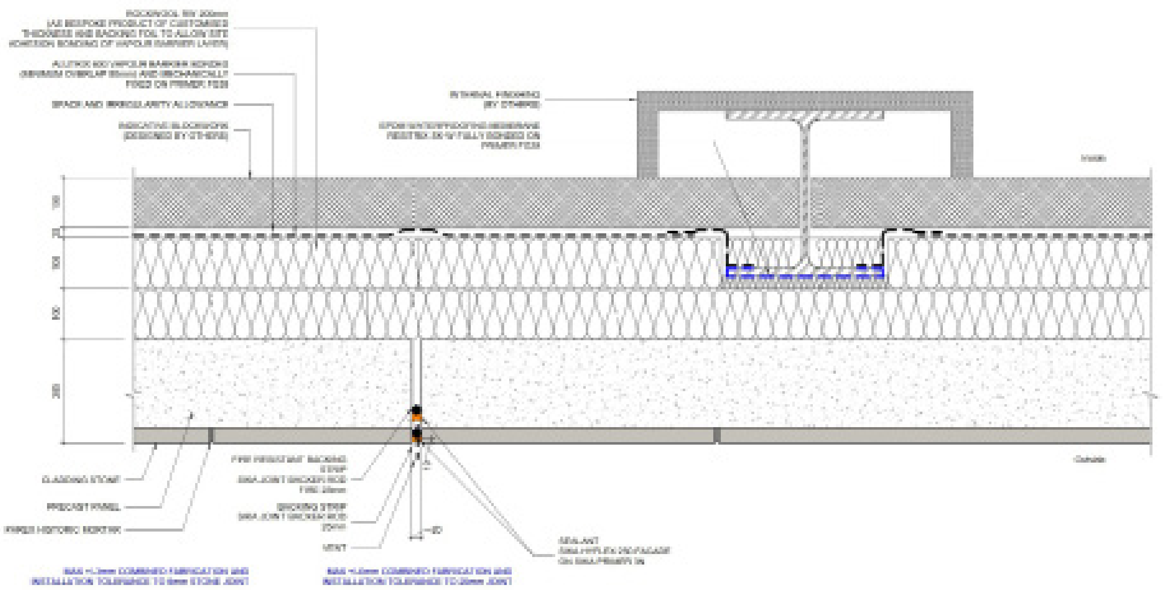
2.1 Edinburgh St James Centre

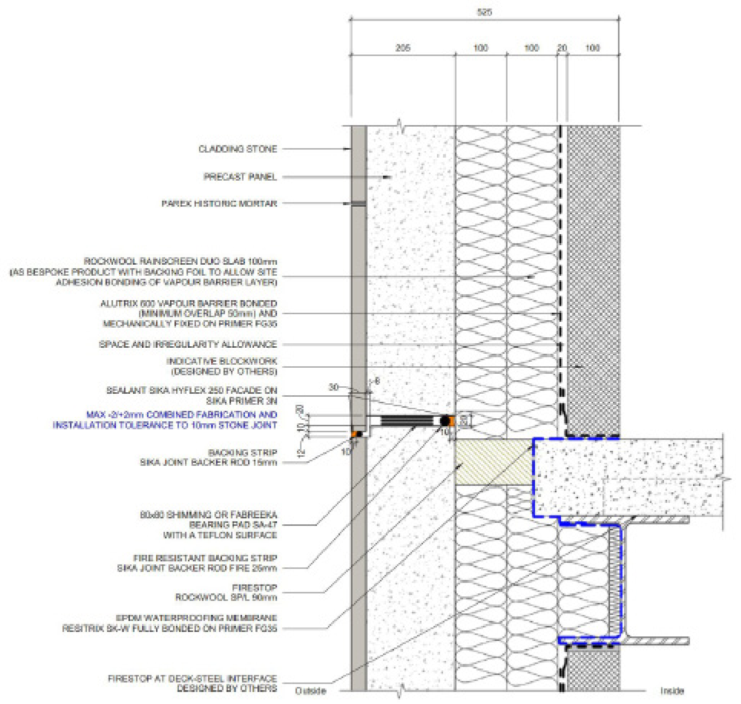
Sample Design Excerpt for bracketry

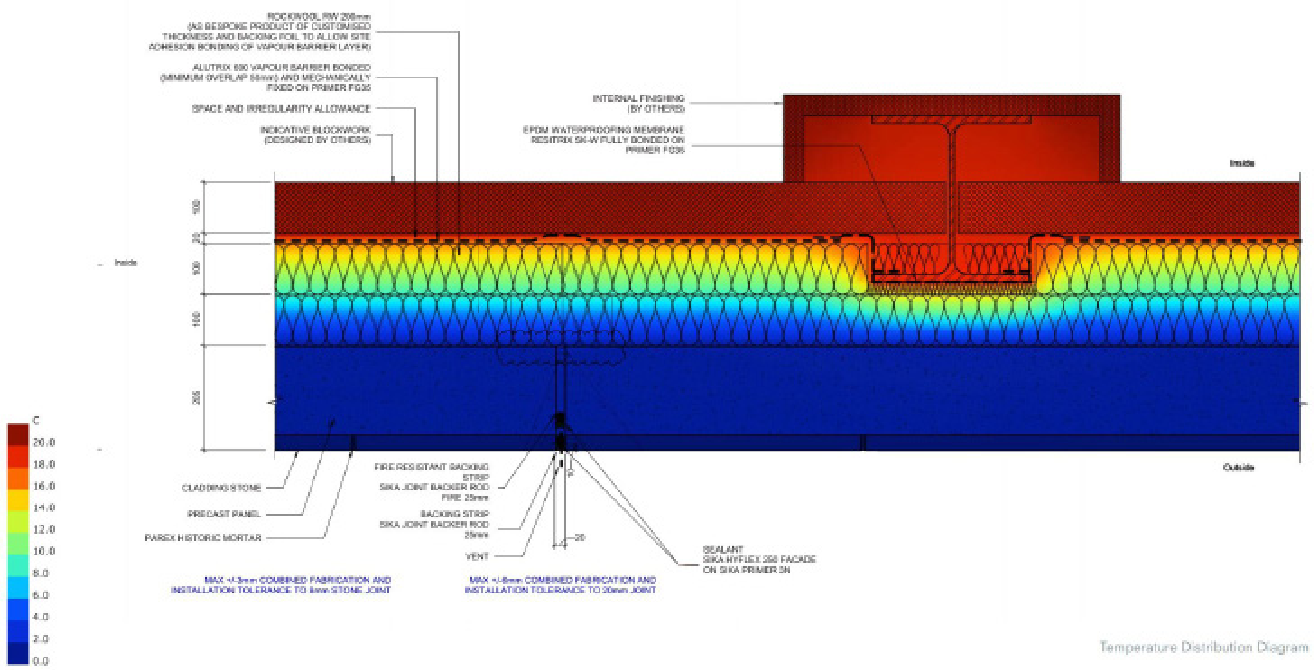


2.1 Edinburgh St James Centre

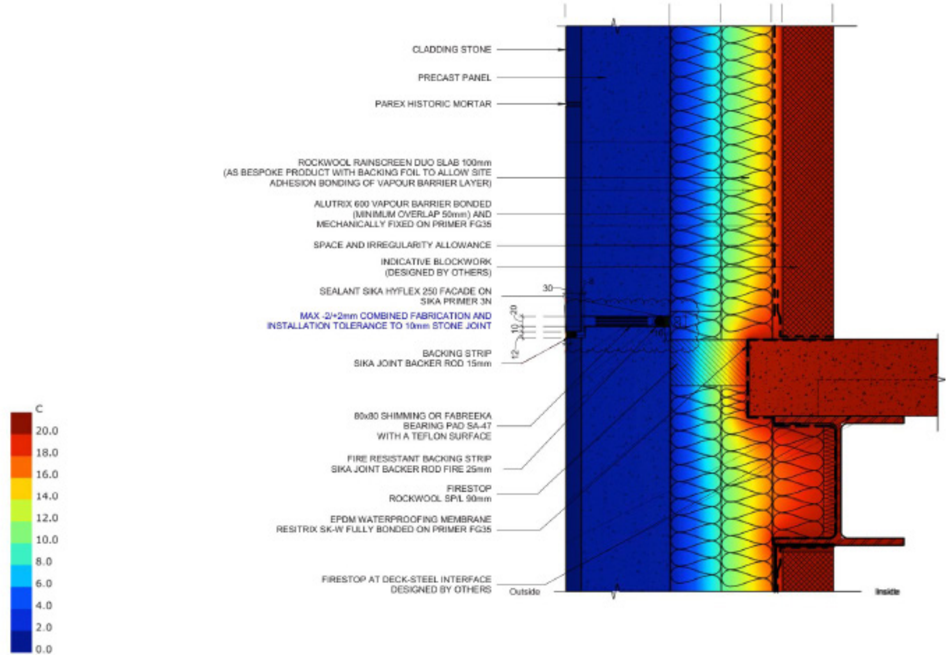
Sample Design Excerpt for details and thermal diagrams







Temperature Distribution Diagram



2.2 Google Headquarters

Project Summary

Client: Google
Our Partners: Laing O' Rourke, Expanded/ExpLORe
Construction Value: £1 billion
Status: Design Stage

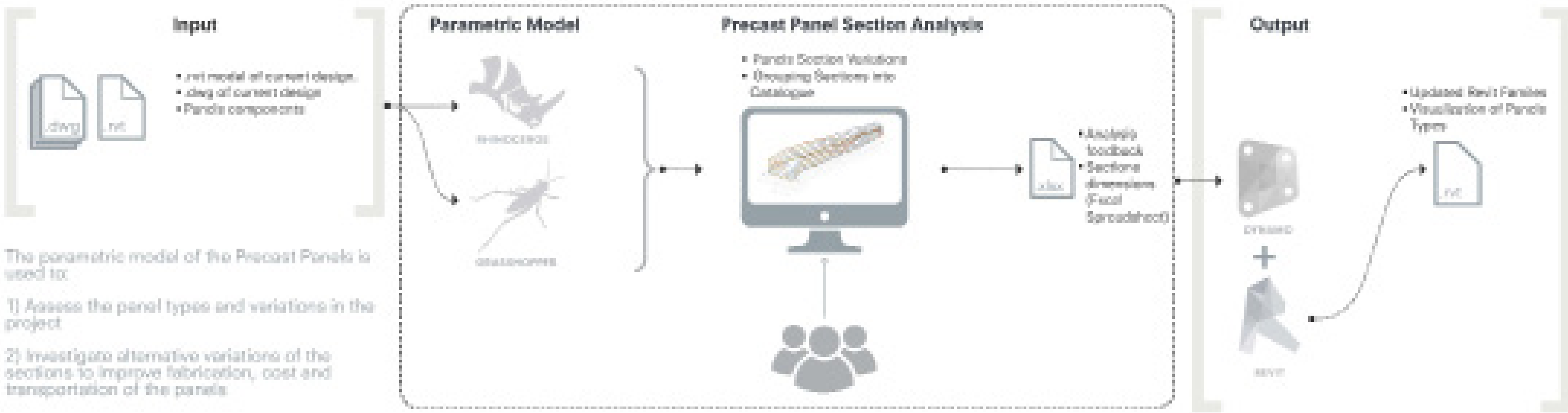
How we added Value:

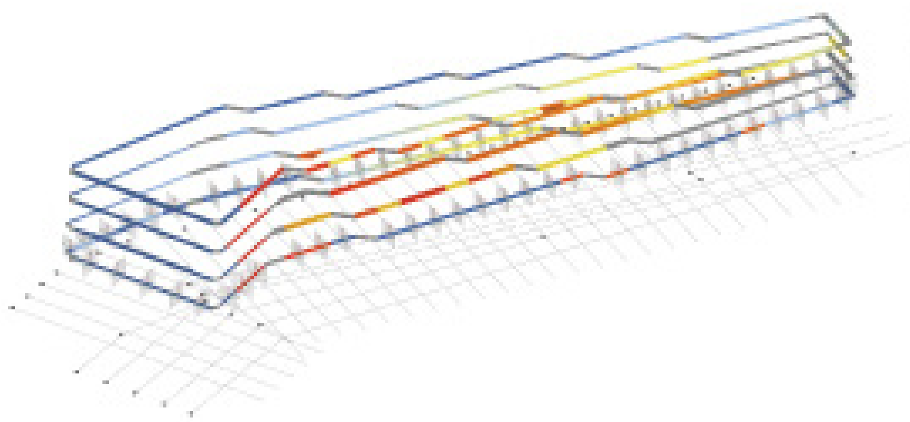
- Rationalisation of the design to afford maximum repeatability within the factory.
- Load testing for full optimisation.

Precast concrete cladding system

Bryden Wood 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.

Bryden Wood are currently working with Expanded/Explore 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. We have also started work on the precast cladding package under a separate contract.





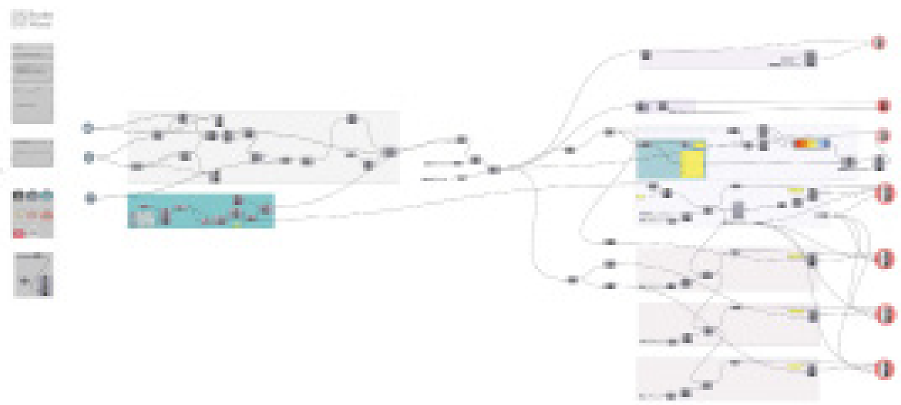
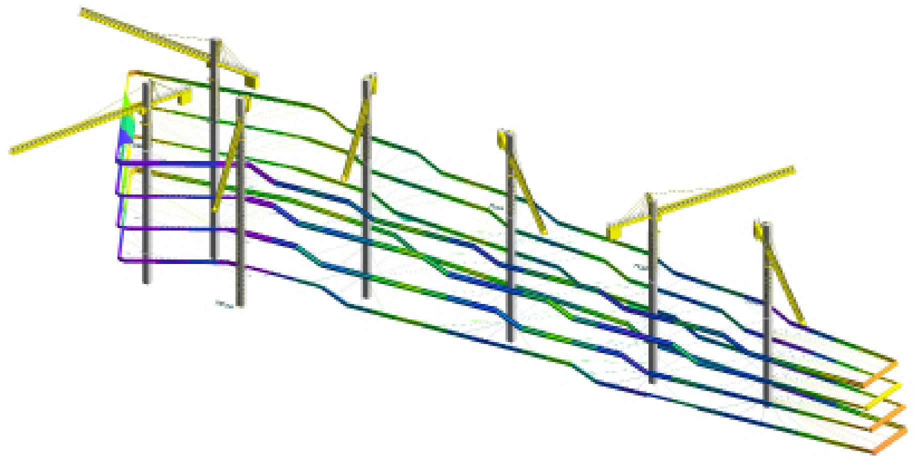
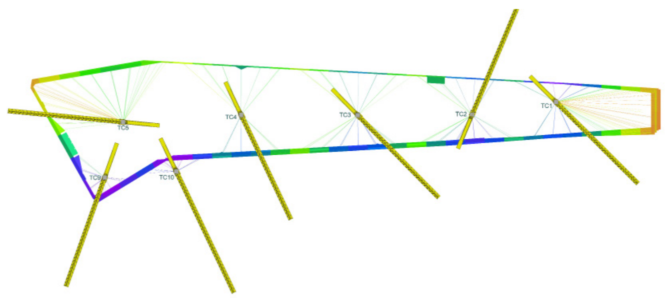
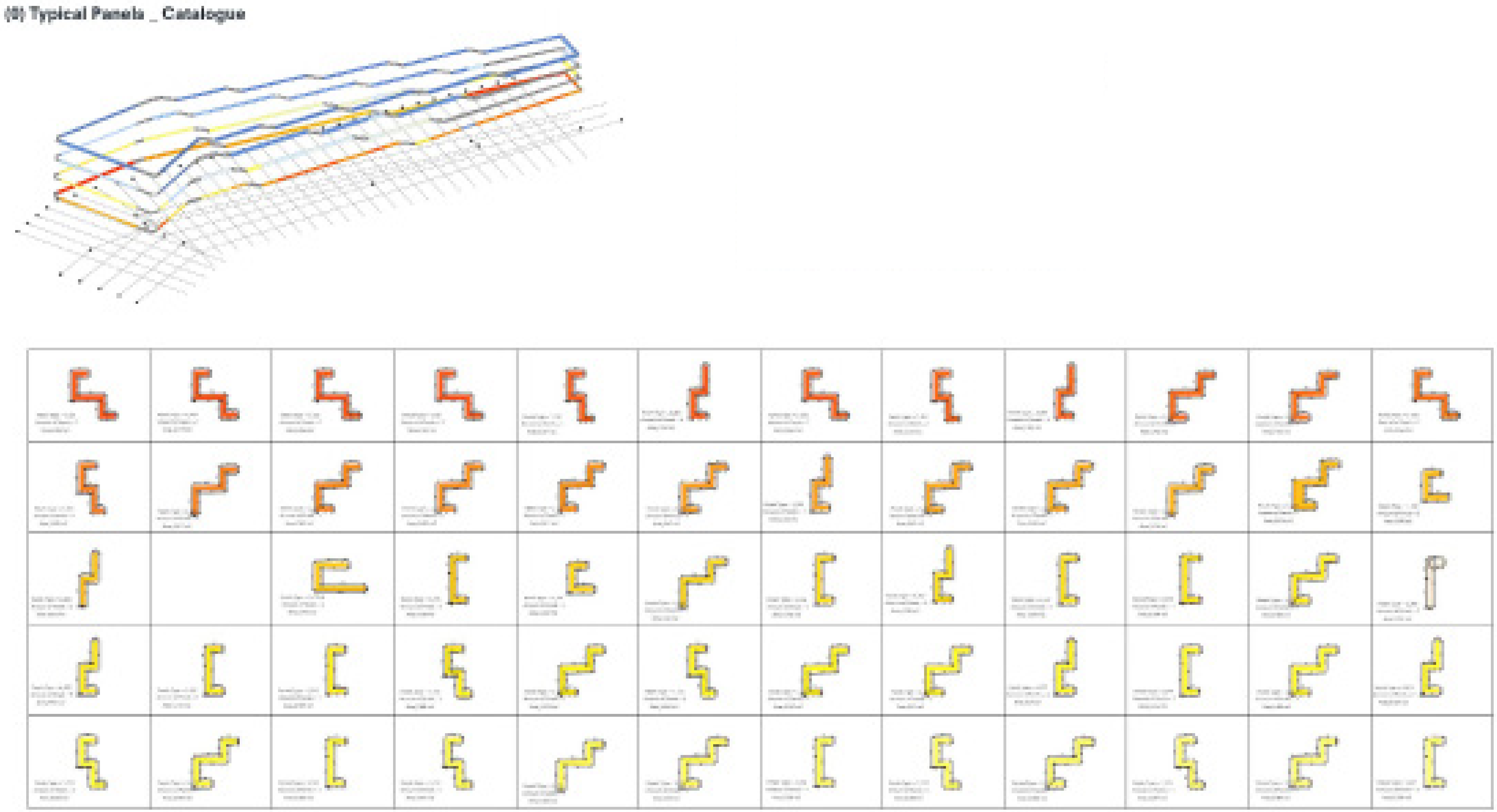



Image taken from Google or alternative source





2.2 Google Headquarters



2.3 Southbank Place

Project Summary

Client: Canary Wharf Group
Our Partners: Laing O'Rourke / ExpLORe
Construction Value: Confidential
Status: Under construction

How we added Value:

- Developed concept, factory and site strategy and full fabrication details for W-panels which provided full height glazing to the architect's requirements while still allowing full offsite manufacturing.
- Windows installed at ground level in the factory eliminates work at height on site.
- Inspection and sign-off of quality is substantially easier.
- Weather tightness achieved shortly after installation of panel through simple sealing operation.

Precast concrete cladding system

Bryden Wood were appointed on the Southbank Place scheme. Southbank Place is one of London's most high profile new landmark developments and is located behind the Jubilee Gardens on the River Thames and adjacent to the London Eye.

Initially, Canary Wharf Contractors commissioned a study to establish the programme and cost implications of different methodologies and what (if any) changes may be required to the architectural fenestration to facilitate each of the methods.

Bryden Wood was then appointed to the Four Casson Square tower to deliver structural engineering design for precast elements and connections. Together with ExpLORe, LOR and other project design team members, Bryden Wood developed a series of pre-cast punched panels in lieu of individual precast elements. The Bryden Wood solution for the façade, which used a post tensioned W shaped pre-cast panel, allowed the windows to be pre-fitted to the precast panels in the factory before delivery to site with no need for separate lifts for the projecting bay windows.

Design verification and factory QA

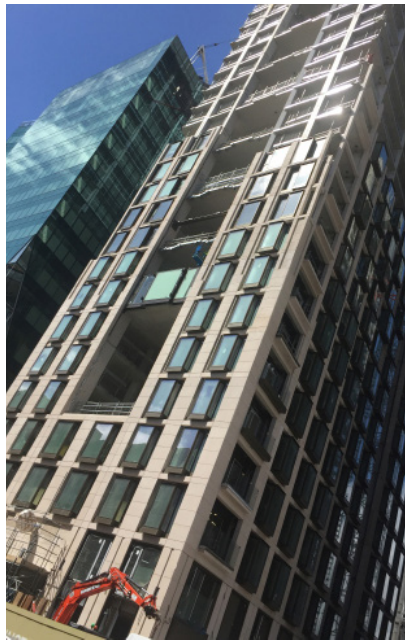
The following studies were undertaken during the design, fabrication and installation of Southbank Place. The images show the process used to confirm calculations that show potential deformation of the panels during stages of construction, assembly and installation.

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,

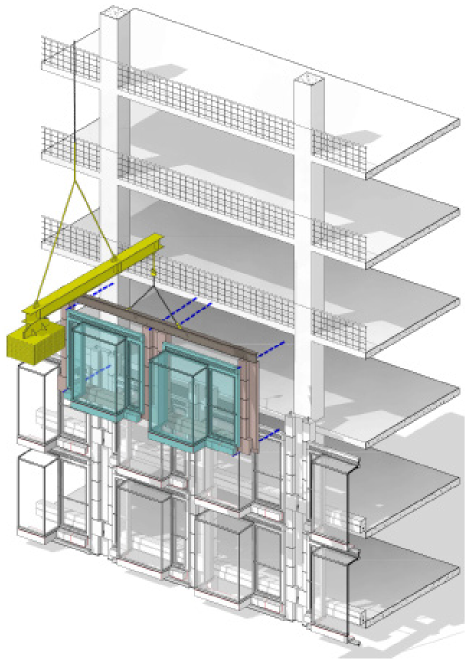
Demoulding, storage, transport and install on site - this design is fully aligned with the factory and installation process.

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 crack tested panels are delivered to site.

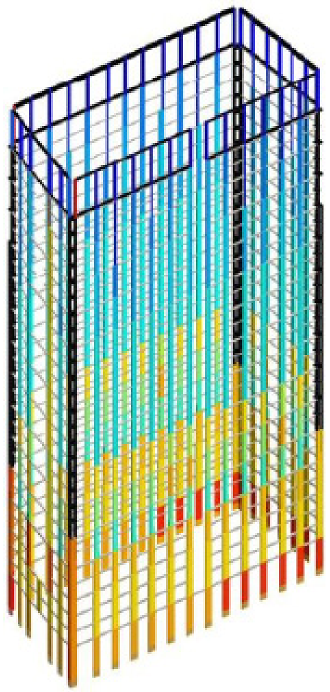
First cladding module lifted on site.



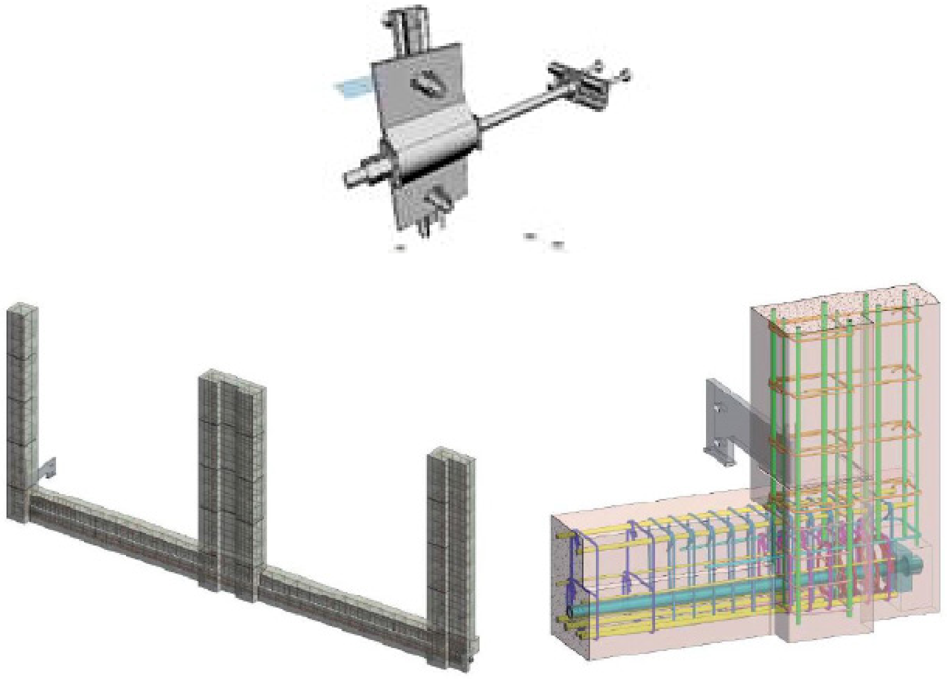
Construction stage - cladding module installation progress.



3D model of construction sequence showing cladding module installation.



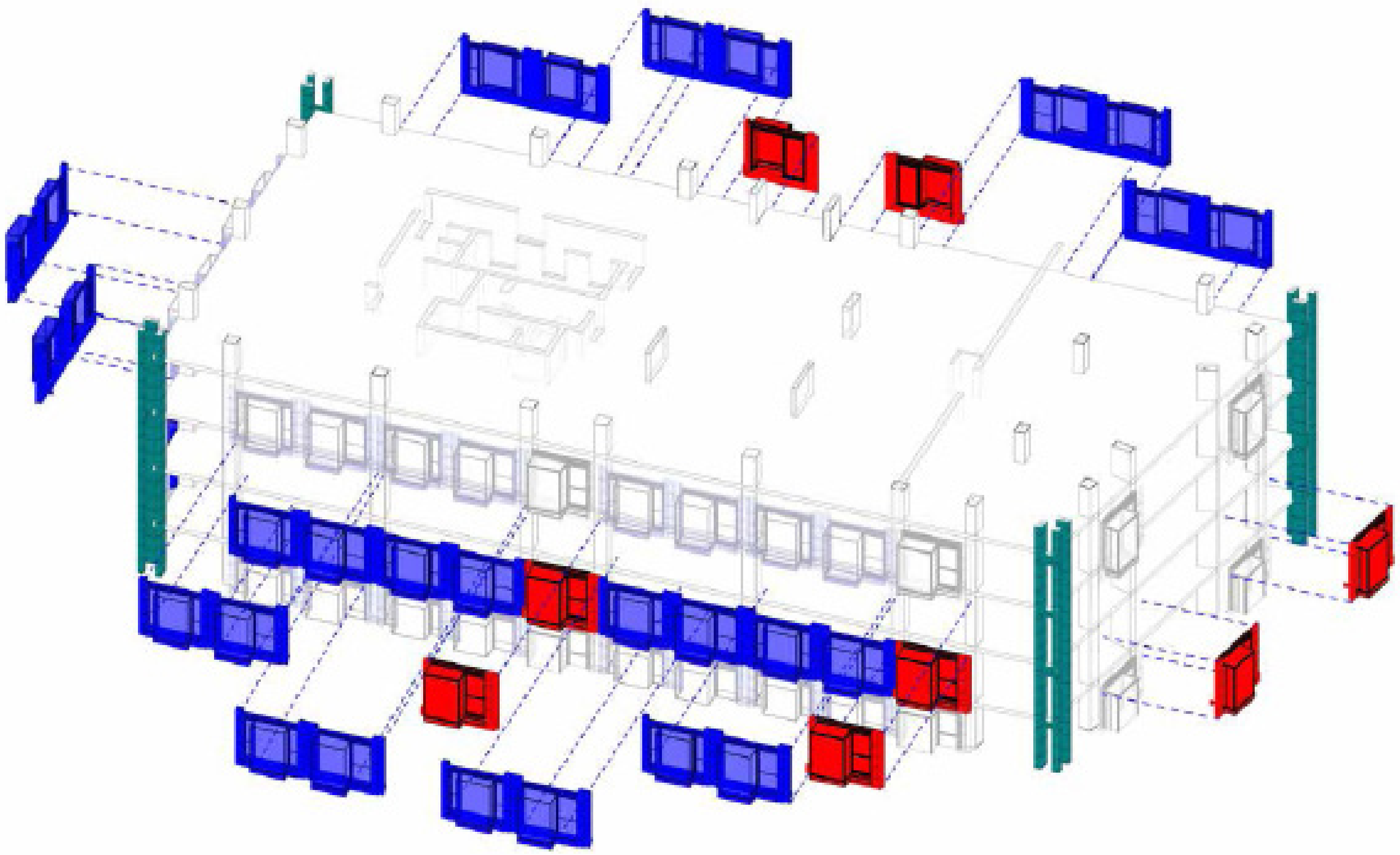
3D model views of structural analysis models showing deflection of structural elements.

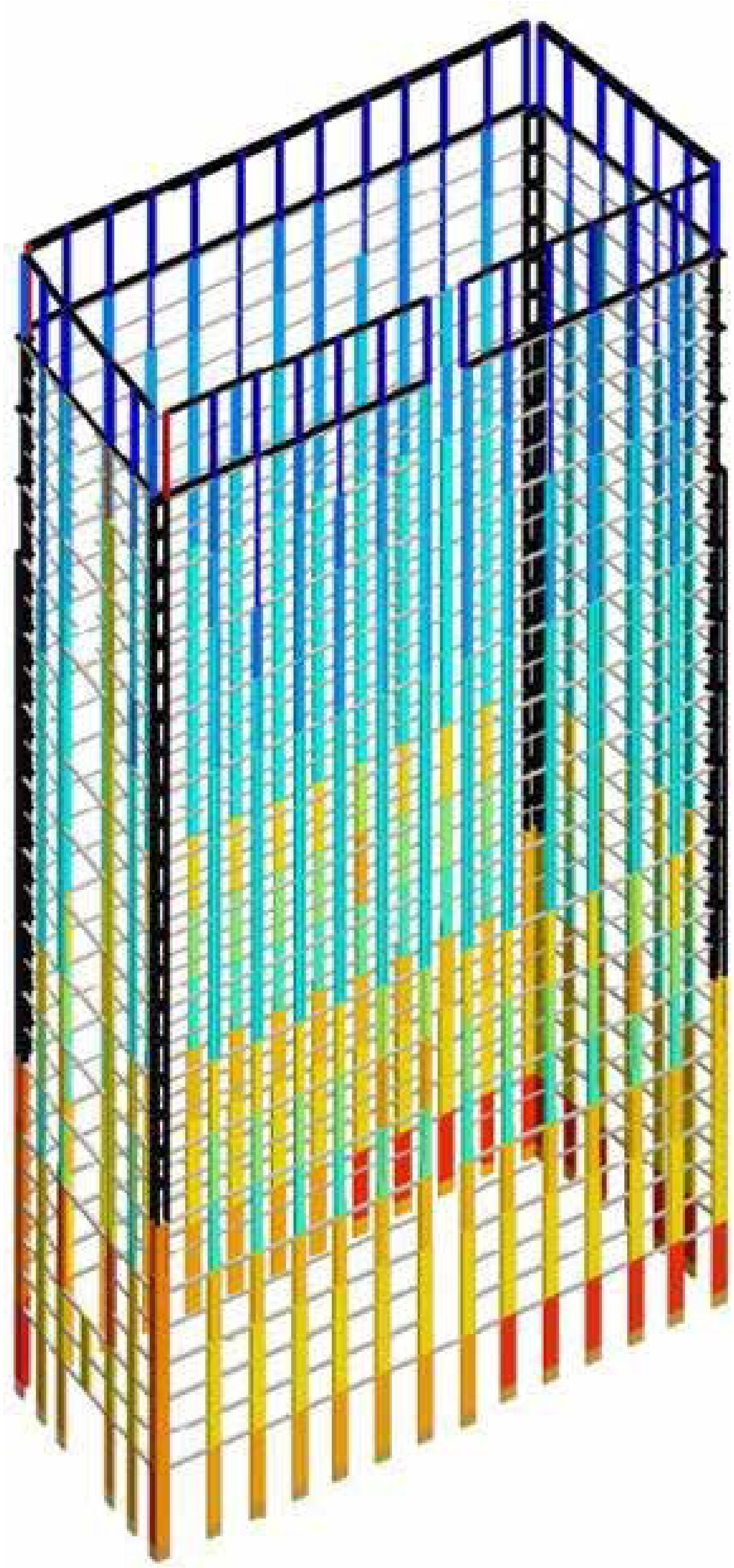


3D models of cladding fixing bracket and precast concrete module rebar

2.3 Southbank Place

Facade Panelisation





2.3 Southbank Place

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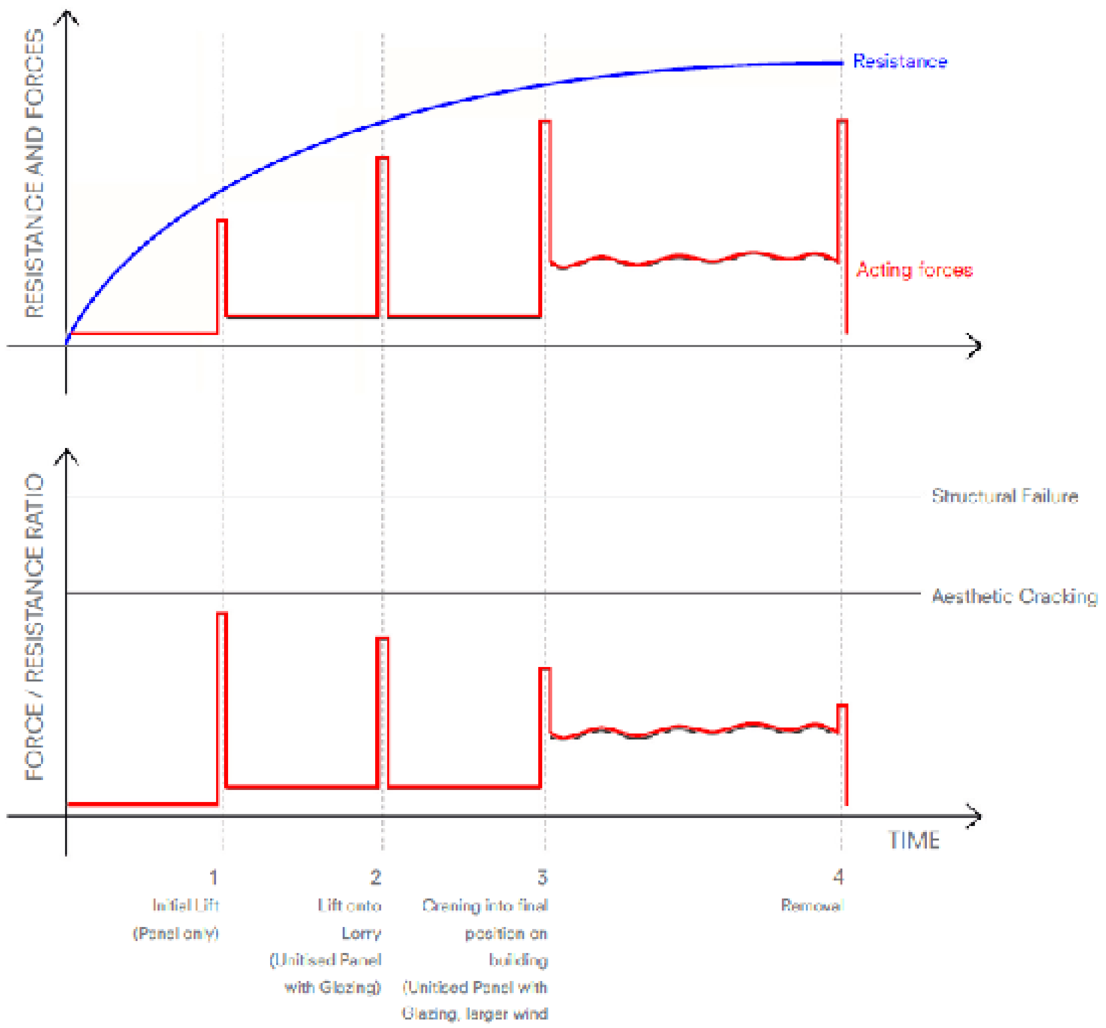
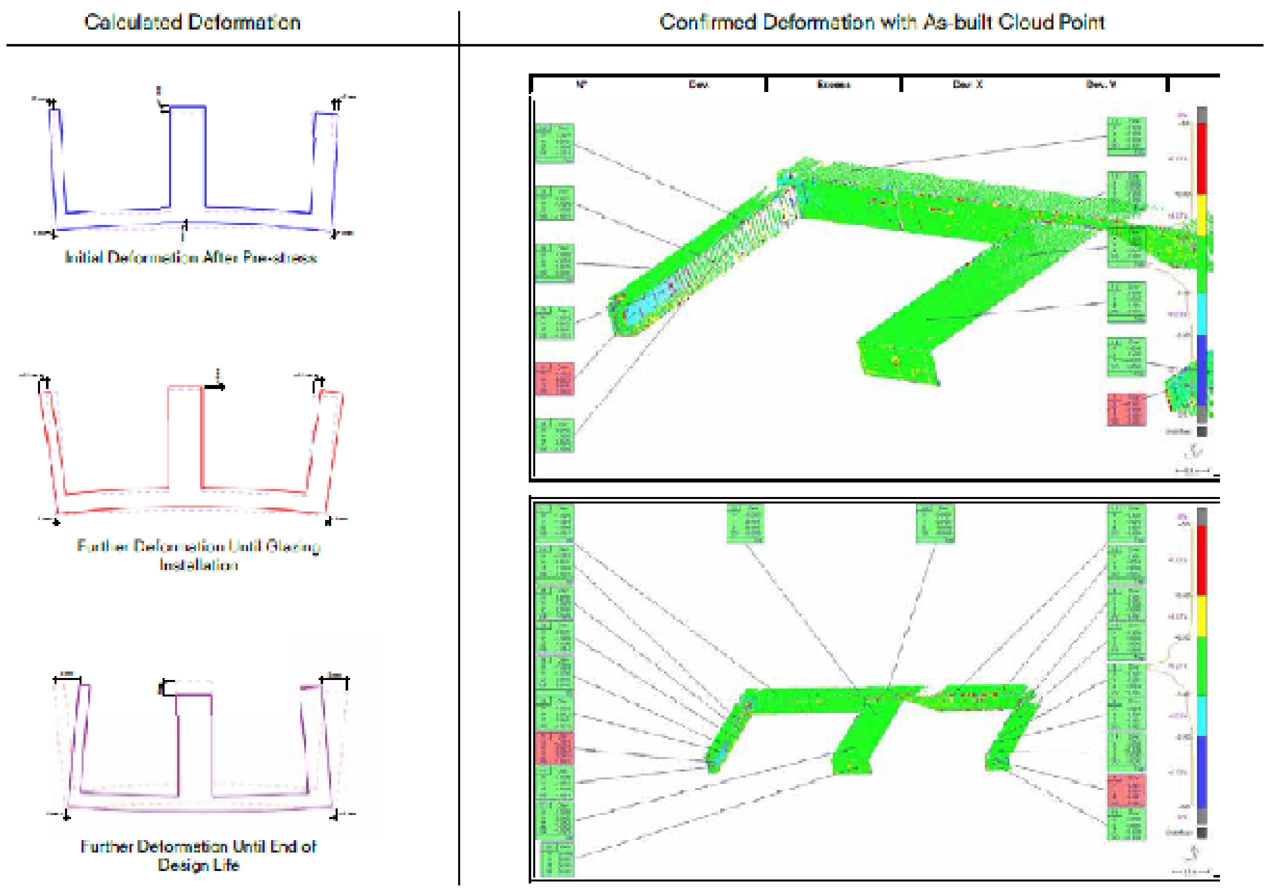




2.4 Brighton 3Ts Hospital Redevelopment

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

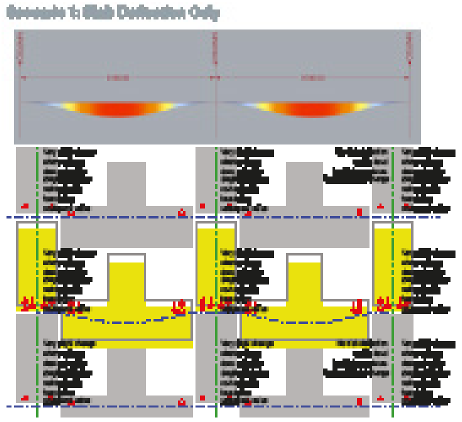
Bryden Wood is involved in the £485 milion development of Royal Sussex County Hospital in Brighton to replace all the buildings on the front of the main hospital site. More specifically, Bryden Wood is involved not only in the precast concrete façade's performance in terms of weather tightness, thermal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

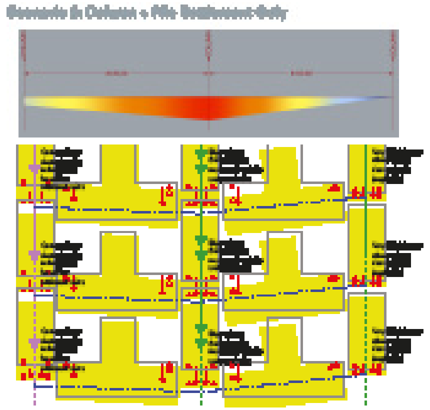
Through working with LOR, Expanded, and GRC UK, Bryden Wood's role has provided a vital link in ensuring that the performance of the precast façade is not just theoretically upheld by international and national standards but also pragmatically feasible on-site by using both finite element analysis and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

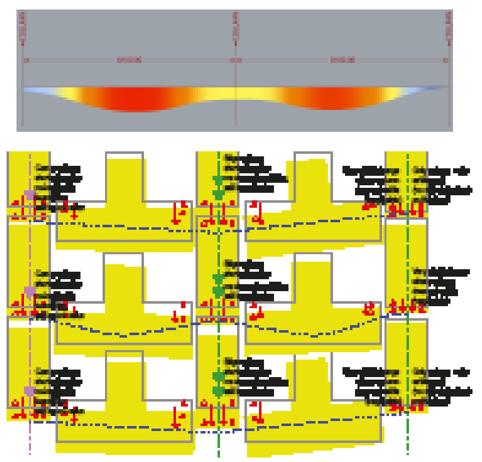
As part of this project Bryden Wood developed a process of following each individual interface joint line through panels, glazing etc. These were then colour coded and referenced to provide all precast and interface details on site.

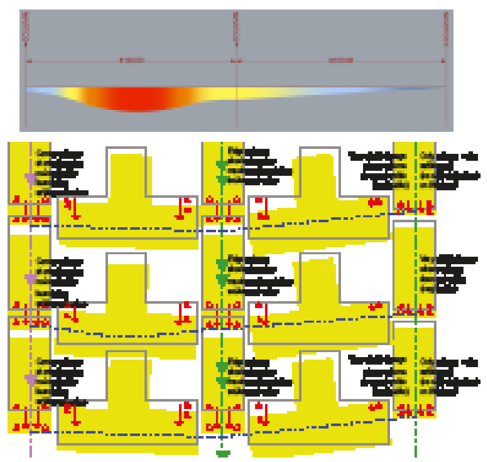
Image courtesy of Laing O'Rourke

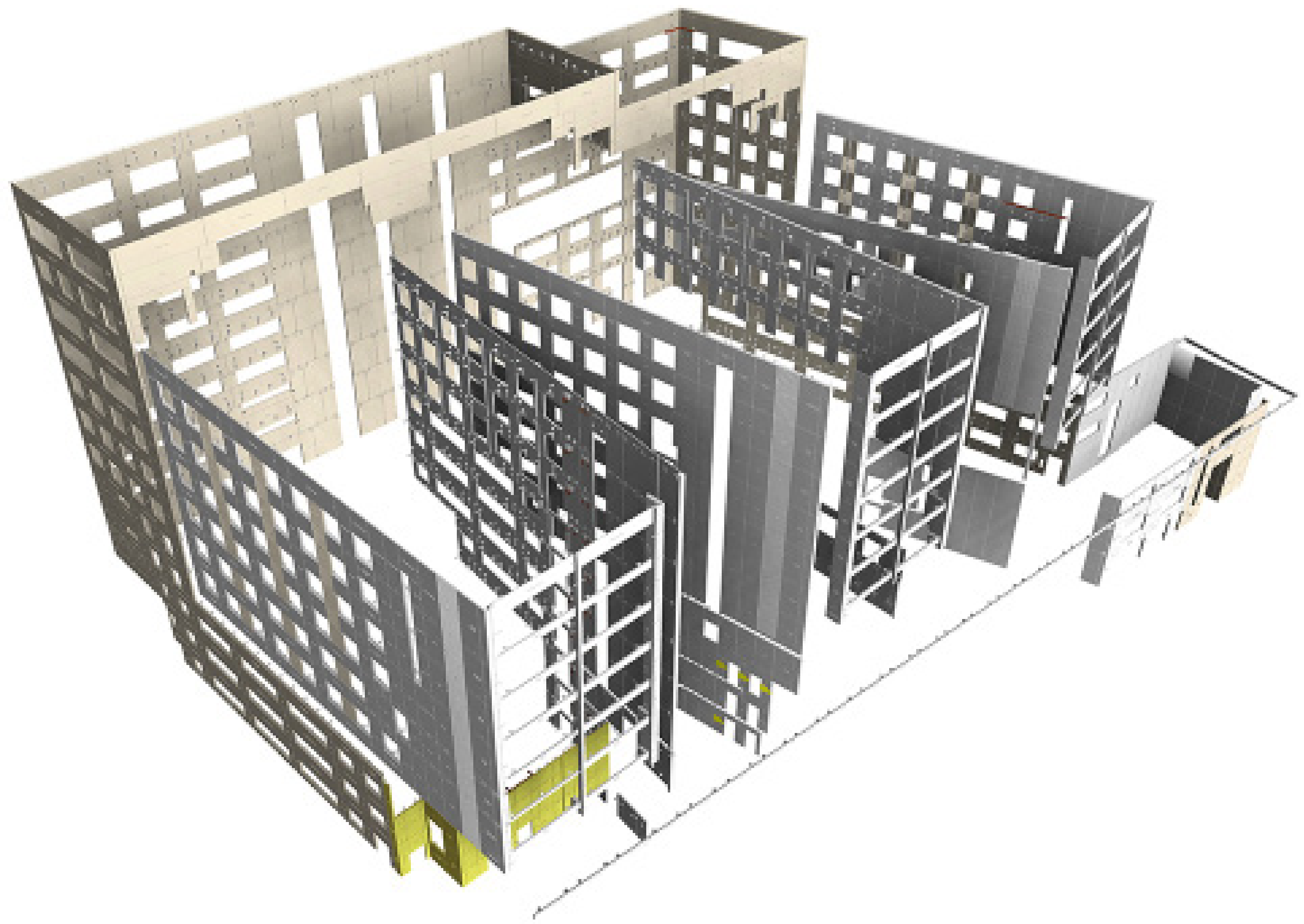
2.4 Brighton 3Ts Hospital Redevelopment

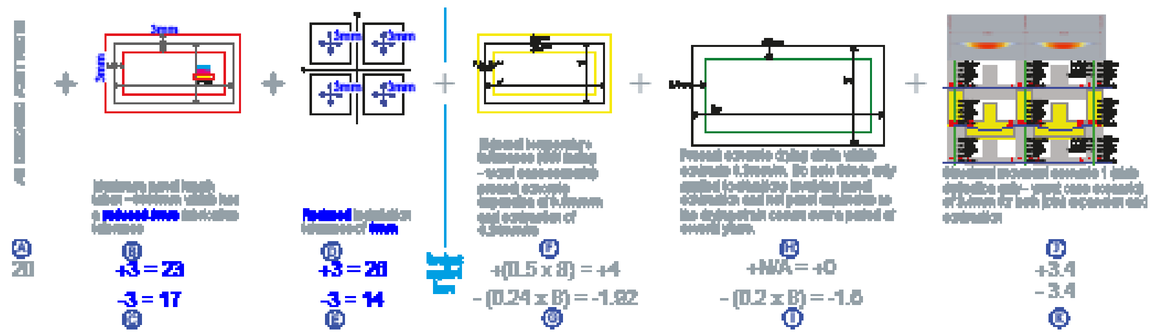




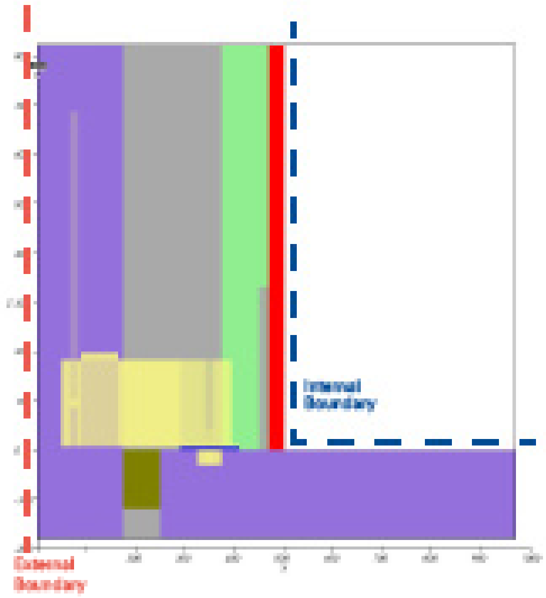


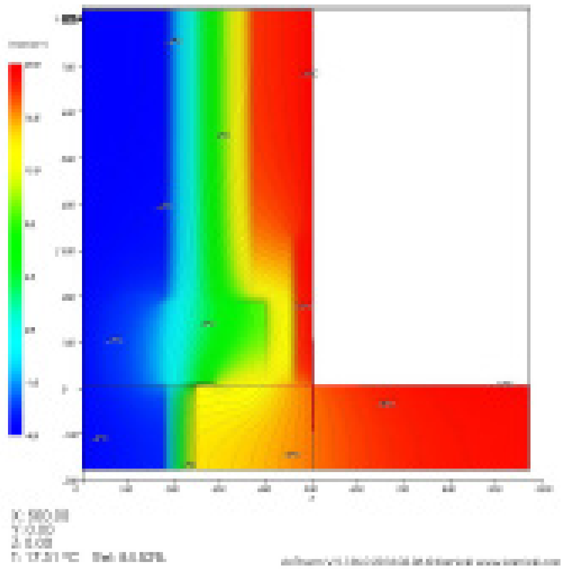


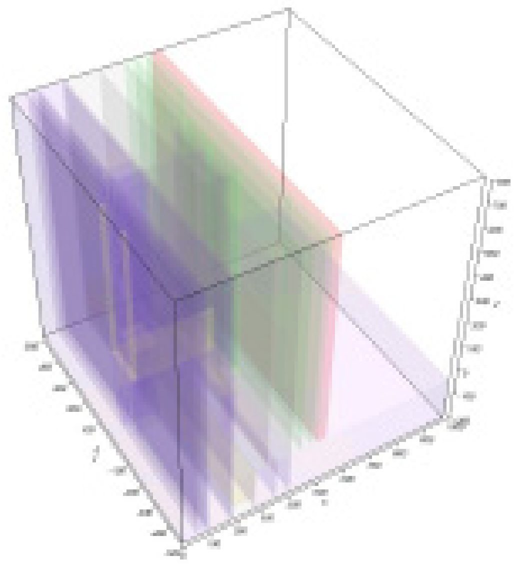


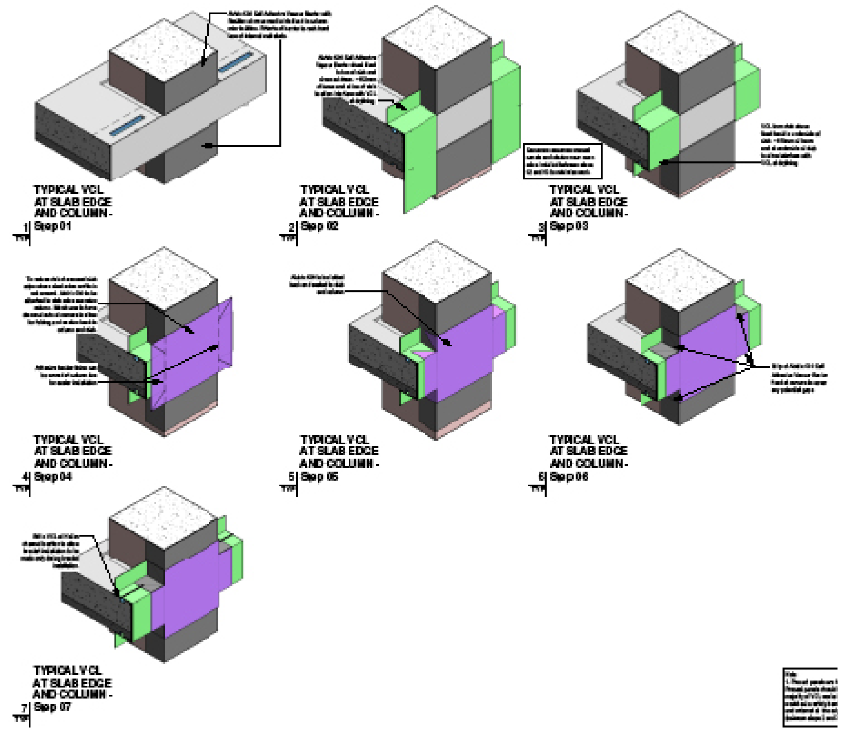


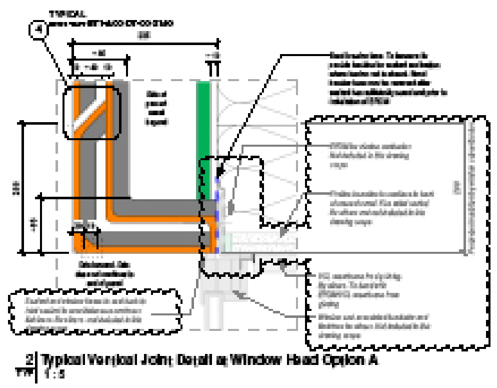
3.4 Brighton 3Ts Hospital Redevelopment

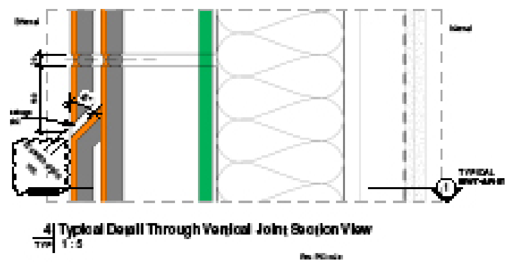


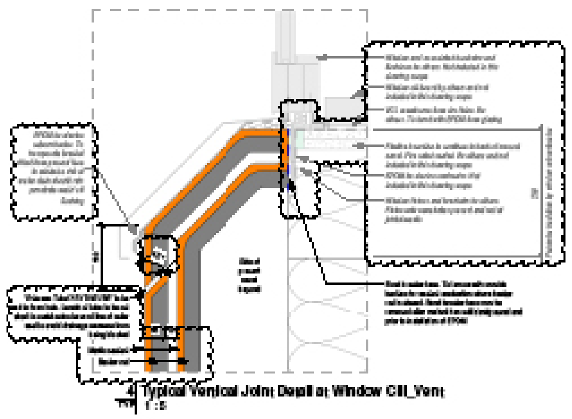


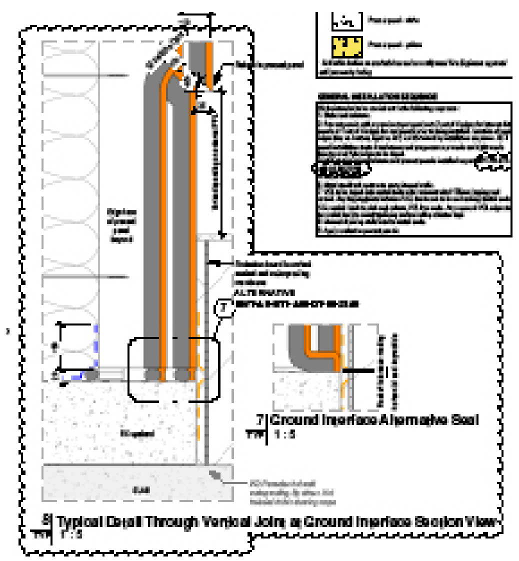












2.5 Bouygues UK Student Accommodations

Project Summary

Client: Bouygues UK
Construction Value: £183m
Status: Under construction

How we added Value:

- Bryden Wood has enabled the integration of above and beyond the industry's conventional stage 4 consultancy services by providing stage 5 level of detail to the building elements.
- We have enabled coordination between the various manufacturers, distributers, the main design team, and the client.
- This not only produces a design that is fully understood by all parties but also ensures industry standards are met thereby limiting the financial risk to the client and providing comfort and peace of mind to end users.

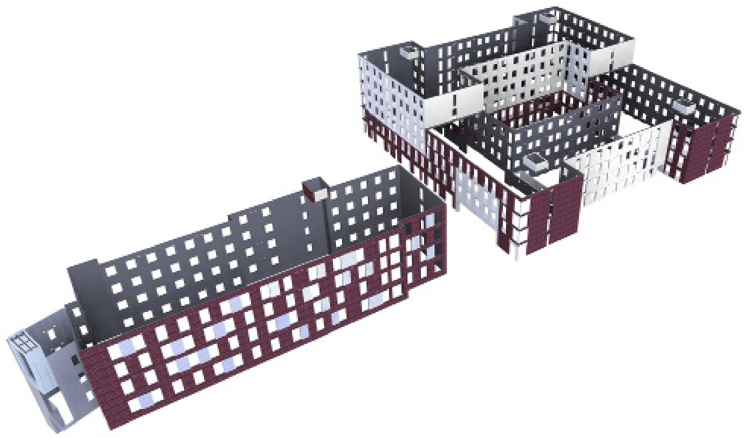
Standardised construction and delivery strategy

Bryden Wood have been appointed for the façade performance and detailing design for two modular student accommodation projects with Bouygues UK.

The first is The Riverside Development, a mixed-use development located in the centre of a new leisure quarter in the historic city of Canterbury, with an overall project value of £115 million. Bryden Wood are responsible for two the two student accommodations buildings within the wider project, which will add 491 new student bedrooms. The buildings are primarily modular in constructions, with modules built in Morocco and shipped to site. The buildings also include areas supported by podium transfer slabs and a steel framed structure supporting a special feature rainscreen-clad terrace.

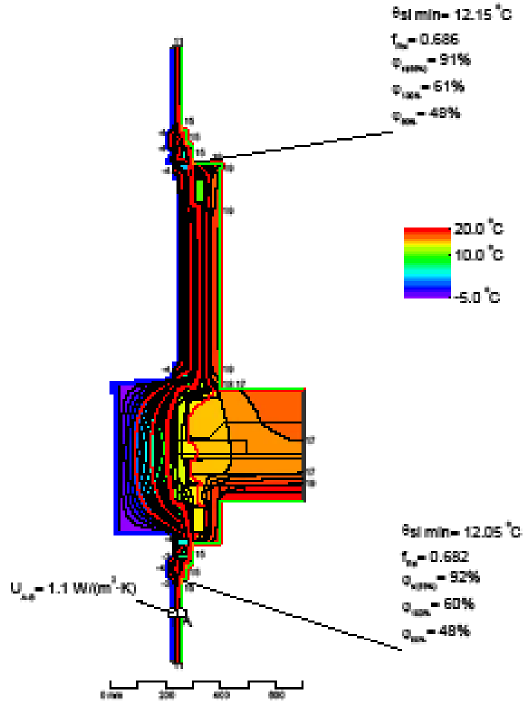
Bryden Wood have developed a novel application of an EWIS (External wall insulation system) cladding system to accommodate the complex modular junctions and have supported the modular manufacturer's by incorporating their fabrication details into the design.

The second project is the University of Essex, a £67.5 million development comprised of 5 blocks of student accommodation with 643 new bedrooms. The bedrooms are constructed modularly while common spaces are built in poured in-situ concrete cores. Bryden Wood is working with Bouygues UK to analyse and detail over 20 different build-ups using 7 different cladding types. The project is targeting BREEAM Very Good Status and Bryden Wood is supporting the modular manufacturers with value engineering efforts to simplify installation of VCL membranes.



Canterbury Riverside Development

Image courtesy of Linkcity



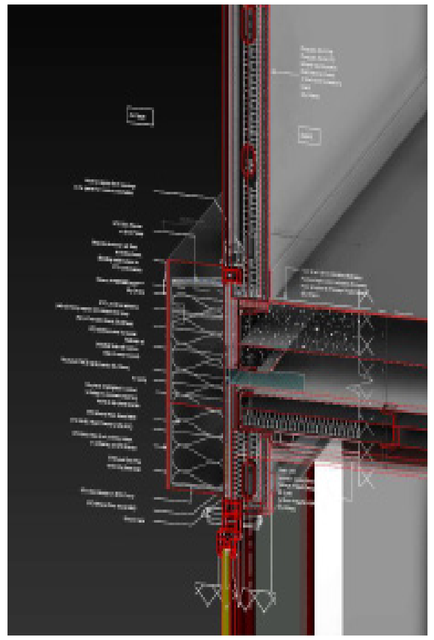


Image courtesy of Bouygues UK

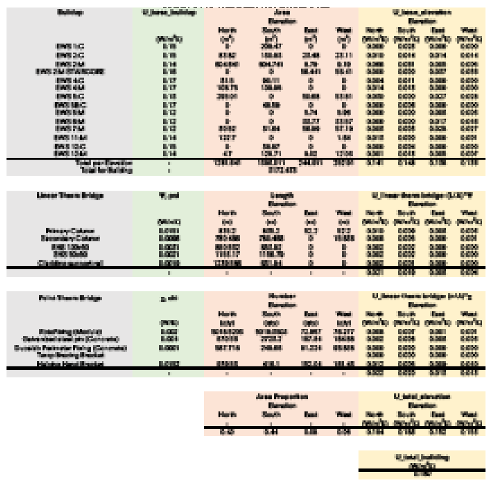
Image courtesy of Bouygues UK

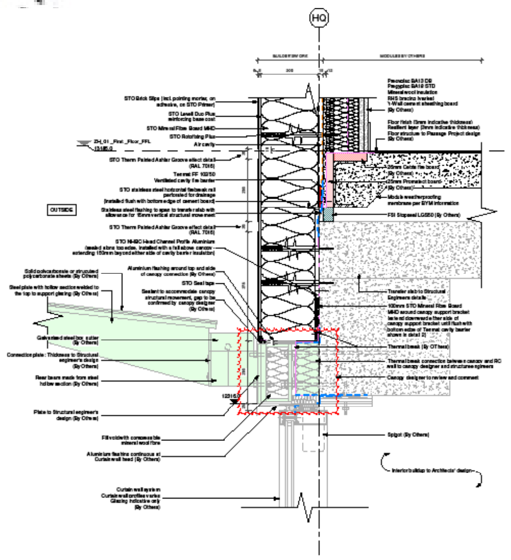
2.5 Bouygues UK Student Accomodations

University of Essex

Image courtesy of Willmore Iles

Image courtesy of Bouygues UK





2.6 Woodwharf D1/D2

Project Summary

Client: Canary Wharf Group
Our Partners: Laing O'Rourke / Expanded
Construction Value: Confidential
Status: Under Construction

How we added Value:

- A holistic approach to the façade/ envelope assessment, spanning from performance analysis to full construction details, covering all performance elements (insulation, VCL), precast and bracketry in a fully integrated way.

Façade design development for a new district in London

Wood Wharf is Canary Wharf's new district in London. It has been designed to provide a new residential led, mixed use, waterside community defined by the quality of its public spaces, the diversity of its land uses and activities, and its exemplary architecture.

Bryden Wood were appointed by Laing O'Rourke / Expanded for the joint design of the precast cladding package on Wood Wharf (plot D1/D2), which is 14 storeys not including the plant level at the top of the tower. The project comprises about 624 precast panels. The fabrication design by Bryden Wood is based on the RIBA Stage 4 design by the project's main design team.

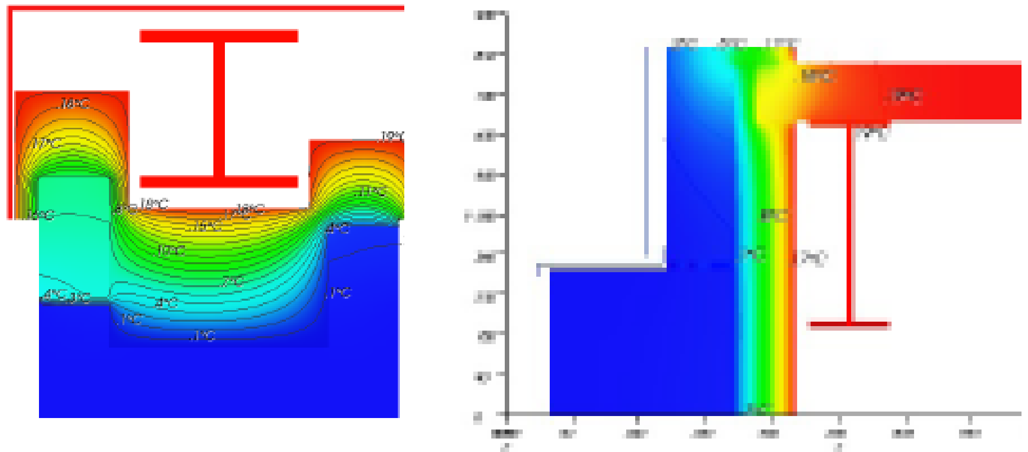
Bryden Wood's documentation provides a holistic approach to the façade design: it includes key details/ interfaces drawings and reports assessing thermal & condensation, acoustic and fire performance as well as movement.

Facade Panelization

Project Overview

Images courtesy of KFK, extract from https://kfk.hr/

Construction stage



Thermal Analysis of Typical Precast Panel

2.7 Woodwharf H1-H4

Project Summary

Client: Canary Wharf Group

Our Partners: Laing O'Rourke / Expanded

Construction Value: Confidential

Status: Under Construction

How we added Value:

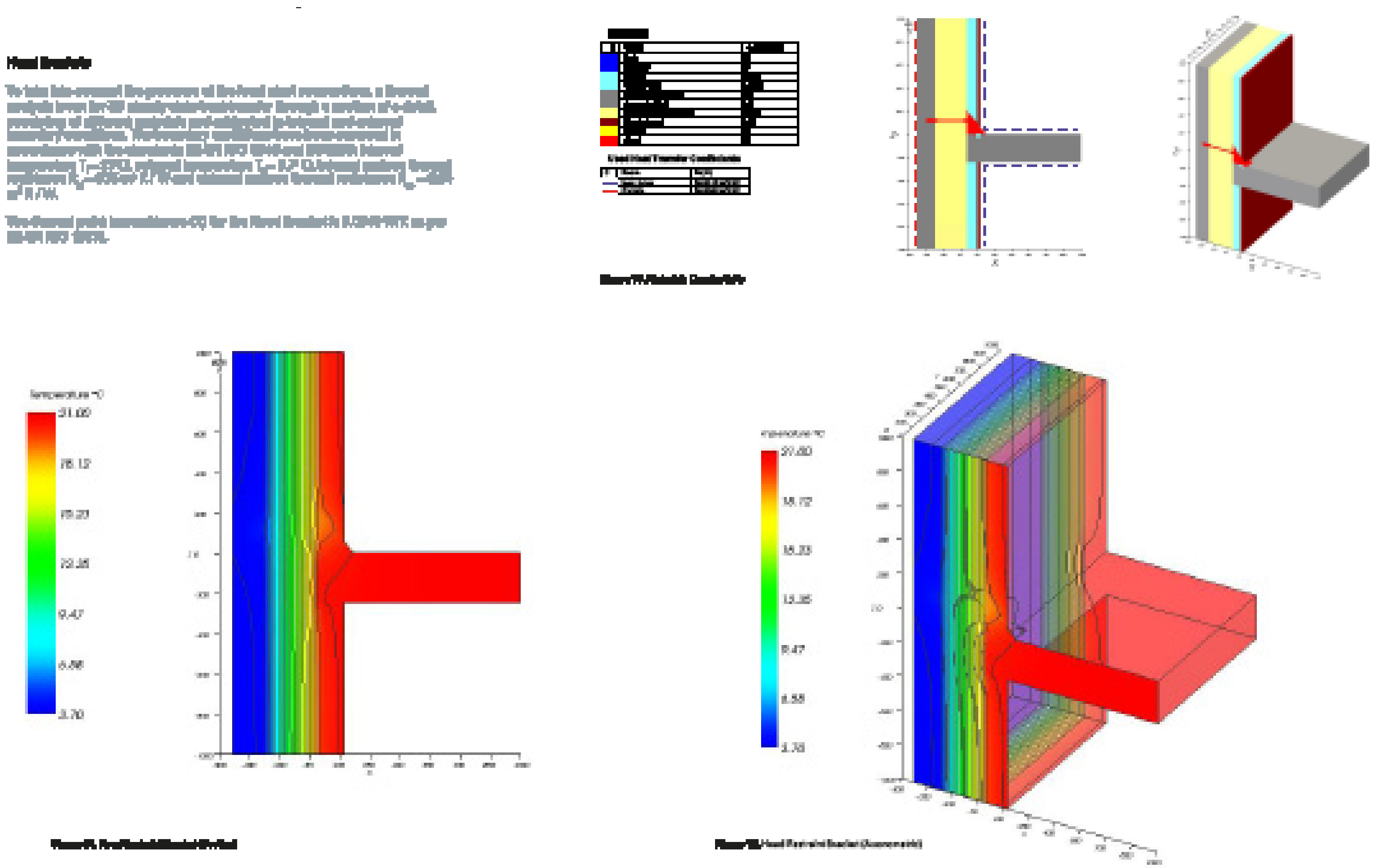
- A holistic approach to the façade/ envelope assessment, spanning from performance analysis to full construction details, covering all performance elements (insulation, VCL), precast and bracketry in a fully integrated way.

Façade design development for a new district of London

Wood Wharf is Canary Wharf's new district in London. It has been designed to provide a new residential led, mixed use, waterside community defined by the quality of its public spaces, the diversity of its land uses and activities, and its exemplary architecture.

Bryden Wood were appointed by Laing O'Rourke / Expanded for the joint design of the precast cladding package on Wood Wharf (plot H1/H4). The fabrication design by Bryden Wood is based on the RIBA Stage 4 design by the project's main design team.

Bryden Wood's documentation provides a holistic approach to the façade design: it includes key details/ interfaces drawings and reports assessing thermal & condensation, acoustic and fire performance as well as movement.



2.8 Kings Cross S5

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

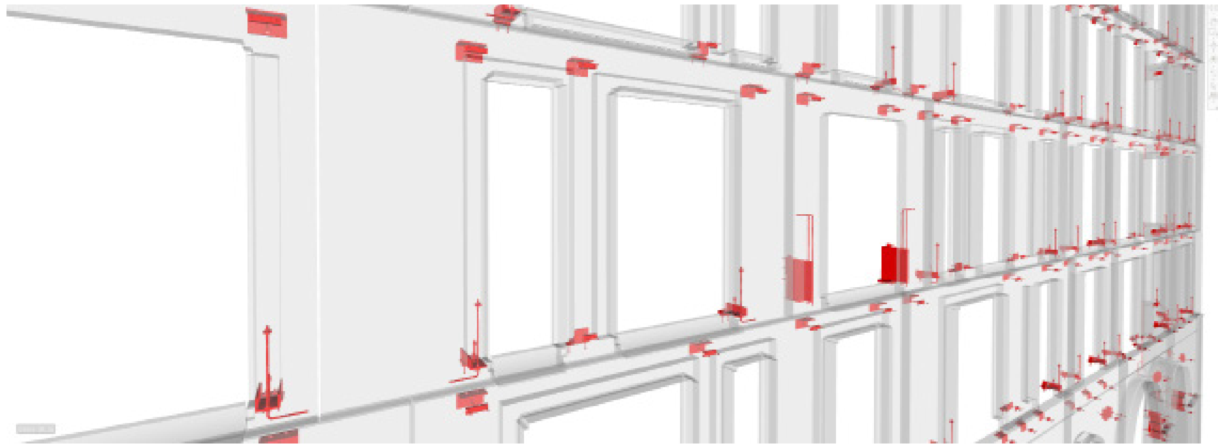
Precast façade project in central London based on integrated panels

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.

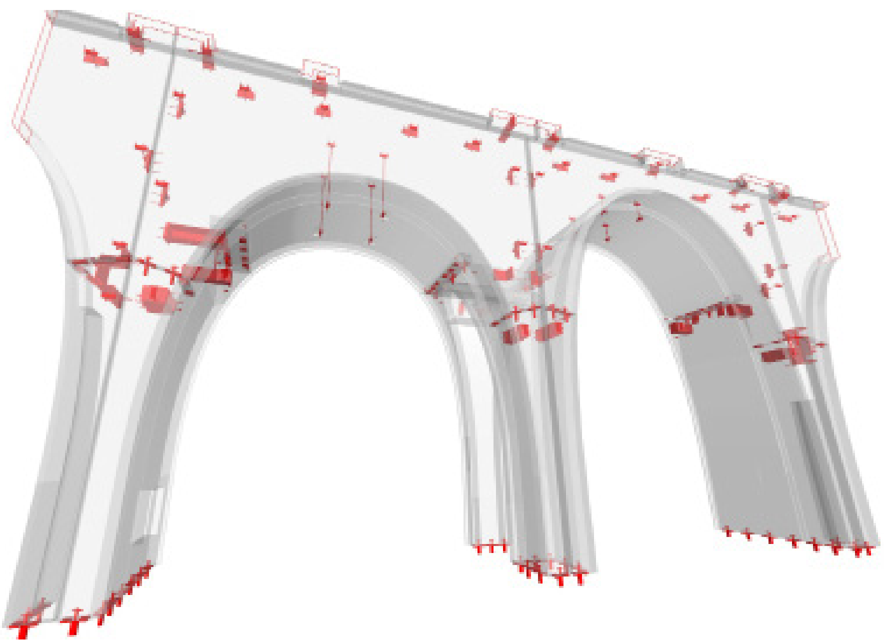
Bryden Wood's appointment encompasses overall façade performance and precast engineering and BIM. Bryden Wood have utilised advanced digital workflows and scripting to calculate panel quantities and rapidly model required precast panel and brick geometries across the entire project.

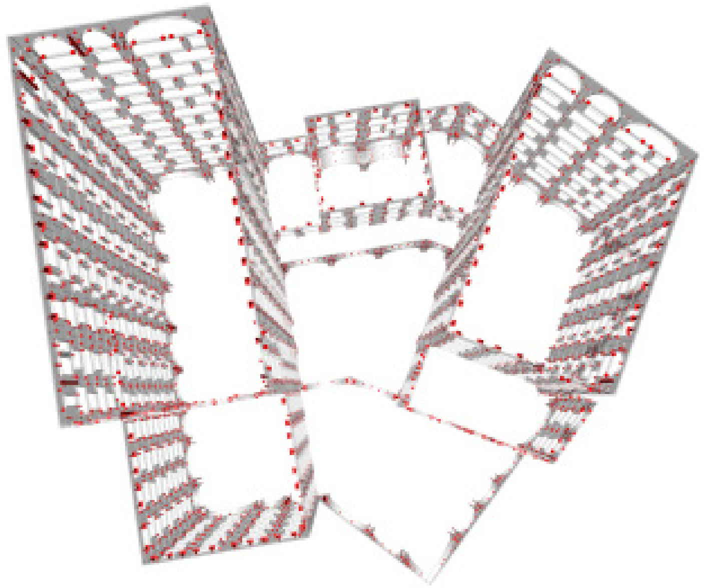
The fabrication design being completed by Bryden Wood is based on RIBA Stage 4 information produced by the project's main design team. Bryden Wood's holistic approach to the façade documentation includes key interface and setting out drawings as well as technical reports and assessments.

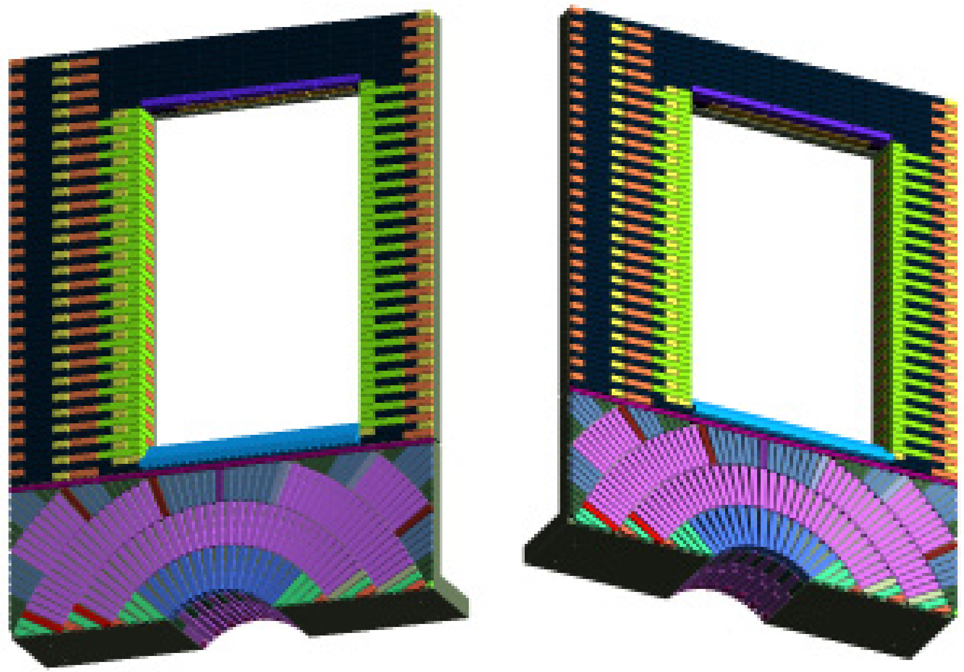
The Kings Cross S5 development will add 158 new dwellings to the vibrant Kings Cross neighbourhood in London with a strategic position at the junction of York Way and Canal Reach. The scheme comprises a six-sided perimeter block with masses of varying height up to fifteen storeys grouped around a central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

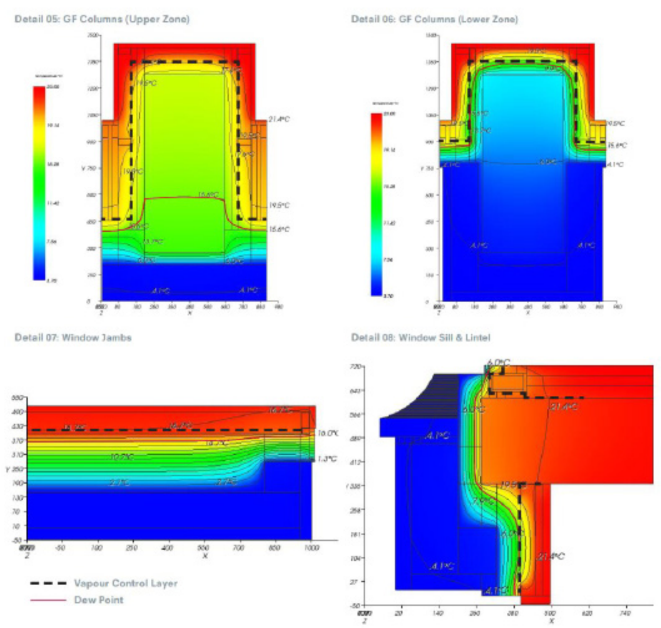


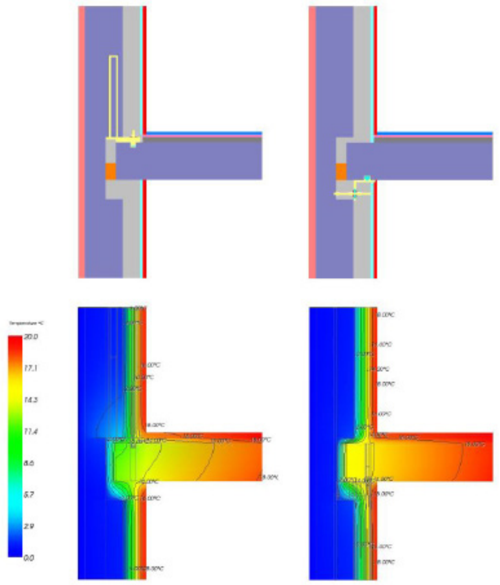
2.8 Kings Cross S5

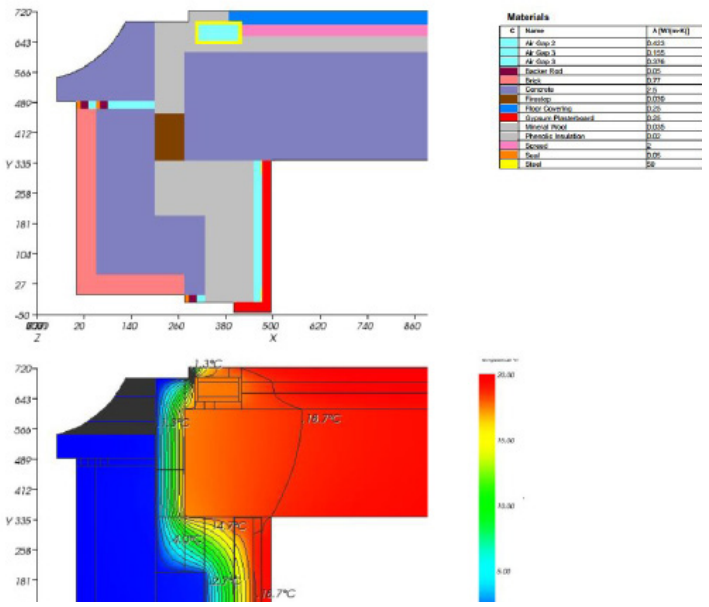












2.9 Hinkley Point C

Project Summary

Client: Rendel Ltd. / ByLOR
Construction Value: £20b
Status: Under Construction

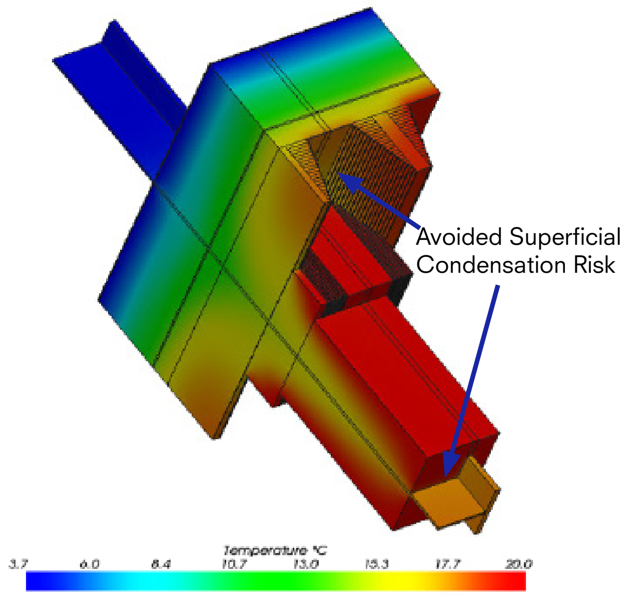
How we added Value:

- Rationalisation of envelope systems
- Optimisation of performance
- Derisk of large envelope package for critical infrastructure

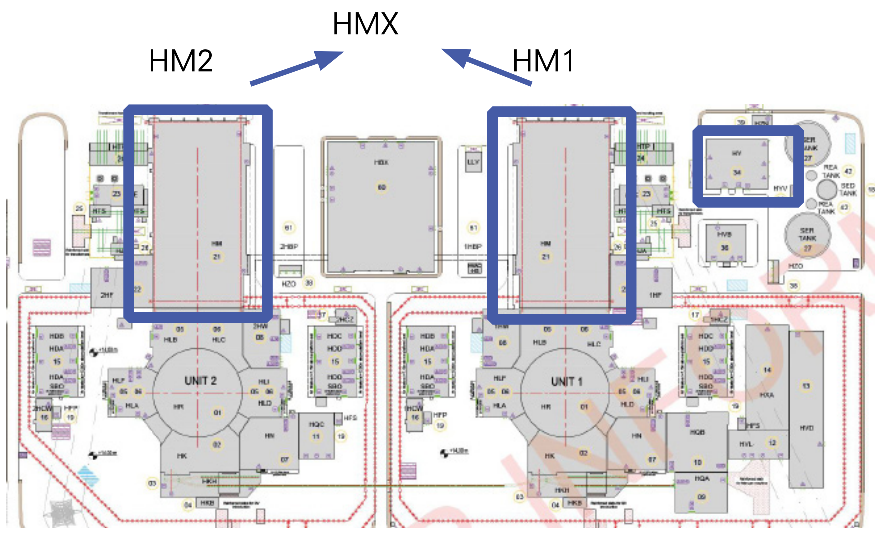
Standardised construction and delivery strategy

Bryden Wood were appointed by Rendel Limited as the subconsultant for facade engineering and contractor detailing of the envelope package of the HMX Turbine Halls and the HY Building at Hinkley Point C.

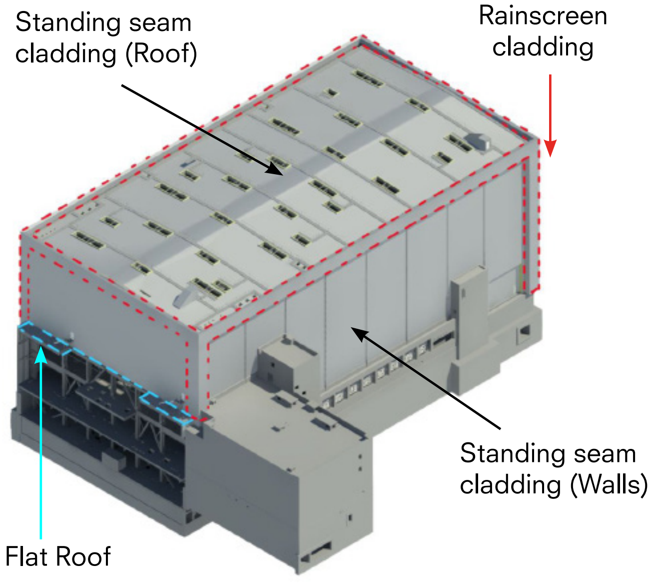
Bryden Wood's scope encompasses all roof and wall systems, including the development of interface details with other architectural components at roof plan and wall elevations, primary and secondary structure.



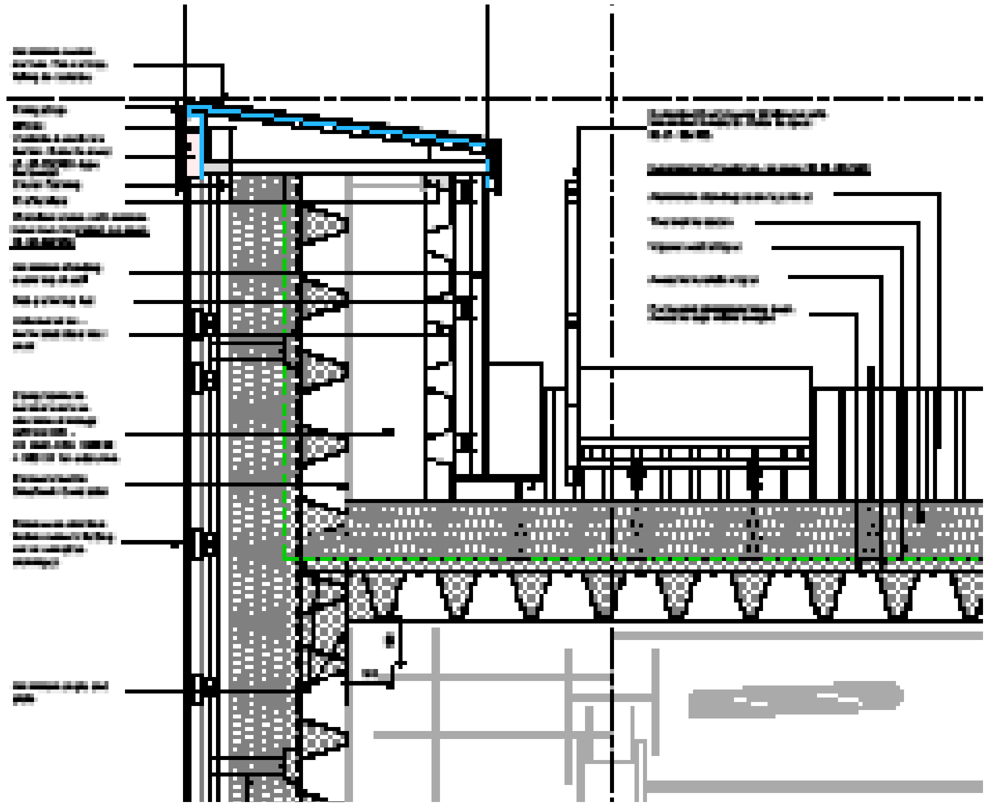
Standing Seam Wall Beam Penetration w/ Insulation Wrap.



Location of HMX Buildings



Location of the Typical Locations of HMX Envelope types


South Gable Interface Detail

2.10 Two Taikoo Place

Project Summary

Client: Swire Properties
Construction Value: Confidential
Status: Pre-construction

How we added Value:

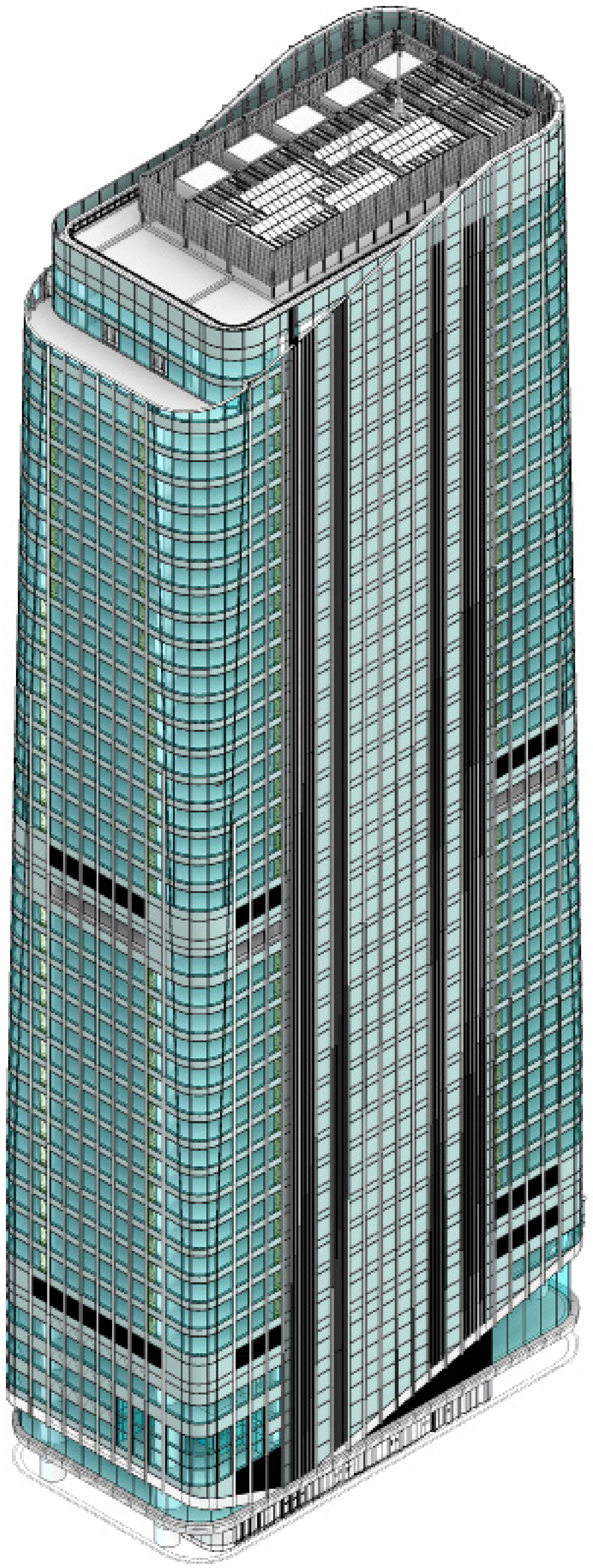
- Provided an optimised design that reduced the total number of unique glazed façade panels on the project while protecting the architectural intent.
- Provided an optimised design for the mullions that reduced the number of unique mullion types while protecting the architectural intent.
- Developed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

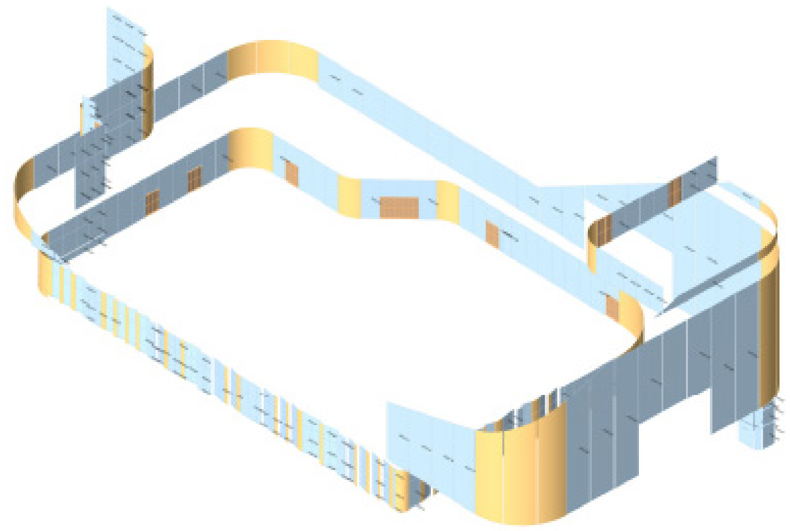
Façade optimisation for landmark hong kong development

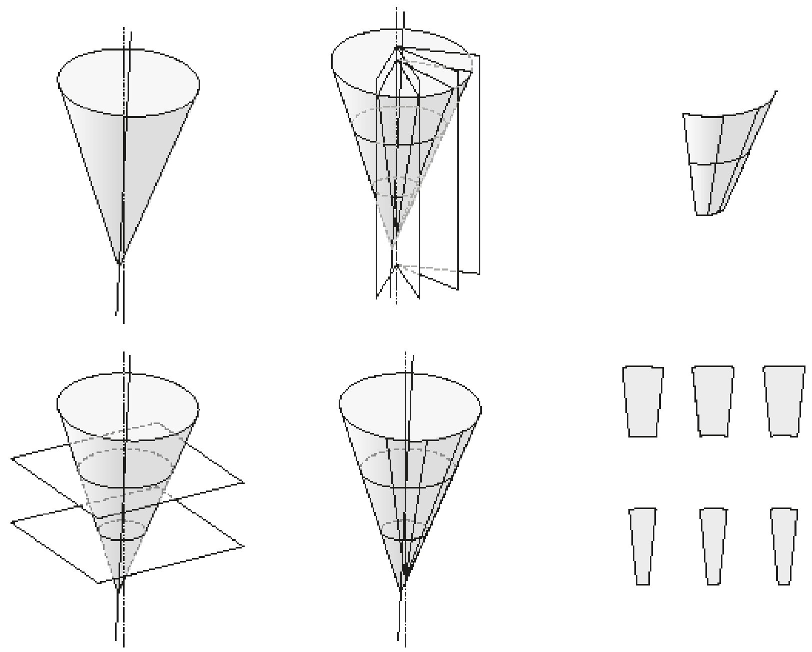
Two Taikoo Place Tower is part of the redevelopment of one of the future best business hubs in Hong Kong. The tower is designed to reach a height of 203m and will host commercial space for local and multinational corporations. The project includes a sophisticated unitised curtain wall façade comprising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

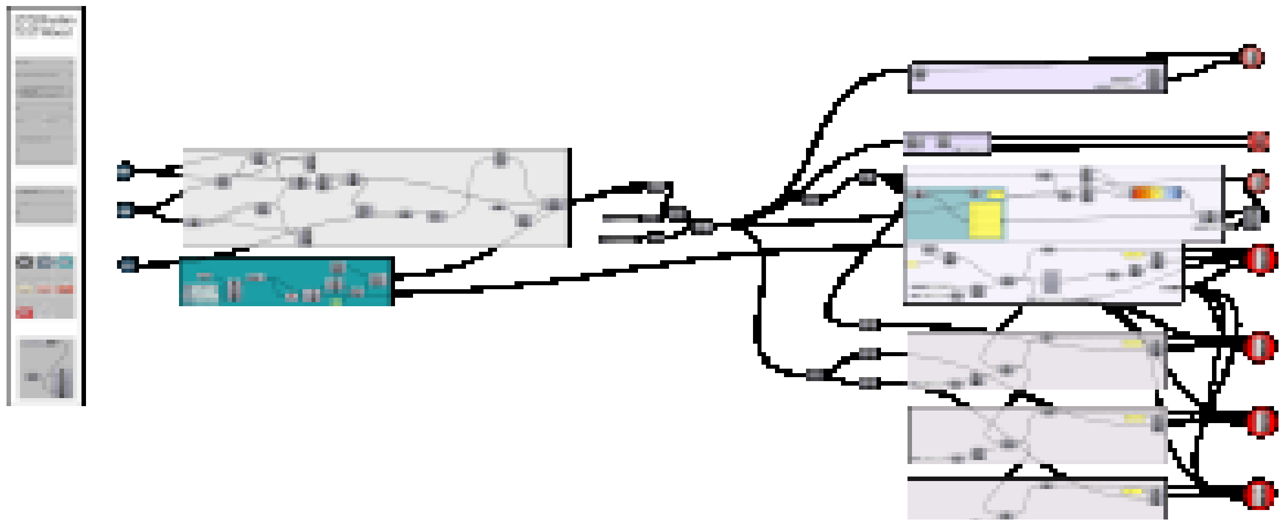
As part of the project Bryden Wood also undertook a design review of the façade details and developed a handling and installation strategy that was used to generate estimates of overall installation time requirements and identify scenarios to accelerate the installation process.

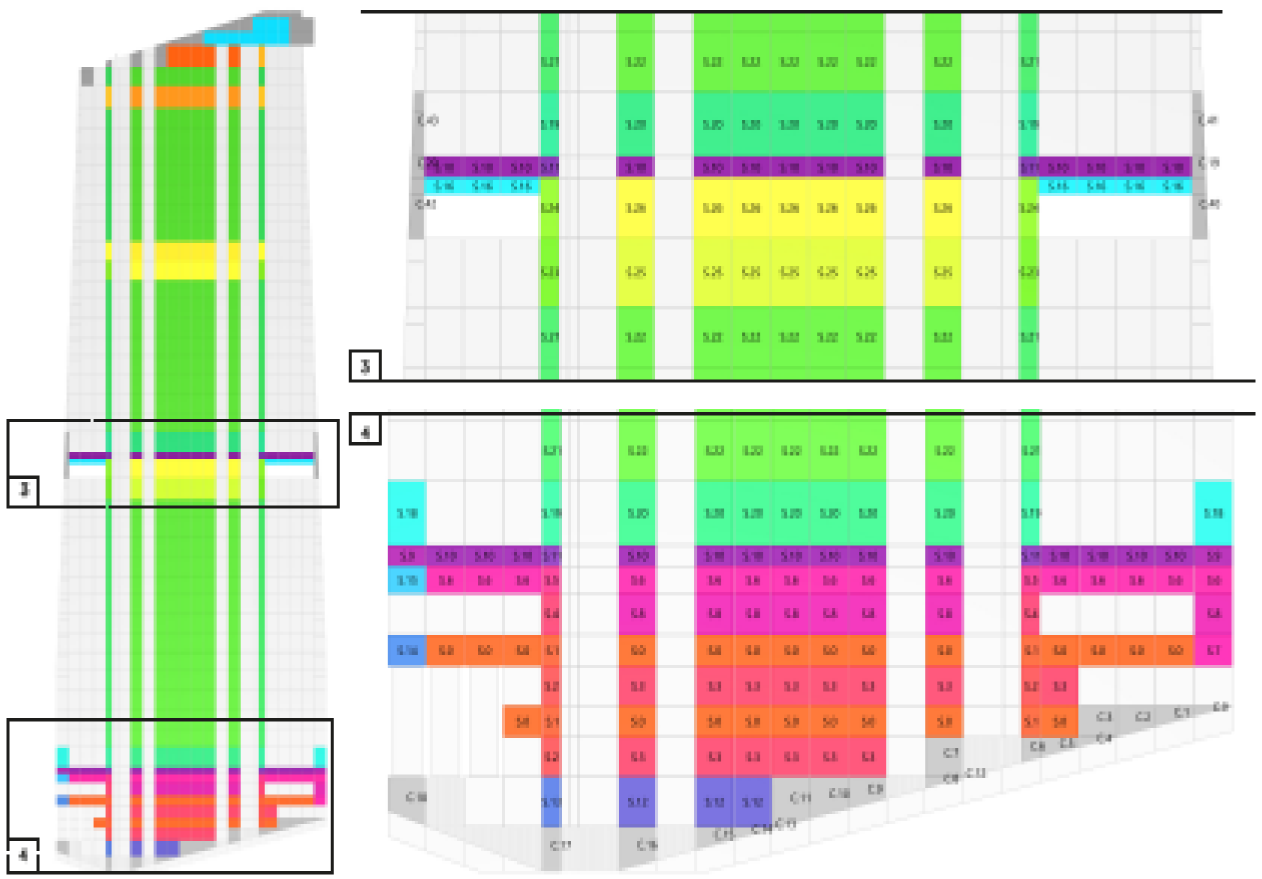


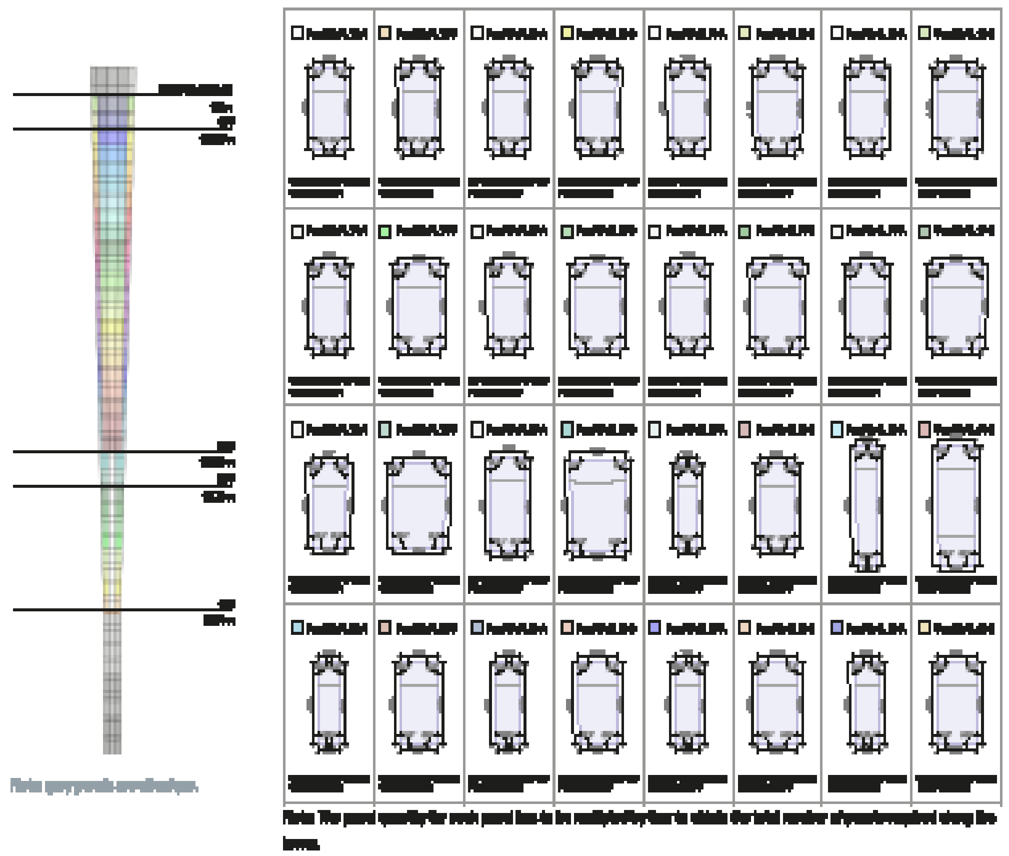




2.10 Two Taikoo Place







2.11 Circle Reading Hospital

Project Summary

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

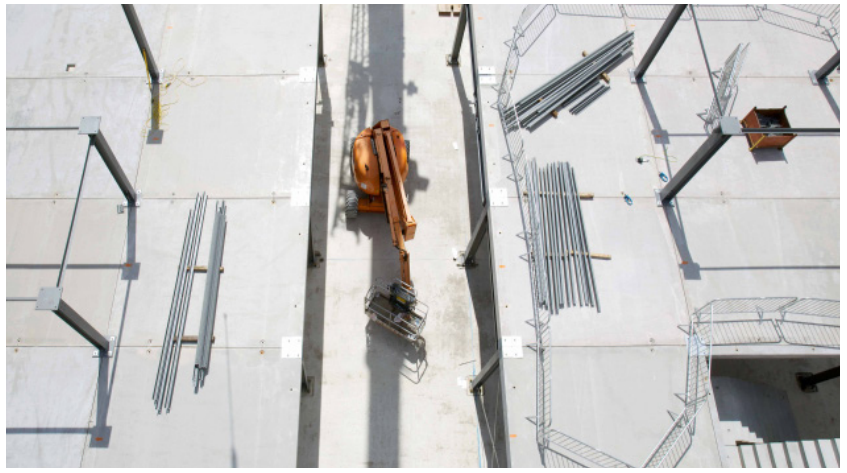
How we added Value:

- Highly standardised and prefabricated building system was built in only 18 months with a 25% cost reduction per sq.m 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.

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.

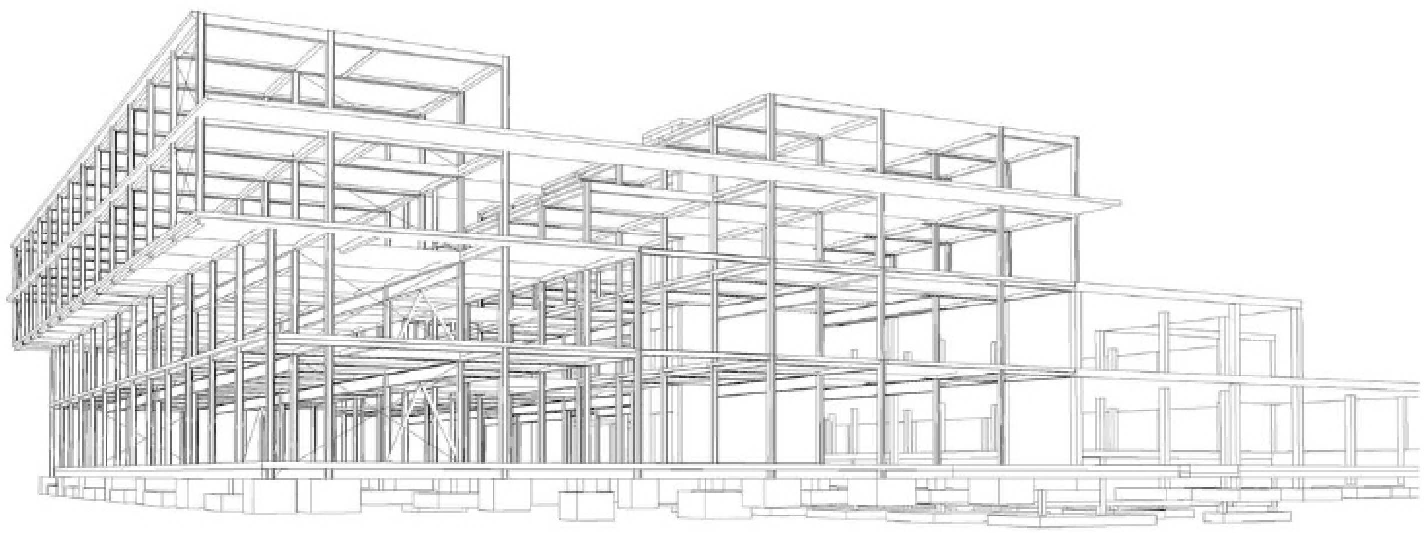
Prescast planks partially supported by structural beams.

Precast slab to steel column connection detail.

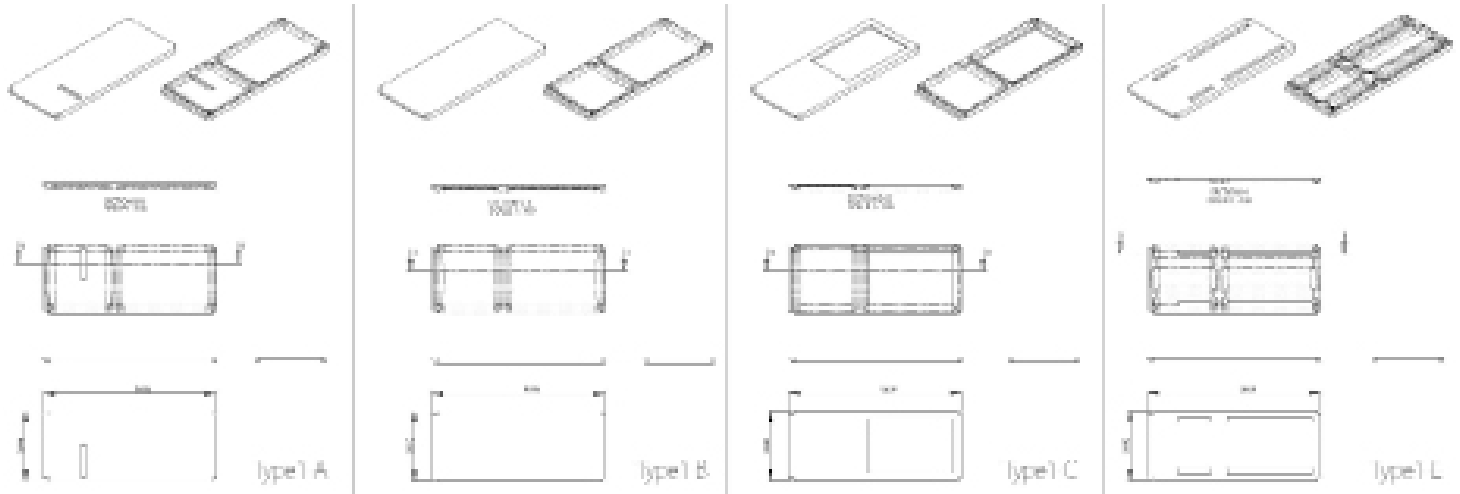
Curtain wall glazing.

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

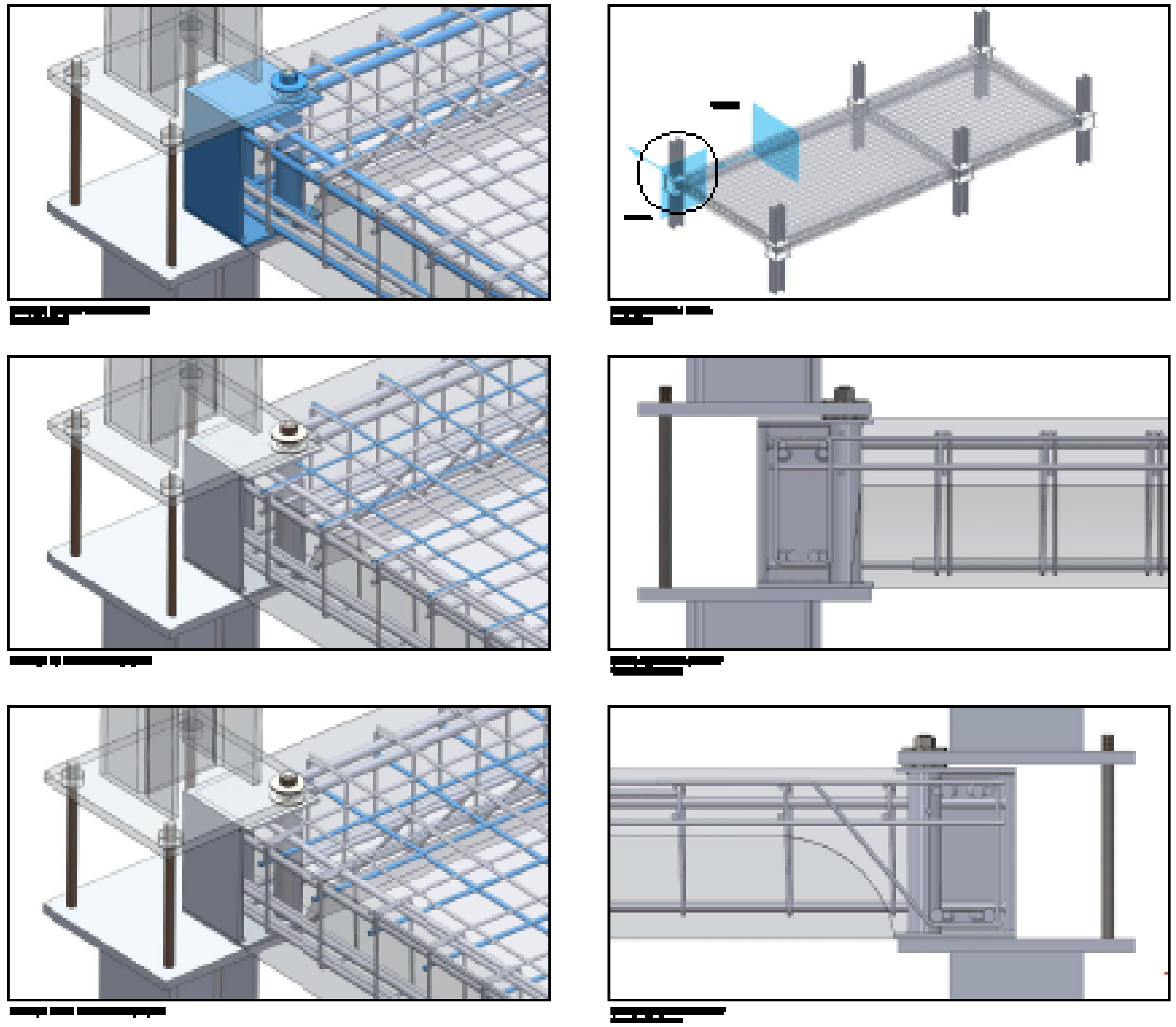
2.11 Circle Reading Hospital



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.



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

2.12 London Heathrow Terminal 3 - Temporary Flight Connections Centre

Project Summary

Client: Heathrow Airport
Our Partners: Mace
Construction Value: £15m

How we added Value:

- Material content of the building significantly reduced through engineering review with a simplified foundation system
- Nearly 75% reduction in the number of personnel on site
- 20% cost reduction and 38% programme reduction estimated compared to traditional build
- Estimated £1.2m saving in the cost of prelims alone

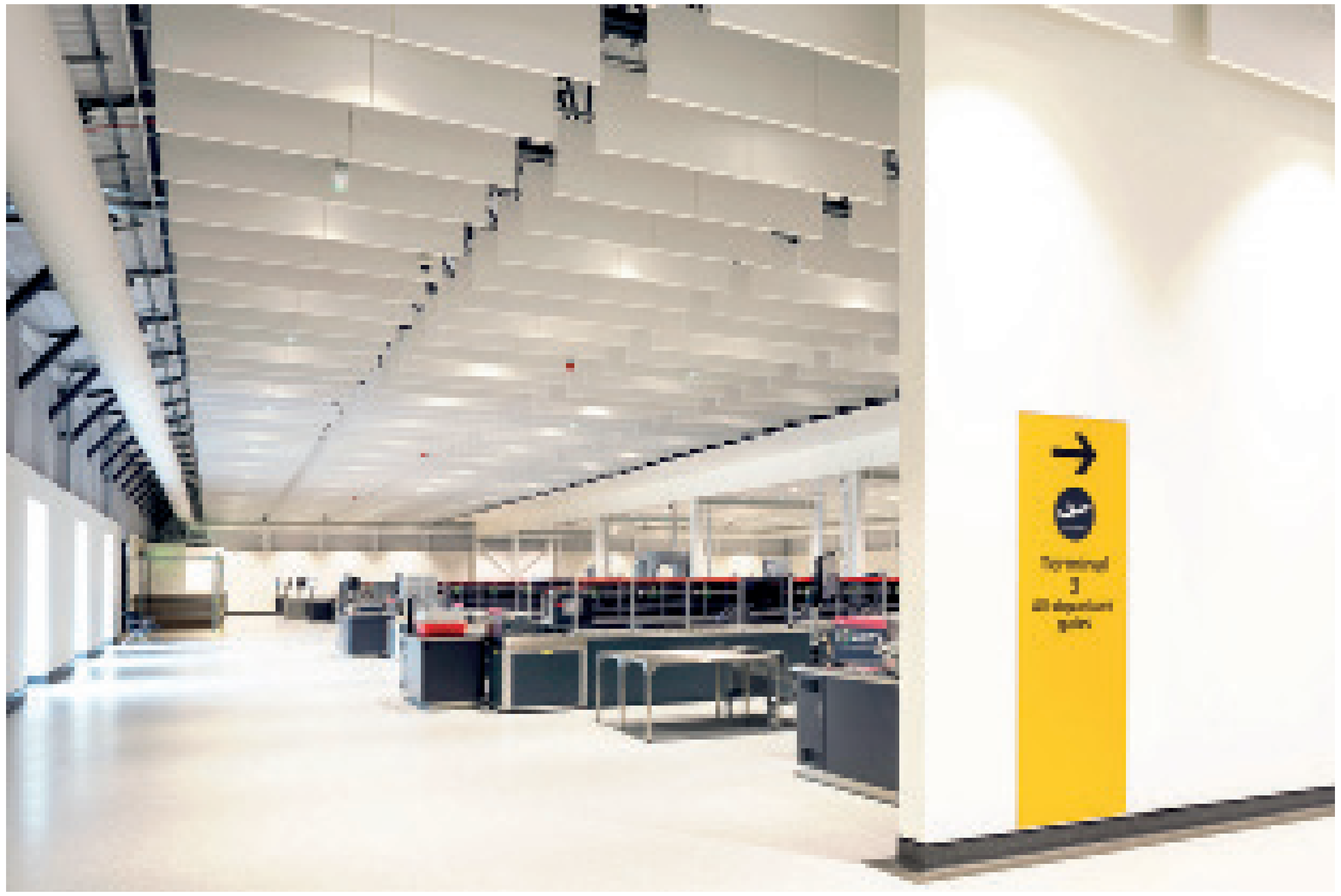
Prefabricated solution for temporary flight connections centre

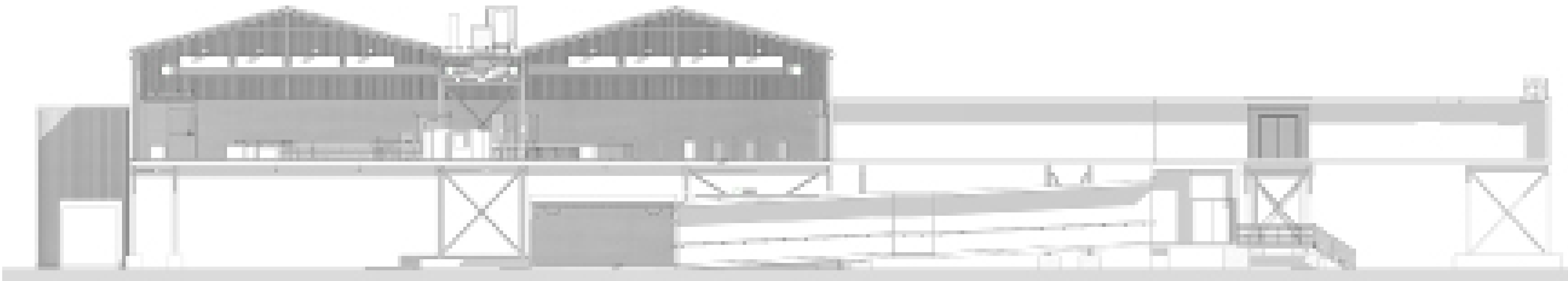
Bryden Wood were appointed by Mace to deliver a prefabricated solution for the 4,000m² Temporary Flight Connections Centre (FCC) at London Heathrow Terminal 3, to serve 9,000 passengers a day. Bryden Wood became involved in the project in July 2014 with a very challenging timescale. Mace's appointment was to deliver a fully operational facility by June 2015. Bryden Wood inherited a design that was not considered possible to construct in this timescale.

Over 11 months, Bryden Wood undertook a re-design of the project and led the construction, successfully delivering the project by the deadline. The solution was based on a portal frame structure and designed to be rapidly deployable in a highly restricted environment. Compared to the previously developed design, the steel tonnage was reduced by 30% and the foundation system was notably simplified to allow the facility to be rapidly and easily deployed and dismantled in a highly restricted environment.

The building is located on an operating aircraft apron with live aircraft movements in the immediate vicinity. The site is shared with an aircraft stand and reducing the construction period meant that the stand could attract revenue for a longer period prior to closure. A combination of volumetric and panelised prefabricated systems were used to ensure rapid assembly during night time hours when the airport is closed.

Since the majority of construction was taken off site the impact on airport operations was minimised and the number of personnel on site was reduced by almost 75%. The result was an exemplary safety record; zero RIDDORs, Lost Time Injuries and operational impacts. Costs were reduced by 27% and construction time scale reduced by 38% compared to traditional build. The total length of stand closures was reduced by 6 months giving £1.2m saving in prelims alone.





2.13 Heathrow and Gatwick Pier Segregation

Project Summary

Client: BAA

Appointment: Integrated DfMA Consultancy

Status: Completed 2005

How we added Value:

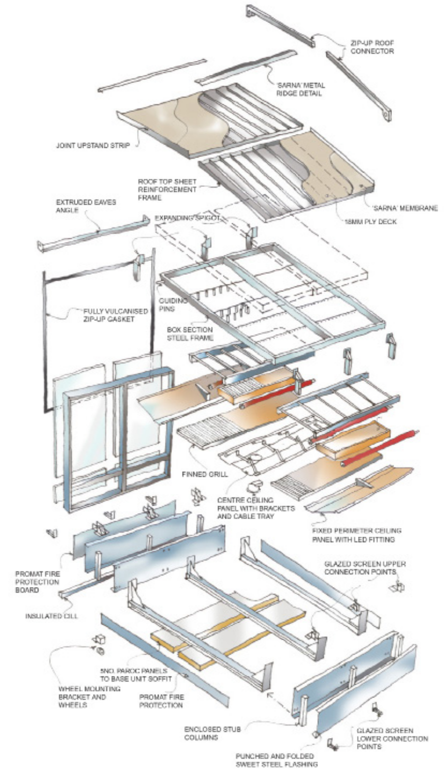
- Pre-assembly used to minimise on-site works
- All modules transported using conventional haulage methods to minimise cost and delay
- 80% of delivery taken offsite with a resulting saving of 36% estimated compared to traditional construction

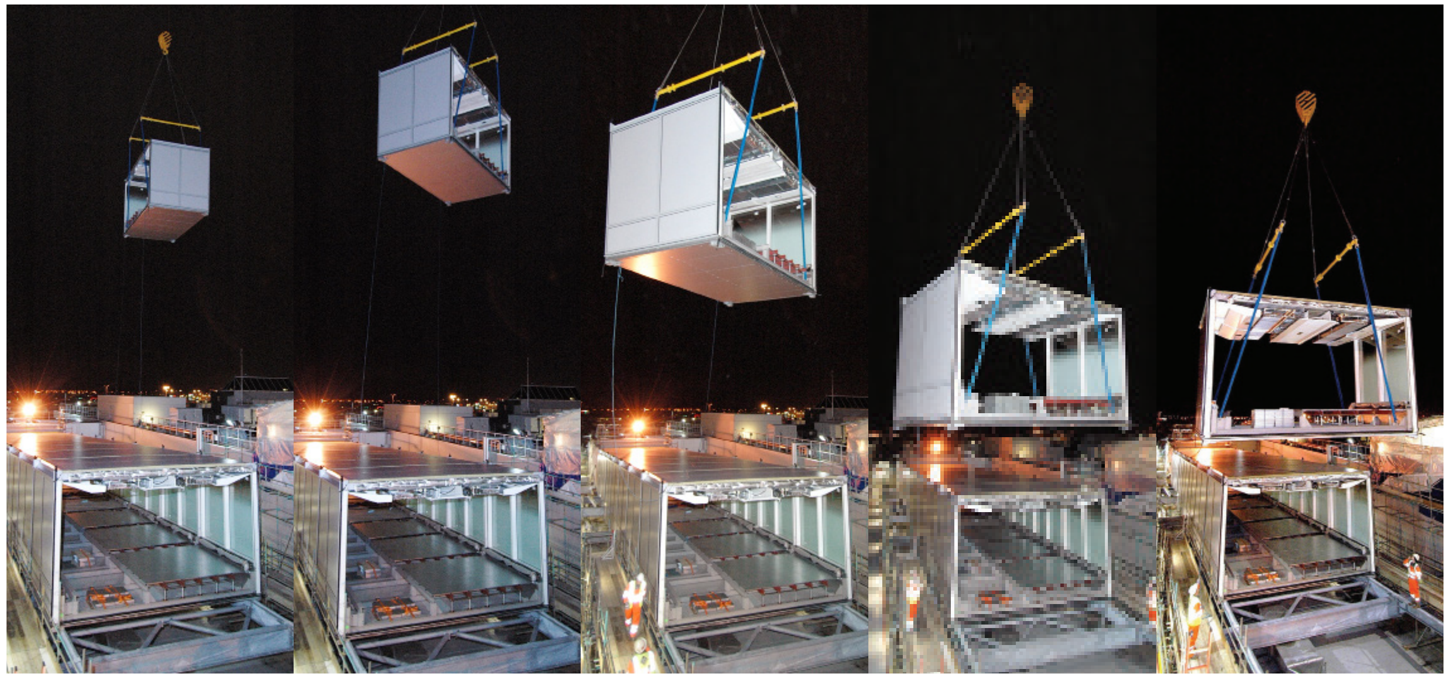
Efficient factory assembled modules forming fully serviced, interlocking corridor units

The Pier Segregation projects at Heathrow and Gatwick airports were complex projects where a passenger route was supported between a host of existing structures. The factory assembled modules form fully serviced, interlocking corridor units, providing the only effective solution to an otherwise virtually insurmountable construction problem: a restricted access site, adjacent to an operational runway on top of an existing terminal. As well as responding to the airport's drivers of speed and reduced impact it was found that the corridor product improved safety through reduced site work, quality through the manufacturing approach, and predictability through pre-engineering.

Wherever possible, pre-assembly was used to minimise on-site works and the number of deliverable components were reduced to a minimum. In addition, all modules were transportable by conventional haulage methods, reducing cost and delays.

A modular, factory finished solution was designed and delivered that took 80% of delivery offsite. The result was a product solution incorporating over 1.5km of pier segregated corridor which could be incorporated into a range of existing environments. The total cost saving over 4 projects was £15.5 million, or 36% versus traditional construction. It was also rated as better-performing in health and safety and build quality compared to typical traditionally built BAA capital projects.





2.14 Multi-storey office development, London

Project Summary

Client: Confidential
Construction Value: Confidential
Status: Under construction

How we added Value:

- Major reduction of site works and labour
- Optimisation of net-gross by integration of columns into cladding
- Reduction of required floor-to-floor heights whilst providing a high quality office space (achieved by full structure and M&E integration in the floor zone)
- The platform approach maximises offsite manufacturing which significantly reduces on-site time.
- The system is fully integrated with the MEP, allowing for ease of installation.

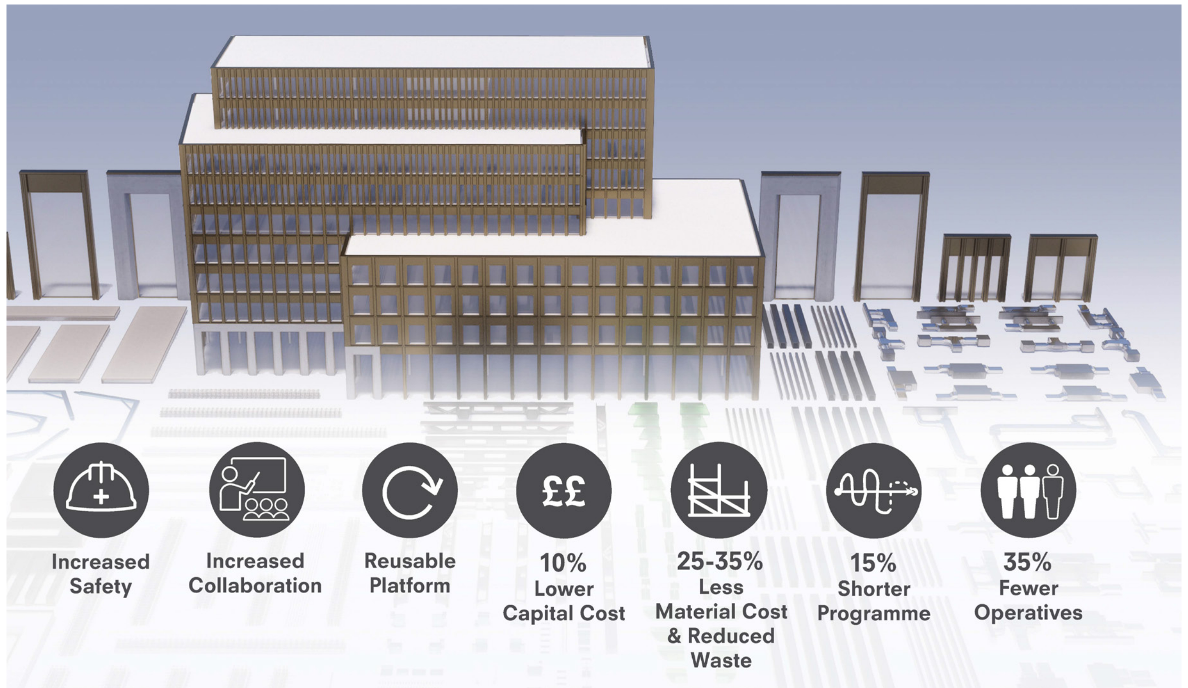
Lightweight composite steel frame office development

The scheme comprises a new build project of office spaces across two buildings. The project consists of the construction of two nine-storey buildings as well as demolition of the existing buildings. Both buildings have been developed using a componentised platform system design approach known as Platform 3.

Platform systems combine design, manufacture, and procurement principles holistically to ensure a greater degree of rationalisation and integration. Platforms manifest themselves as a "kit of parts" of pre-engineered components, assemblies and products that go together in pre-defined ways. They may be subdivided into 4 main elements: Superstructure, façade, M&E and fit out.

The Platform 3 system works within a grid spacing of 9x9m. The primary frames consist of goalposts and infill components made of a girder beam with services penetrations and steel columns. Platform 3 seeks to use the minimum volume of concrete required for the provision of sufficient acoustic and fire separation between floors (which is little more than that used for a topping to precast) and use it as an effective spanning element.

The Platform 3 strategy also seeks to integrate the construction and services zones without detrimentally affecting the services zones, enabling a maximised floor to ceiling height in a minimised overall envelope.



2.15 Lennig House

Project Summary

Client: Durkan Ltd
Status: Completed 2008

How we added Value:

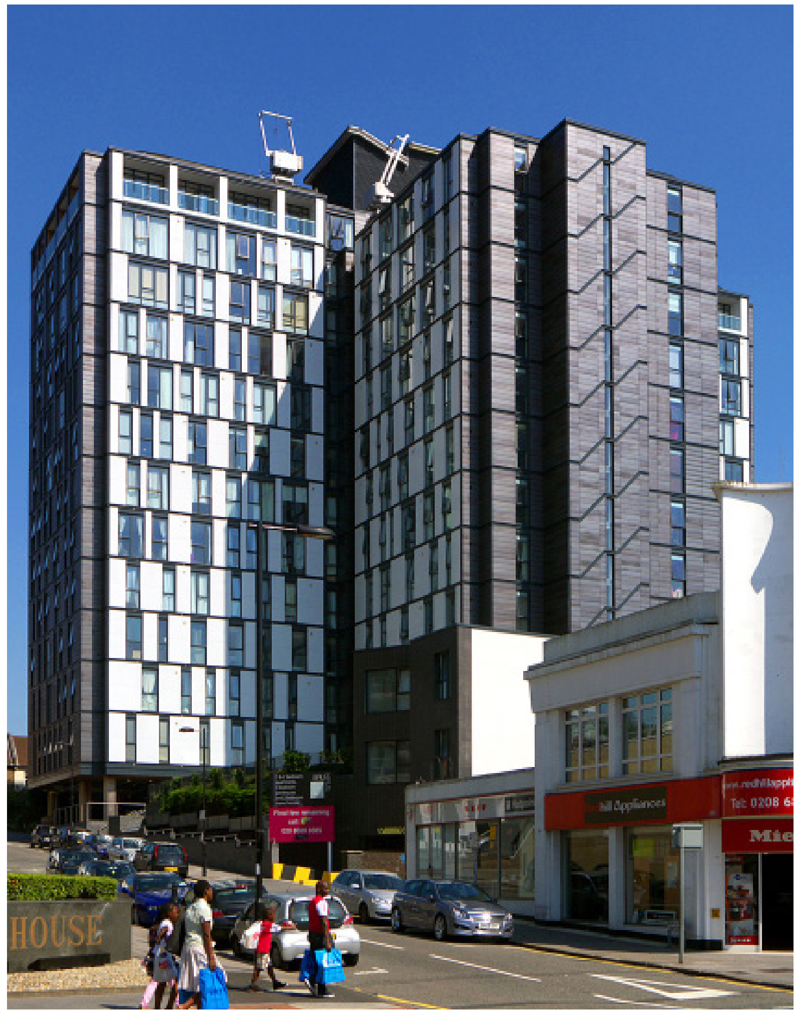
- Revitalisation of a deteriorated building to create a new local landmark and urban space.
- Innovative cantilevering façade system created a substantial increase in sellable floor area.
- Three additional storeys added to the existing building creating new premium residential units.

Transformation of an iconic housing development

Lennig House is an iconic housing development of 190 high-quality residential units in London. The project comprised the refurbishment and reactivation of an existing 10-storey concrete-framed office building built in the 1960s. The building had a limited future commercial viability as office space. With its exposed structure and spandrel panels, the building typified the unfavourable aesthetic which is often associated with concrete buildings.

Two new levels of car parking were concealed beneath a new urban space, bordered by 5 new build mews houses. In addition to extending the building upwards by three storeys, the construction employed an innovative new façade system cantilevered from the existing concrete floor planes by approximately one metre. A mixture of solid and glazed cladding allowed the building to become increasingly 'perforated'; at higher levels, the degree of transparency increases to form an inverted cascade of clear glazing, lightening the external appearance.

While addressing the visual qualities of the building and affording a delicate new texture to the façade, the cladding therefore also provided a substantial increase in floor area.



2.16 East Village

Project Summary

Client: Qatari Diar Delancey
Construction Value: Confidential
Status: Completed

How we added Value:

- Incremental increase in sophistication from plot to plot allows the scale of benefit to increase as the project team and supply chain grows in experience.
- The uniqe architectural character of each plot is protected by flexibility designed into the structural components.
- Component library includes a range of structural options for buildings ranging from 5 to 38 storeys, enabling the most efficient structural solution to be applied for each plot.

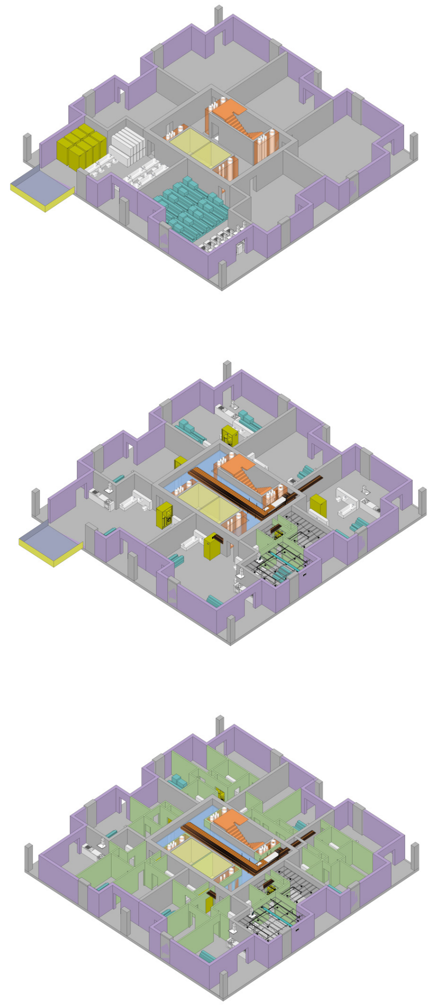
Standardised construction and delivery strategy

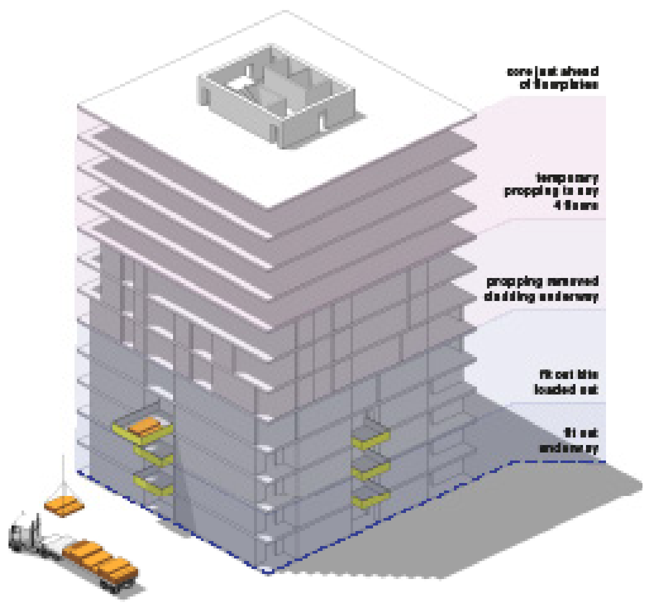
East Village is a development adjacent to the Olympic site in Stratford, East London, to create a mixed-use scheme including 1,900 new apartments. Bryden Wood were appointed by Qatari Diar Delancey to develop a delivery strategy for the project which comprises 6 plots ranging in height from 5 to 38 storeys. Each of the plots is to have its own unique architectural character, while being based on a standard set of components (the 'Integrated Platform').

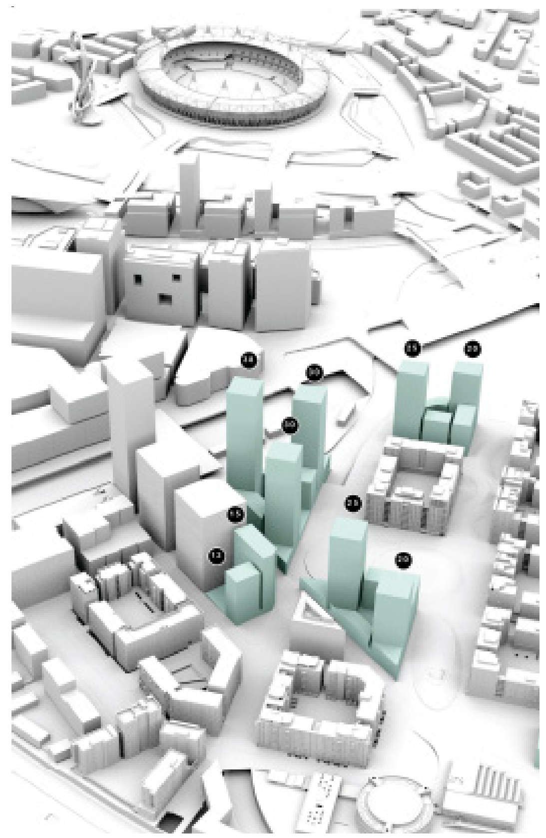
By adopting a strategic approach to delivery, the East Village project aims to benefit from significant savings compared to a 'traditional' construction project, where typically only half of the construction sum remains as residual value in the final product. A strategy based on a delivery concept that relies on the appropriate level of standardisation, and that from the beginning takes into account how building elements are procured, will result in significant improvements in cost, programme and quality.

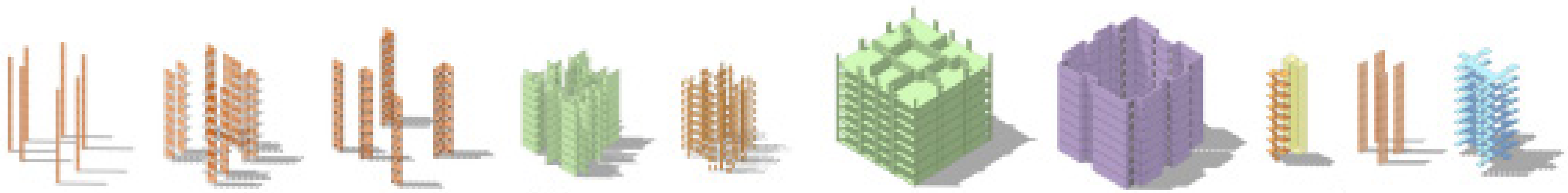
Bryden Wood's leading approach to Building Information Modelling (BIM), along with the adoption of best-in-class design, coordination and delivery tools and processes, were the key concepts to allow these savings to be realised.

The strategy allows for an incremental increase in sophistication from plot to plot, adopting first standard building frameworks and interface details, before introducing off site manufactured elements in later plots as the project team and supply chain grows in experience. This approach also allows for a wide range of procurement options.









2.17 Ponton Road

Project Summary

Client: 46 Ponton Road

Our Partners: Laing O'Rourke / ExpLORe

Construction Value: Confidential

Status: Under construction

How we added Value:

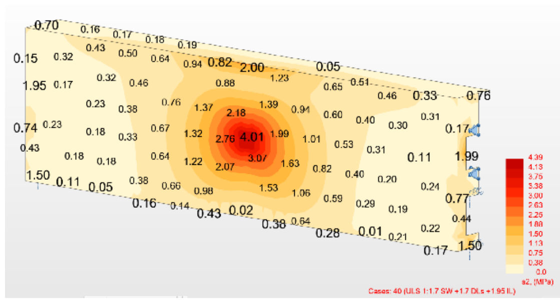
- Full fabrication details of GRC panels & fixings for cladding mullions, spandrel panels, and other bespoke elements.
- Developed through-bolt fixing design to reduce manufacturing costs and still allow for preferred installation sequences.
- Each variety of GRC panel and fixing bracket were systematically 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

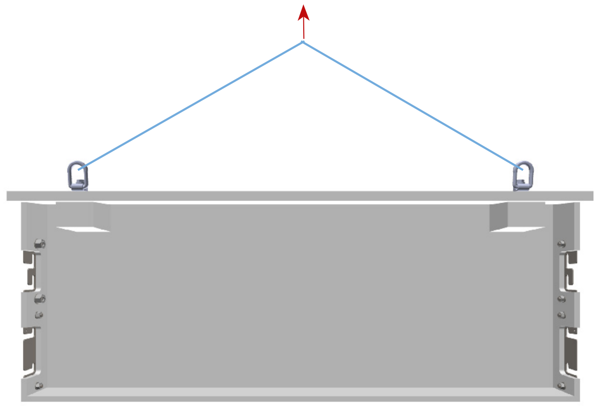
46 Ponton Road development is made up of three blocks of flats ranging between 10 – 13 storeys located in Nine Elms which is a fast transforming district in Battersea. The design intent is a redevelopment of the site to provide affordable housing that will comprise of 357 residential units, mixed with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

Bryden Wood was appointed by Laing O'Rourke/Expanded for the joint design of the precast cladding package which encompasses all three blocks at 46 Ponton Rd. Our client advised 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.

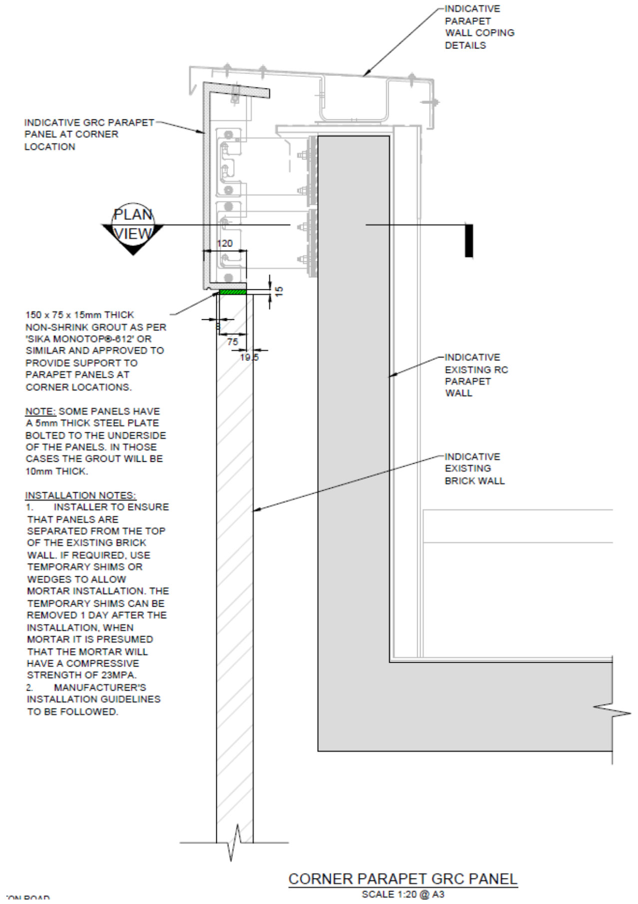
Site Concept



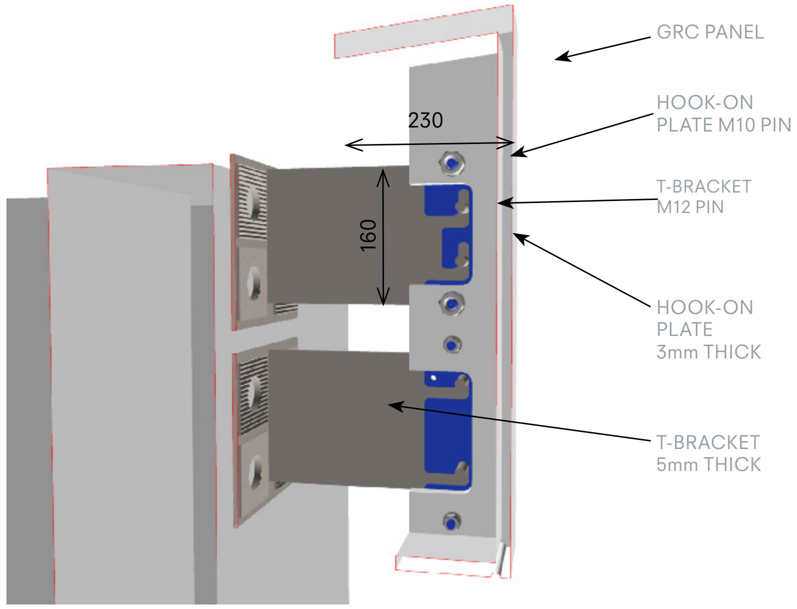
Structural Verification



Typical Lifting Arrangement



Detail Drawings



GRC Panels, Bracketry, Fixings

Mock-Ups

2.18 LCF

Project Summary

Client: Laing O'Rourke/Expanded
Construction Value: To add
Status: Under construction

How we added Value:

- Converted large volume of complex structure into buildable DfMA elements

Precast and façade engineering for iconic education campus

Bryden Wood 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 Site Photo 20201008

LCF Site Photo 20201015

2.19 Hong Kong Lyric Theatre

Project Summary

Client: Gammon Construction Limited
Construction Value: HK$ 5.5bn
Status: Construction Stage

How we added Value:

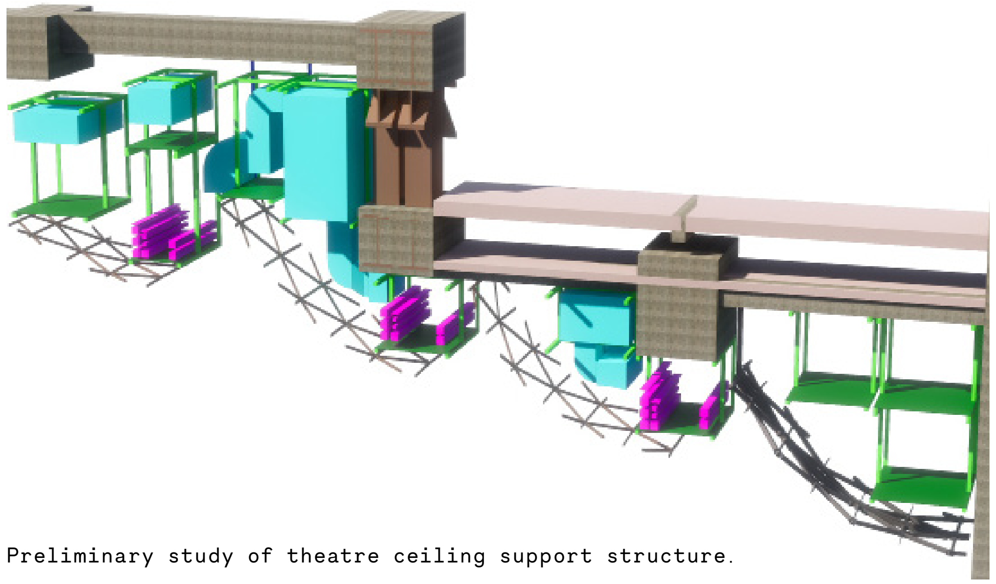
- Developed design proposals for efficient and constructable solutions to achieve highly complex geometric forms in an efficient way
- Standardisation opportunities investigated to increase value without compromise to the design intent
- Introduced prefabrication strategies for key components to move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

DfMA opportunities review

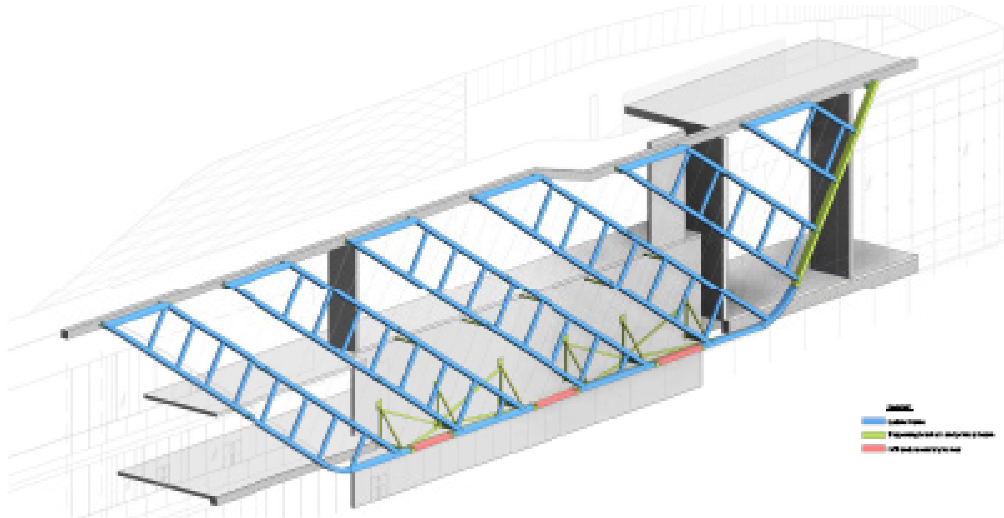
Bryden Wood were appointed by Gammon to support their successful tender for the construction of the Lyric Theatre complex in the West Kowloon Cultural District of Hong Kong. The Lyric Theatre complex is scheduled to be completed in 2023 and will be a world-class cultural facility incorporating a 1,450 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.

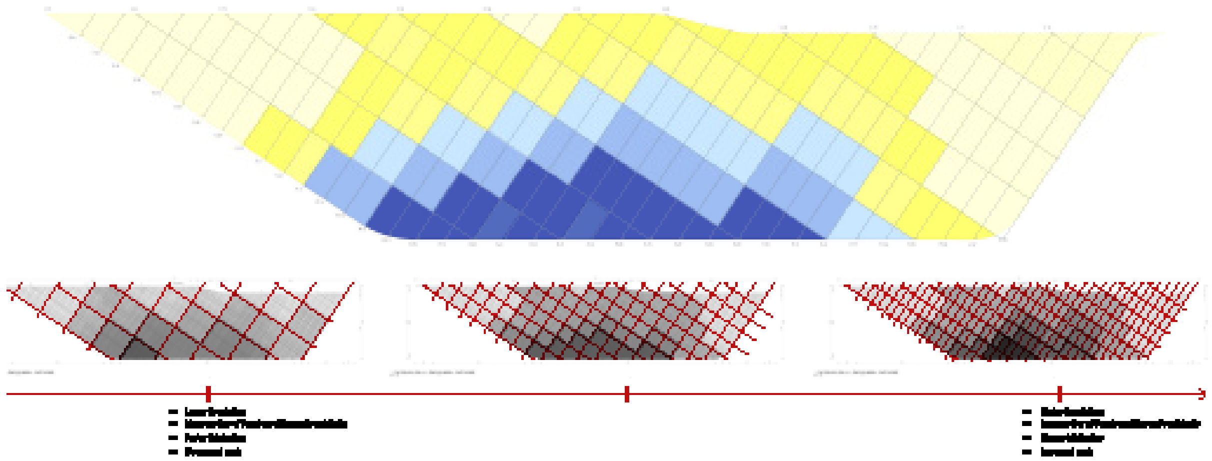
Bryden Wood provided a number of specialist engineering studies focused on identifying opportunities for optimised DfMA solutions for the delivery of the façade elements, very complex theatre ceilings and M&E prefabrication and specialist in-situ and precast concrete elements (e.g. curved seating areas).



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.

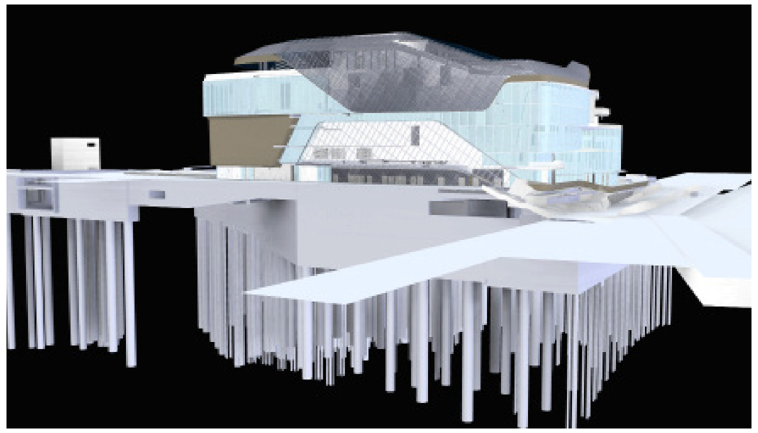


Image of 3D model showing pile foundations.

Architectural exterior visualisation.

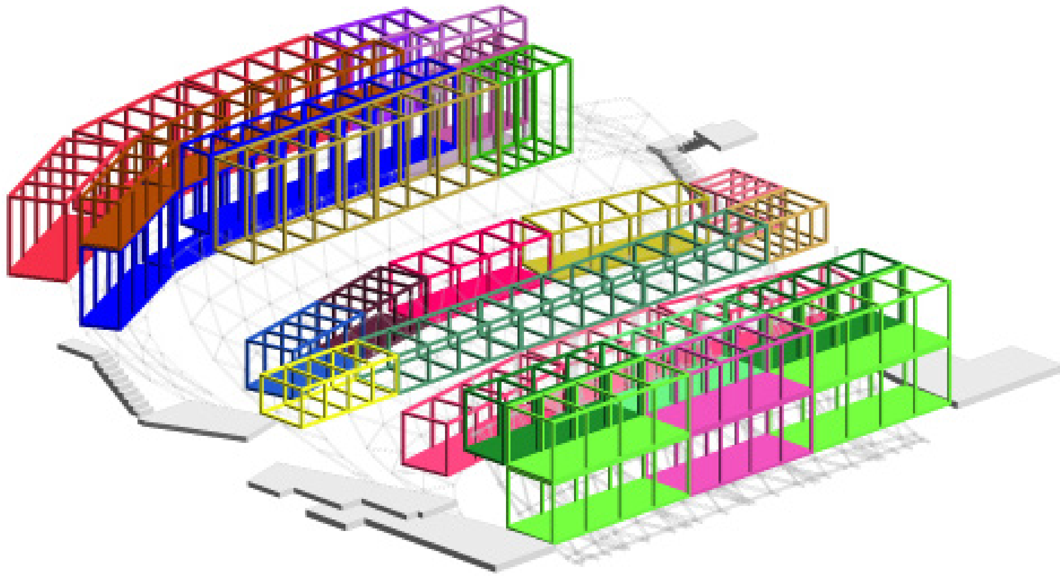
2.19 Hong Kong Lyric Theatre

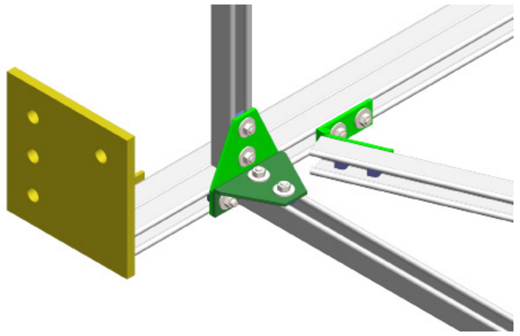
DfMA solutions for theatre feature ceilings

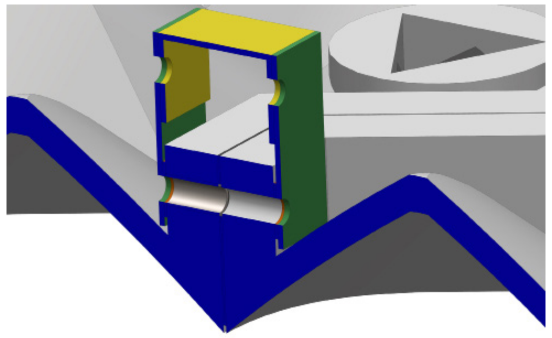
Subsequently to Gammon's successful tender for the project, Bryden Wood were appointed by Gammon to further develop the design of DfMA elements including GRG Ceilings in the Large and Medium Theatres, including the hanging modular support structure (for walkways, lighting and M&E distribution), the secondary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

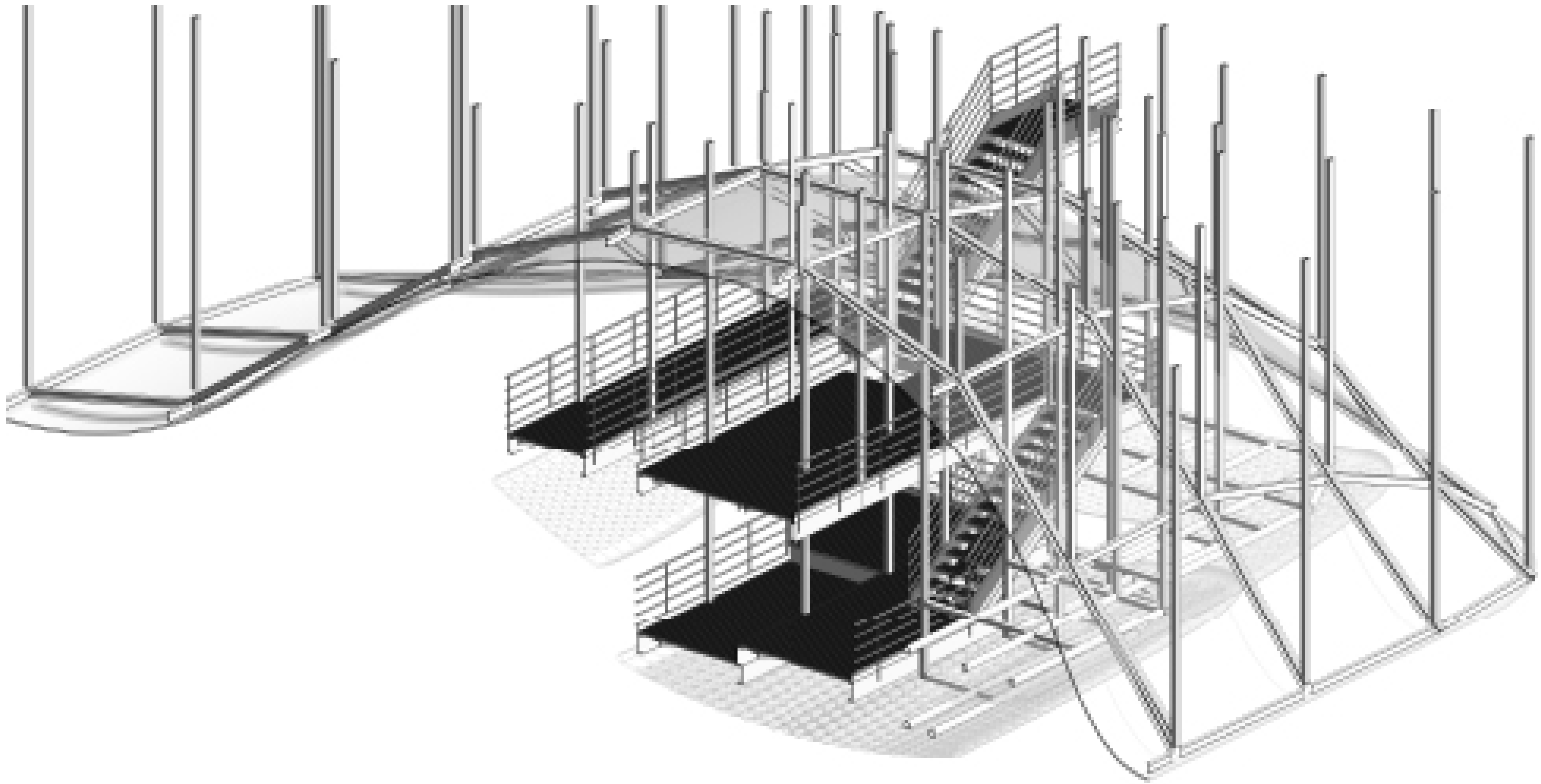
Bryden Wood are providing a comprehensive design service for these specialist packages including:

- 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.







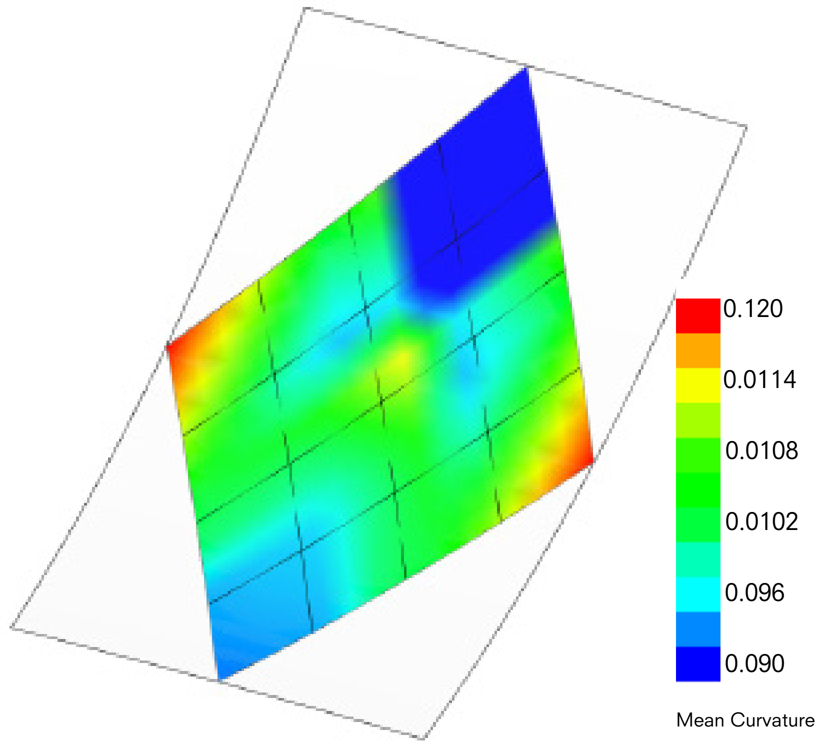


2.19 Hong Kong Lyric Theatre

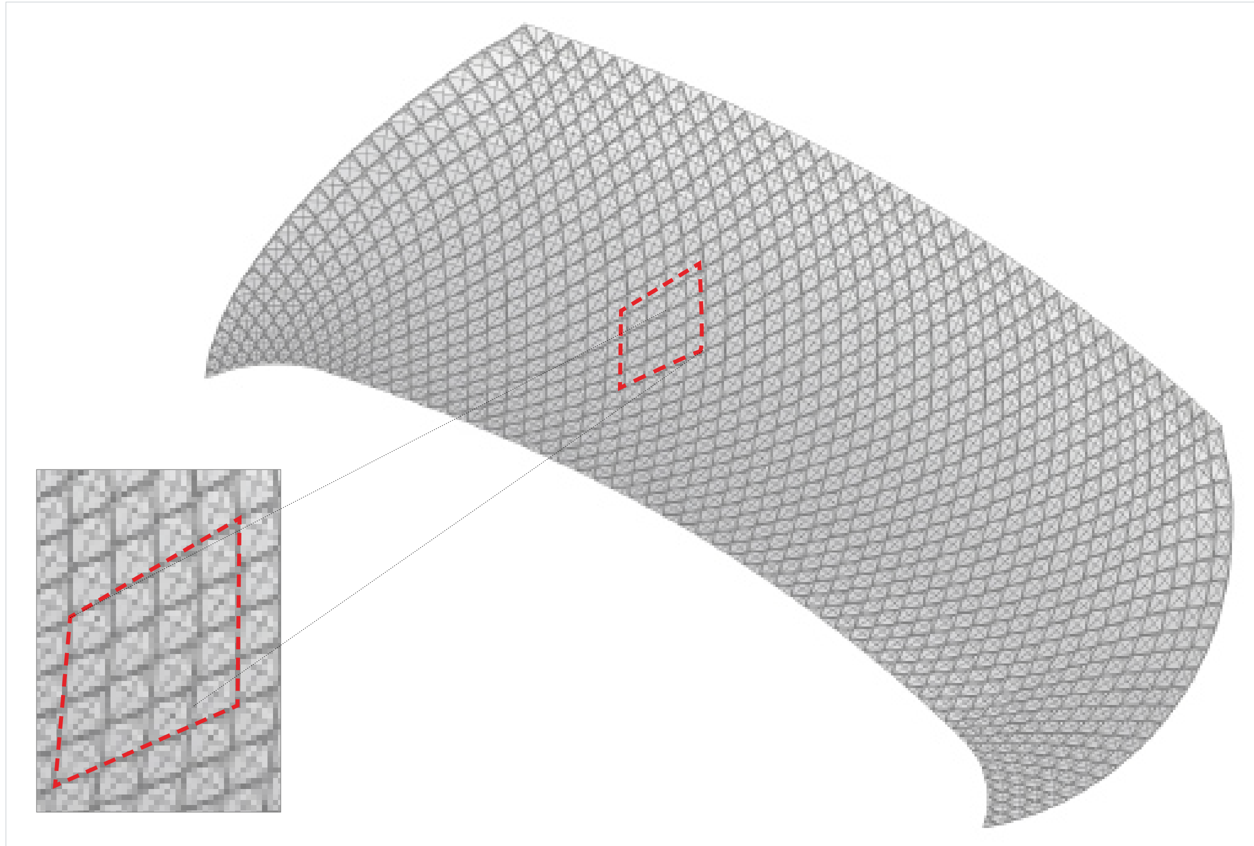
Analysis and rationalisation

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.

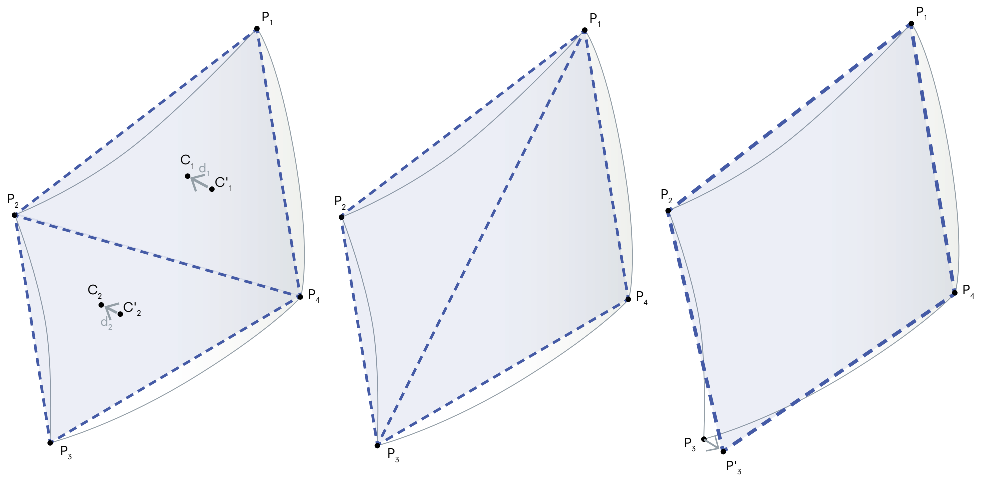
The analysis and rationalisation exercise resulted in a series of possible design interventions with a quantified benefit in terms of lower cost and faster fabrication as well as a defined impact on the overall ceiling geometry.

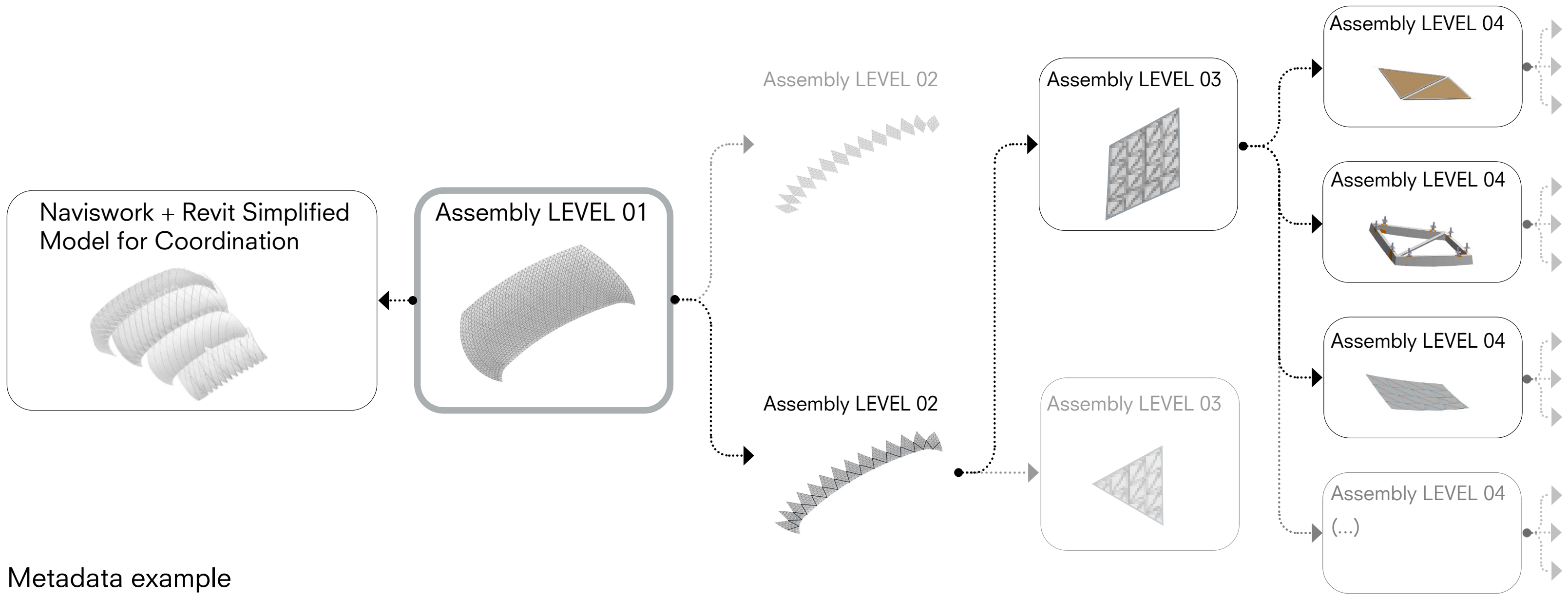


Mean Curvature of the current base Surface.



Mean Curvature of Simplified Geometry proposed for GRG panels.



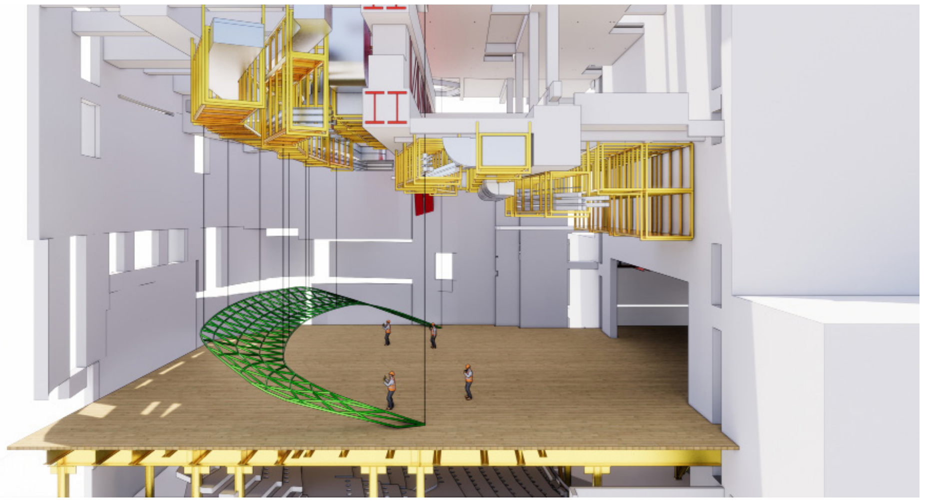


Metadata example

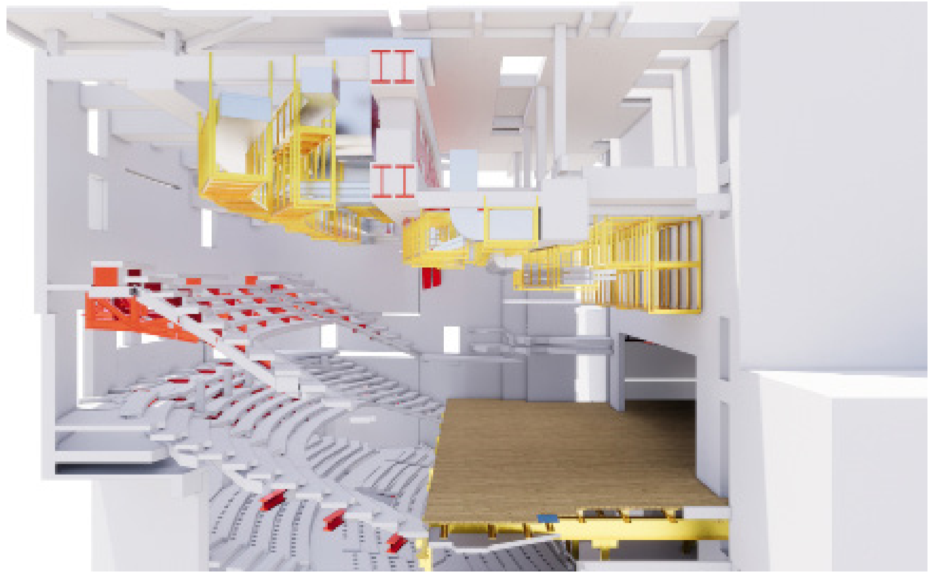
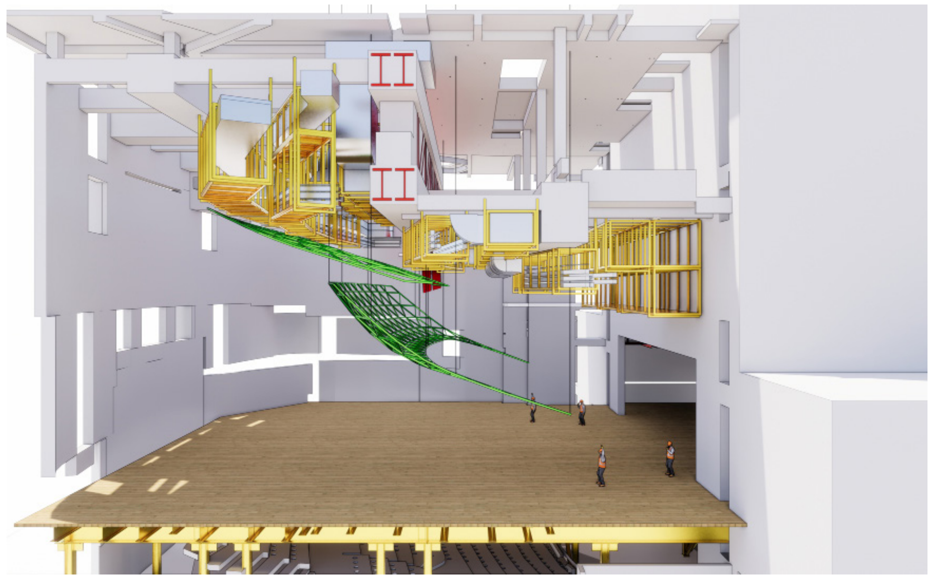
- A - LT Location
- B - MT Location
- S1 - Ceiling Strip 01
- S2 - Ceiling Strip 02
- R1 - Row 01
- R2 - Row 02
- F - Flat Geom.
- D - Double Curved Geom
- G - GRC
- CS - Carbon Steel

2.19 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.



2.20 Hong Kong International Airport- Terminal 2 Redevelopment and Third Runway Concourse

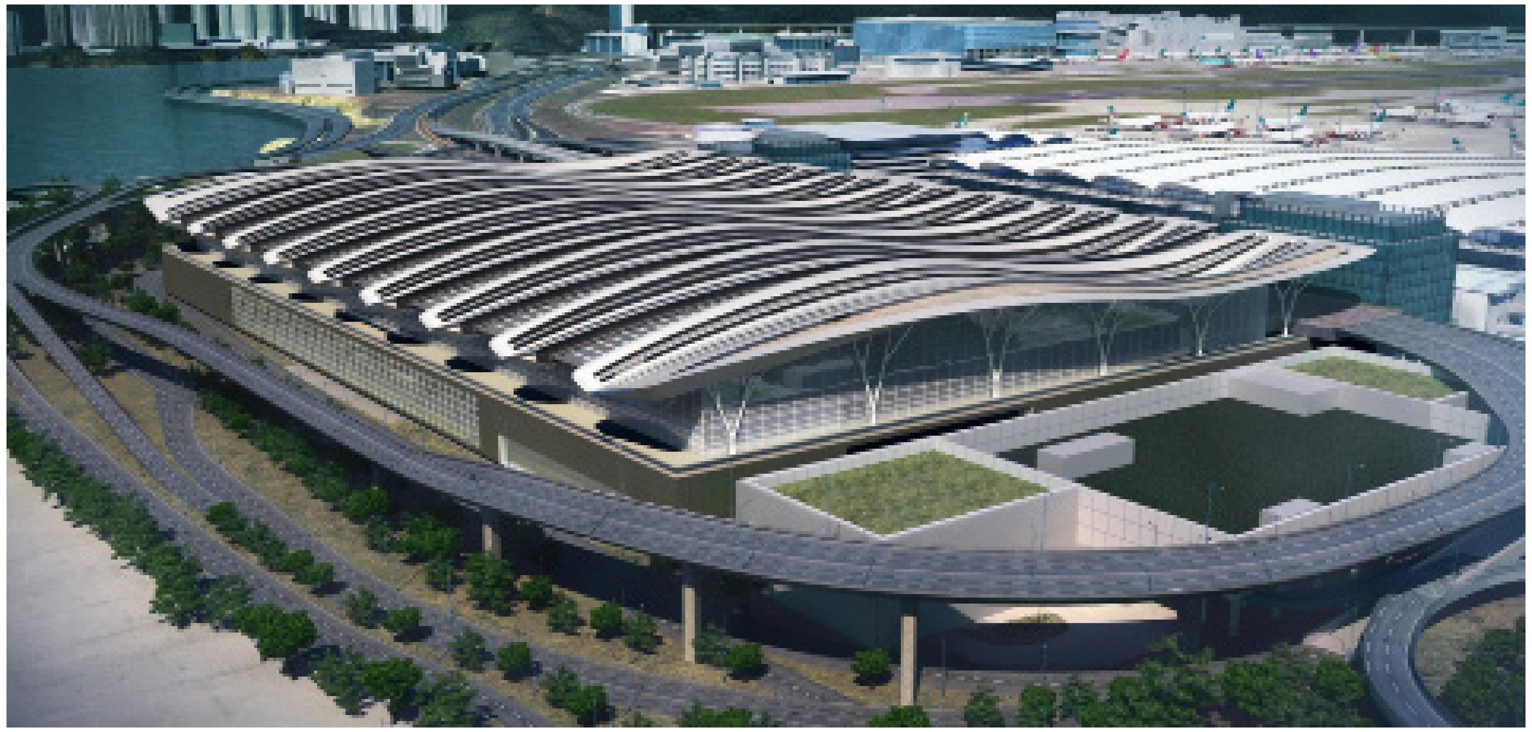
Project Summary

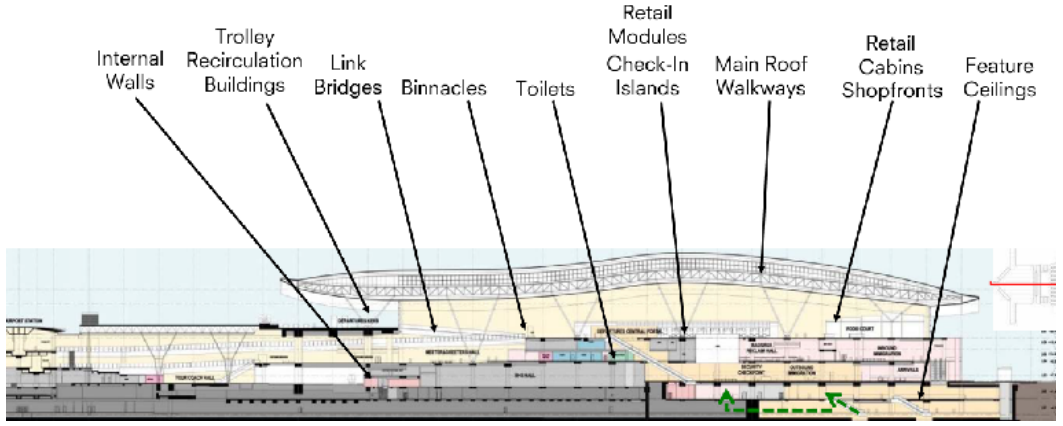
Client: Gammon Construction Limited
Construction Value: HK$ 12.88bn (£1.27bn)
Status: Pre-construction (T2)

Bryden Wood was appointed by Gammon Construction Ltd, a leading contractor in Hong Kong, to join their tender for the redevelopment of Terminal 2 at Hong Kong International Airport. We were also a part of Gammon's team for their bid for the airport's new Third Runway Concourse and associated apron works. For both bids, Bryden Wood reviewed the tender stage design proposals and identified opportunities to apply a DfMA approach for the delivery of elements of the project. A design study was carried out for each opportunity to develop the DfMA solution in sufficient detail to allow the scale of potential benefits (e.g. time, cost, material reduction and installation efficiency) to be better understood.

Bryden Wood provided a range of outputs for each of the DfMA design studies including drawings, schedules, calculations, BIM models, assembly and installation sequences and technical notes to fully explain the concept. The DfMA solutions we developed were incorporated into Gammon's tender for each of the projects.

Gammon's tender for the Terminal 2 redevelopment was successful and pre-construction works are now well underway. Following the tender award Bryden Wood and Gammon presented the DfMA opportunities that were explored in the tender stage to the Hong Kong Airport Authority and it was agreed that some of the DfMA packages would be implemented on the project with the others to be reviewed later in the construction programme. We are now working to develop the design of the initial DfMA packages and preparing detailed documentation for regulatory approval.

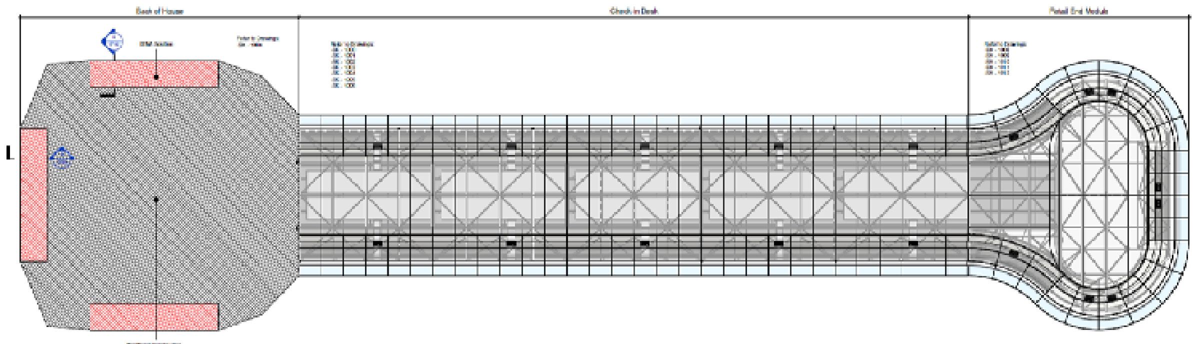


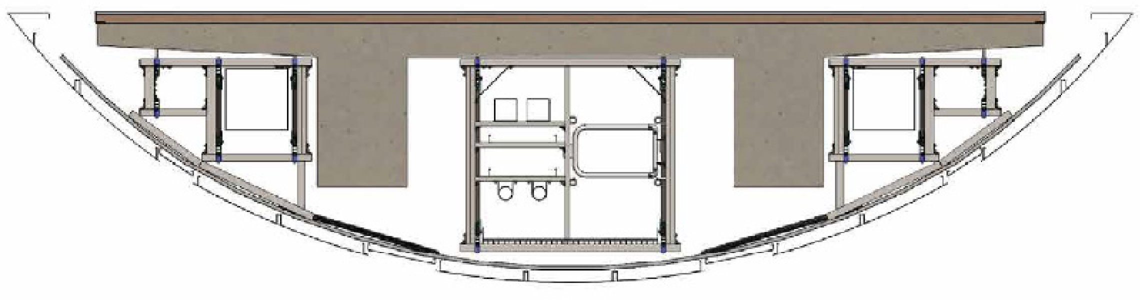


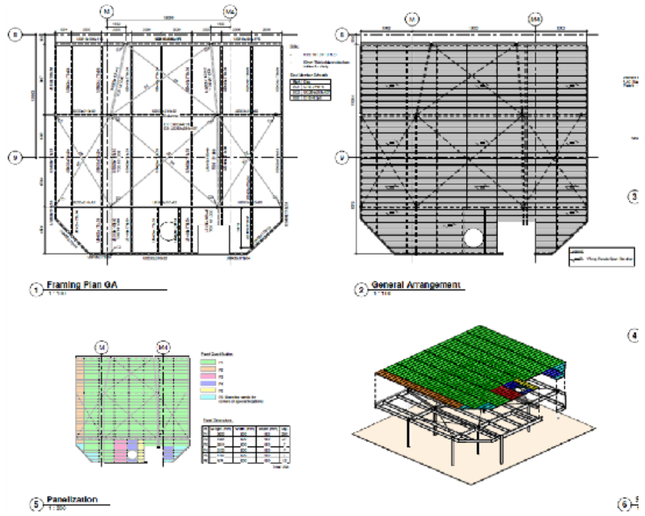
2.20 Hong Kong International Airport- Terminal 2 Redevelopment and Third Runway Concourse

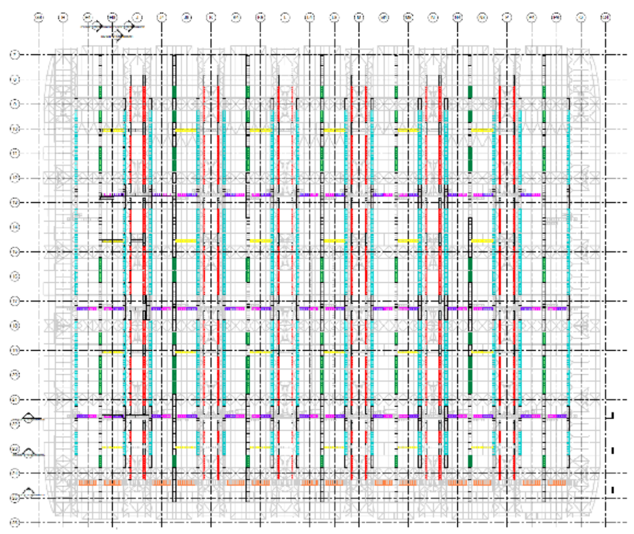
DfMA solutions were developed by Bryden Wood for many aspects of both projects including architectural fit out, superstructure and MEP elements. For the Terminal 2 redevelopment the packages that we explored in the bid stage were internal walls, trolley recirculation buildings, internal pedestrian link bridges, binnacles, volumetric and componentised toilets, retail and check-in island modules, maintenance walkways in the main roof, retail cabins and shopfronts, and feature ceilings on the railway station platforms. The initial packages that are being further developed post-tender award are the main roof maintenance walkways and internal link bridges.

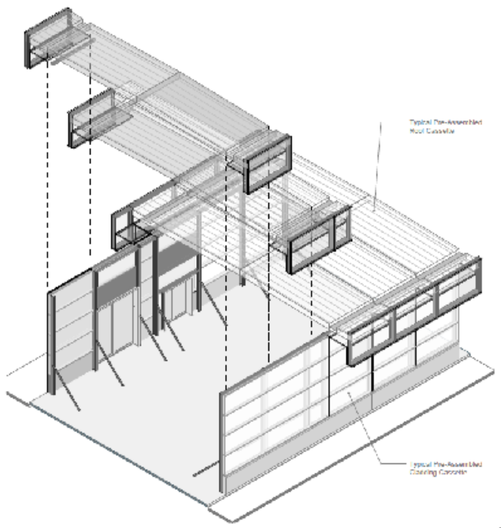
For the Third Runway Concourse bid, we also developed DfMA solutions for volumetric and prefabricated toilets, binnacles and retail cabins as well as the following additional packages: volumetric transit hotel rooms, fixed link bridges, ancillary buildings and an integrated prefabricated solution for the air traffic control tower.

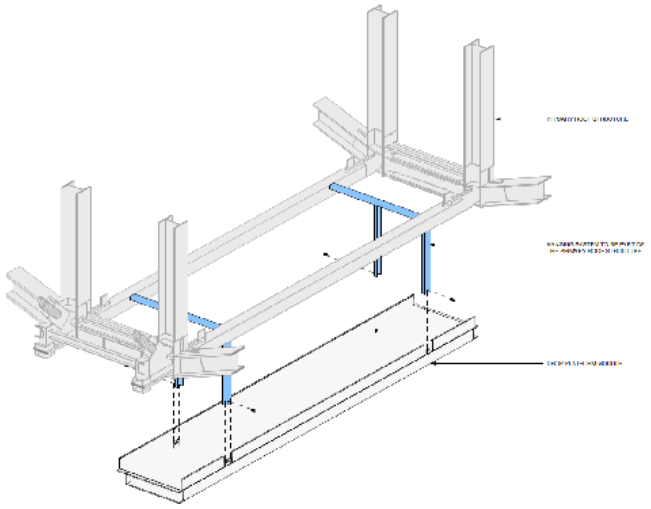


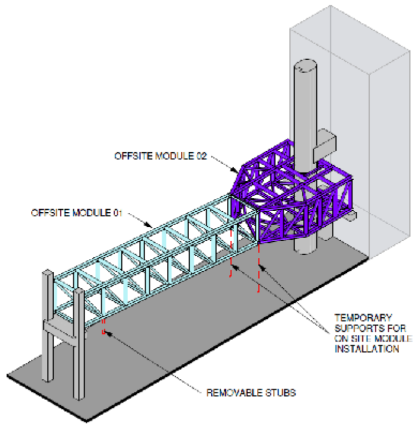


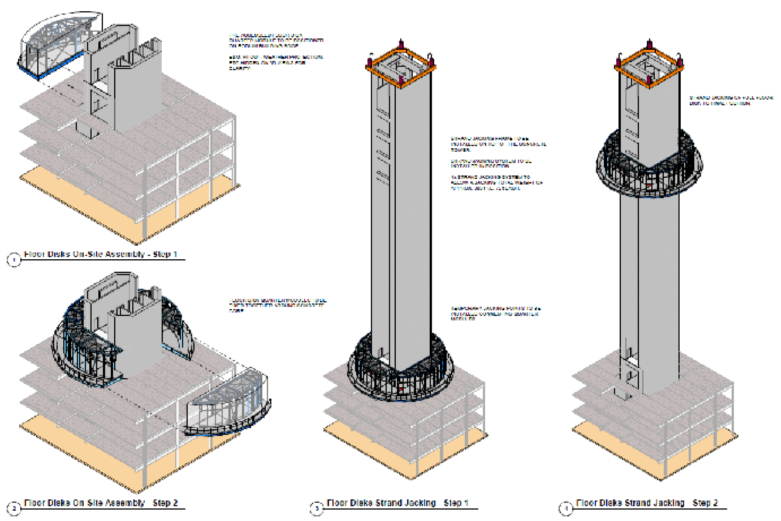


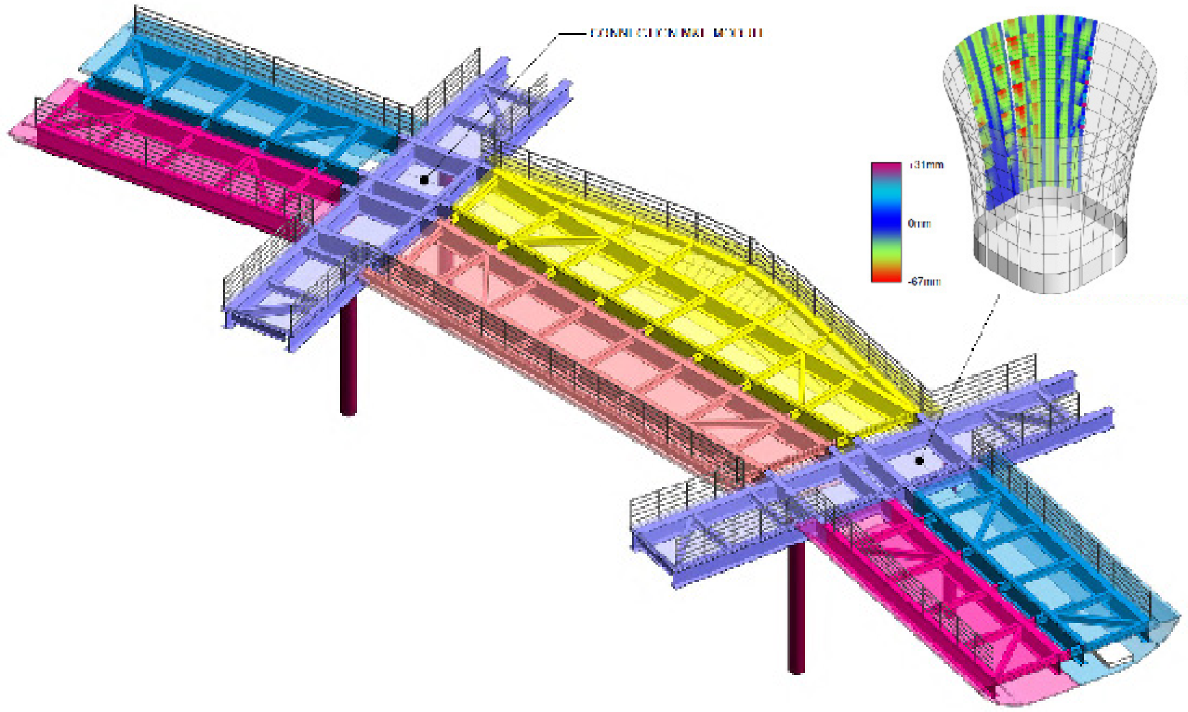


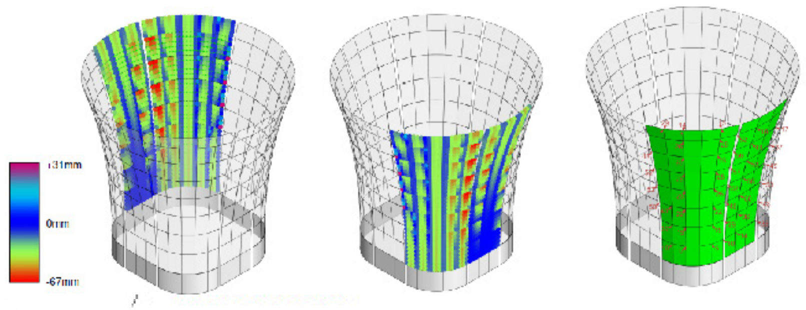












2.21 Crossrail

Project Summary

Client: Laing O'Rourke
Our Partners: GRC UK
Construction Value:
Status: Bryden Wood works complete

How we added Value:

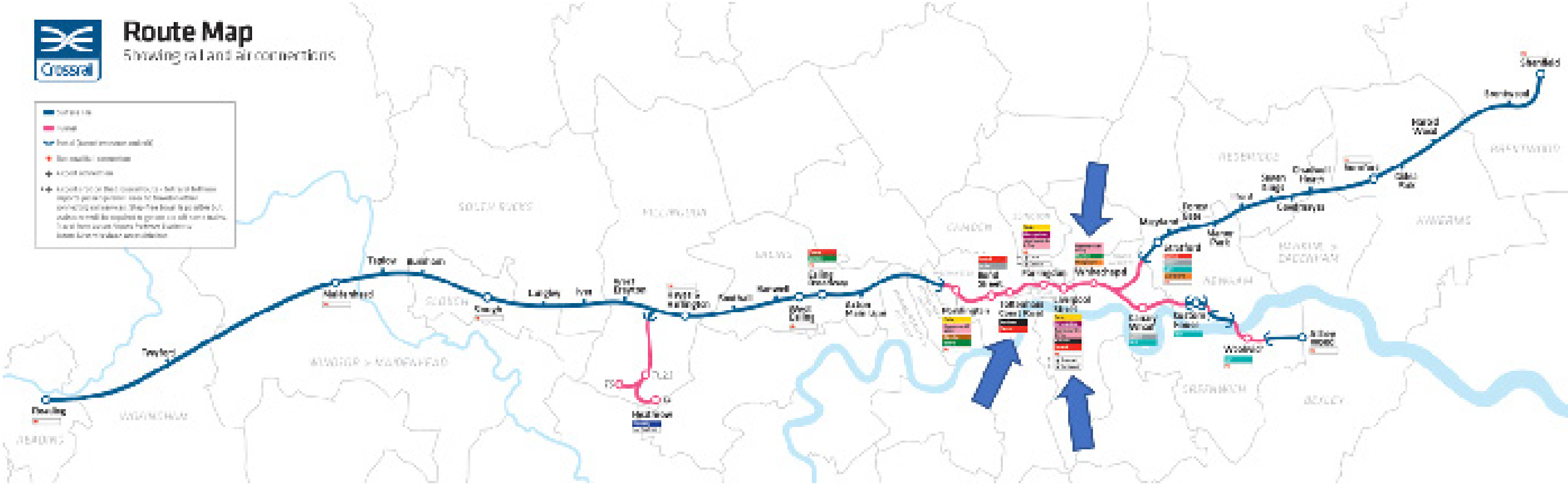
- Compressed site construction/install programme due to off-site fabrication
- Lightweight panels leading to improved health & safety.
- Tolerance and accuracy maintained by CNC cutting and forming machinery across all molds, panels and steelwork.
- Reduced the total quantity of tunnel lining fixings 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 GFRC 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 Crossrail underground train stations - Tottenham Court Road, Liverpool Street and Whitechapel Stations.

Due to the high level of complexity and the aesthetically critical detail that has been required, it has made this project truly unique but has also put the project under extreme time pressures. Bryden Wood have used several different workflows to ensure a timely and high standard delivery of this project.

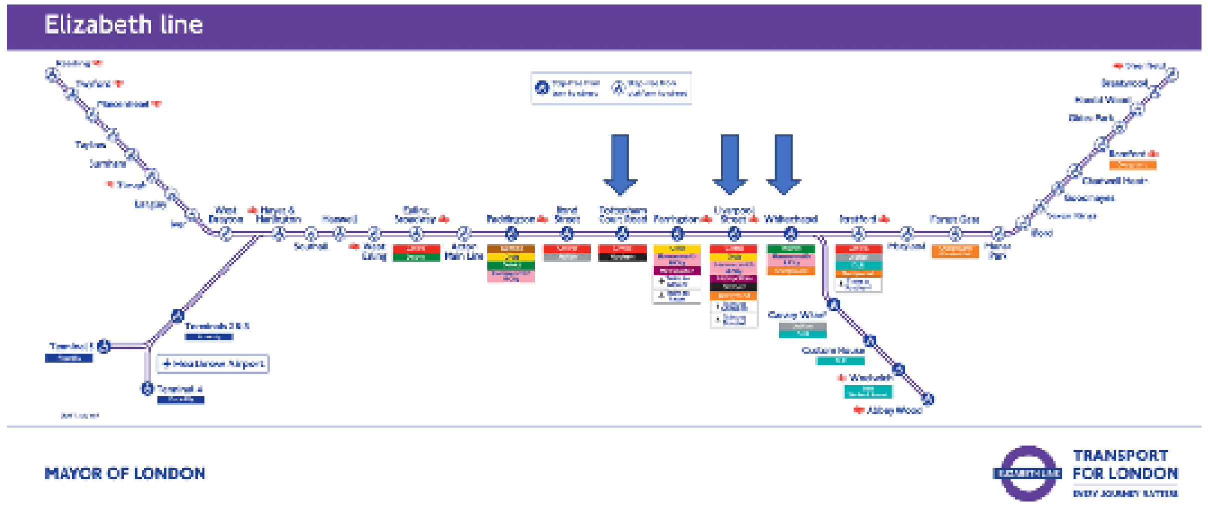
The scope included full fabrication models of the station platforms, concourses and passages in both circular and rectilinear configurations. Multiple optimisation studies were carried out in order to consolidate variations. Point cloud surveys of the tunnel's sprayed concrete lining were taken to accurately 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.



42 kilometres of new tunnels
10 new stations
50 kilometres of new track

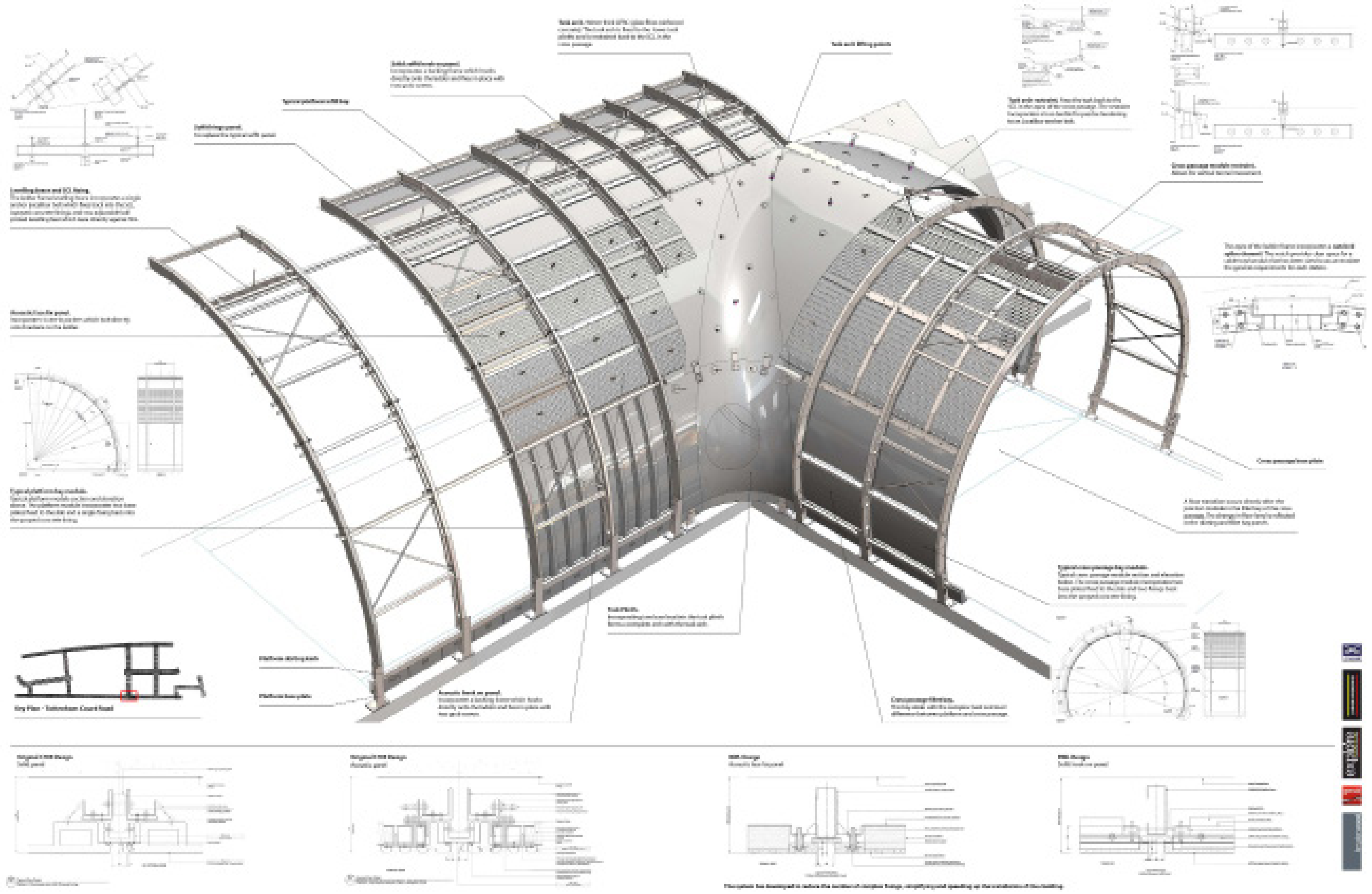
200m long trains
1500 passengers per train
200 million passengers per year

£14.8 billion project cost
£42B benefit to the UK economy
55,000 full time jobs



2.21 Crossrail

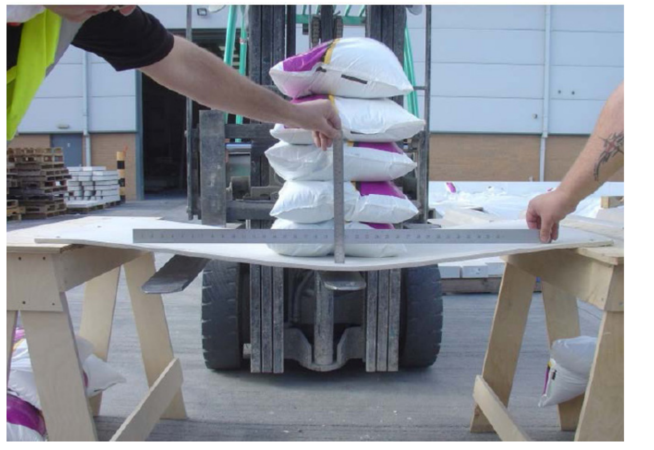
Film Set - 3D Model - Mock Up - On Site

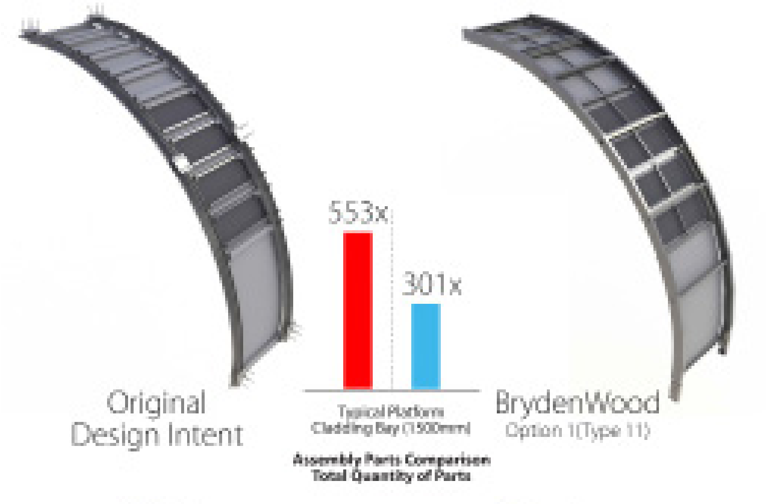


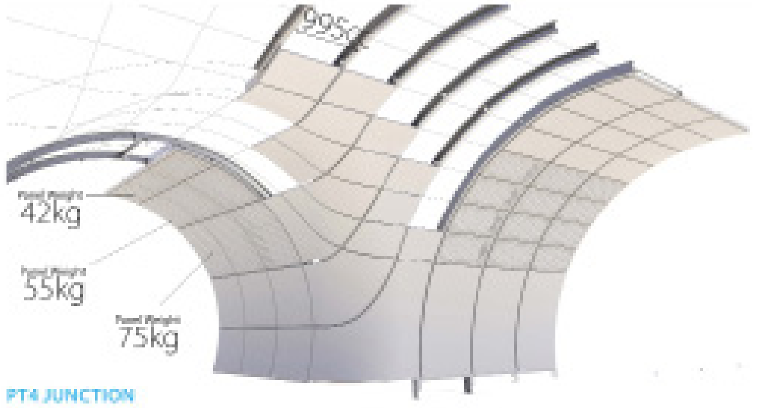
2.21 Crossrail

Optimisation by specialist design and testing

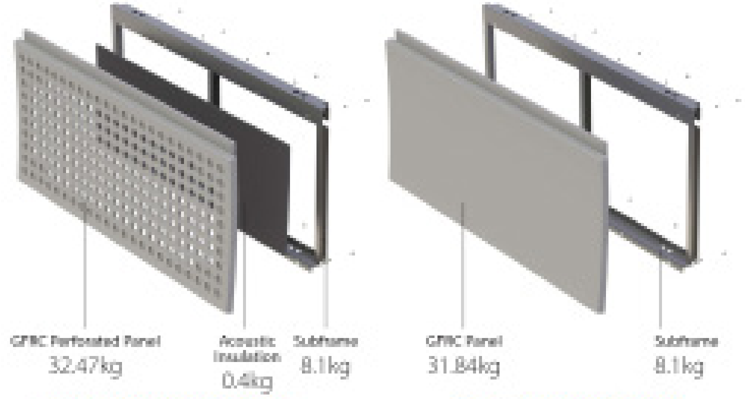
OPTION 1 (Type 11) | OPTION 2 (Type 04) | OPTION 3 (Type 09) | OPTION 4 (Type 06) | OPTION 5 (Type 12)





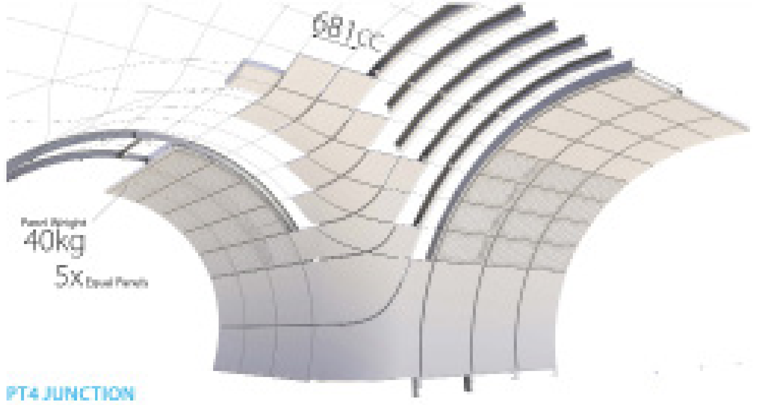


PT4 JUNCTION
Original Intent

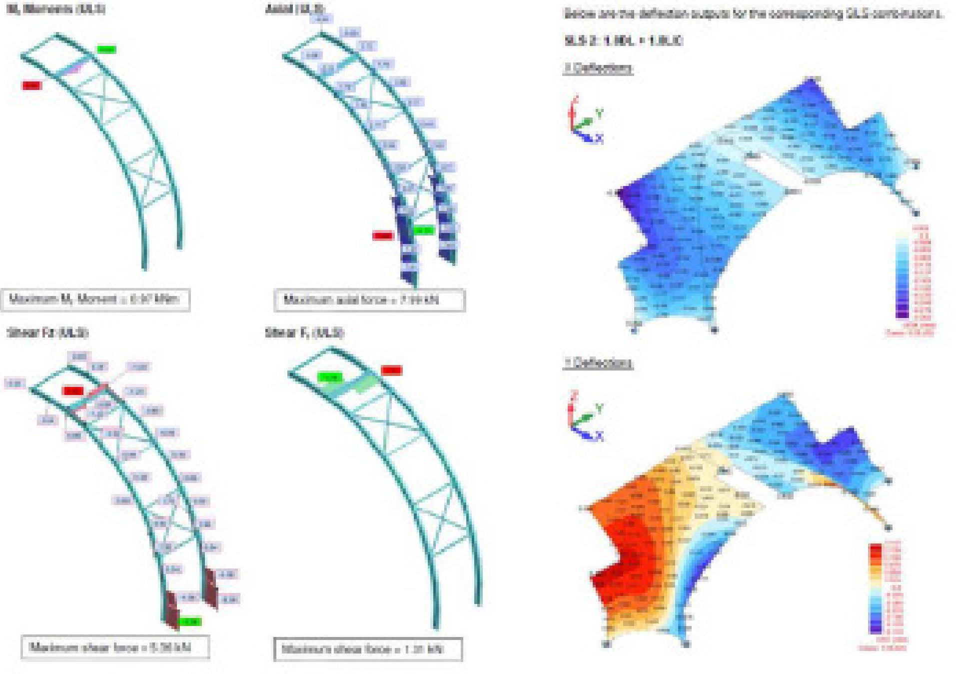


Platform GFRC Acoustic Panel
Weight: 40.1kg
Body Thickness: 10-20mm
GFRC Side Ribs: 30x30

Platform GFRC Soffit Panel
Weight: 39.96kg
Body Thickness: 10mm
GFRC Side Ribs: 30x30

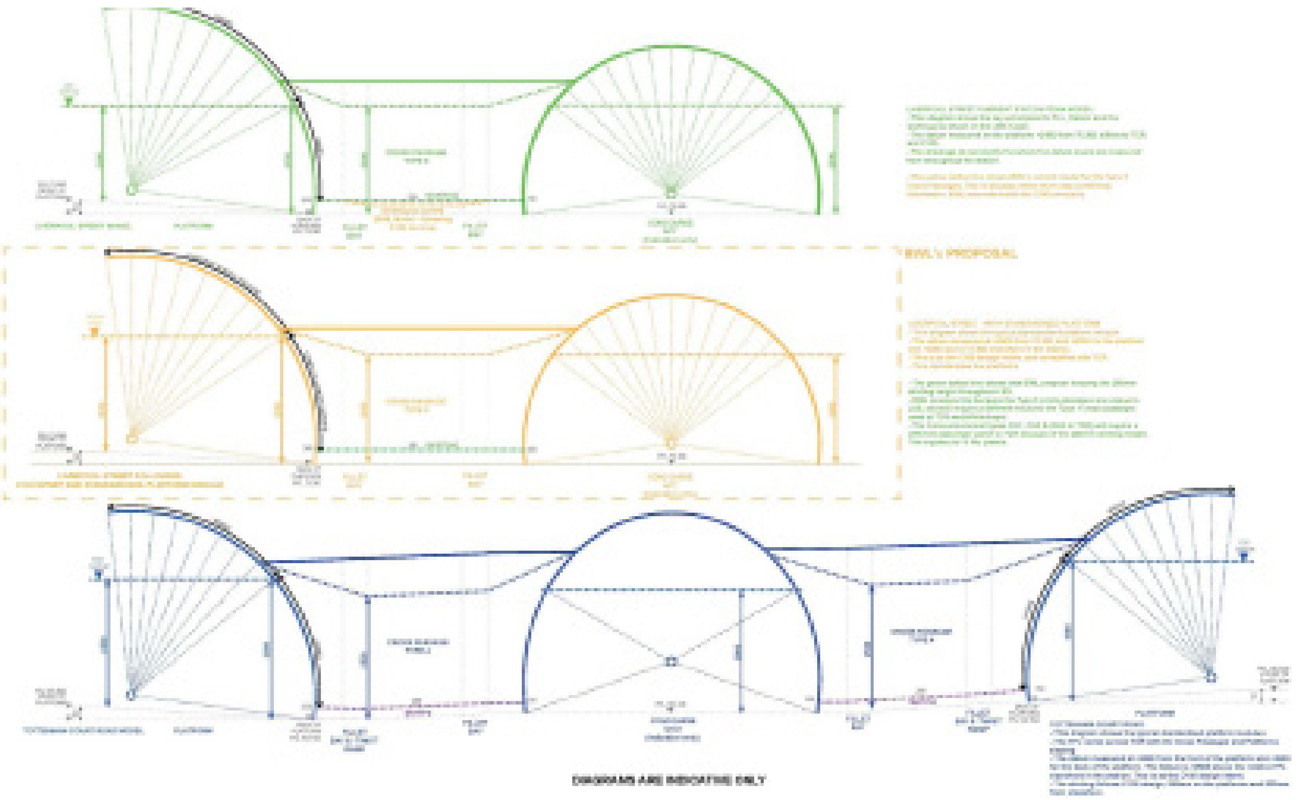


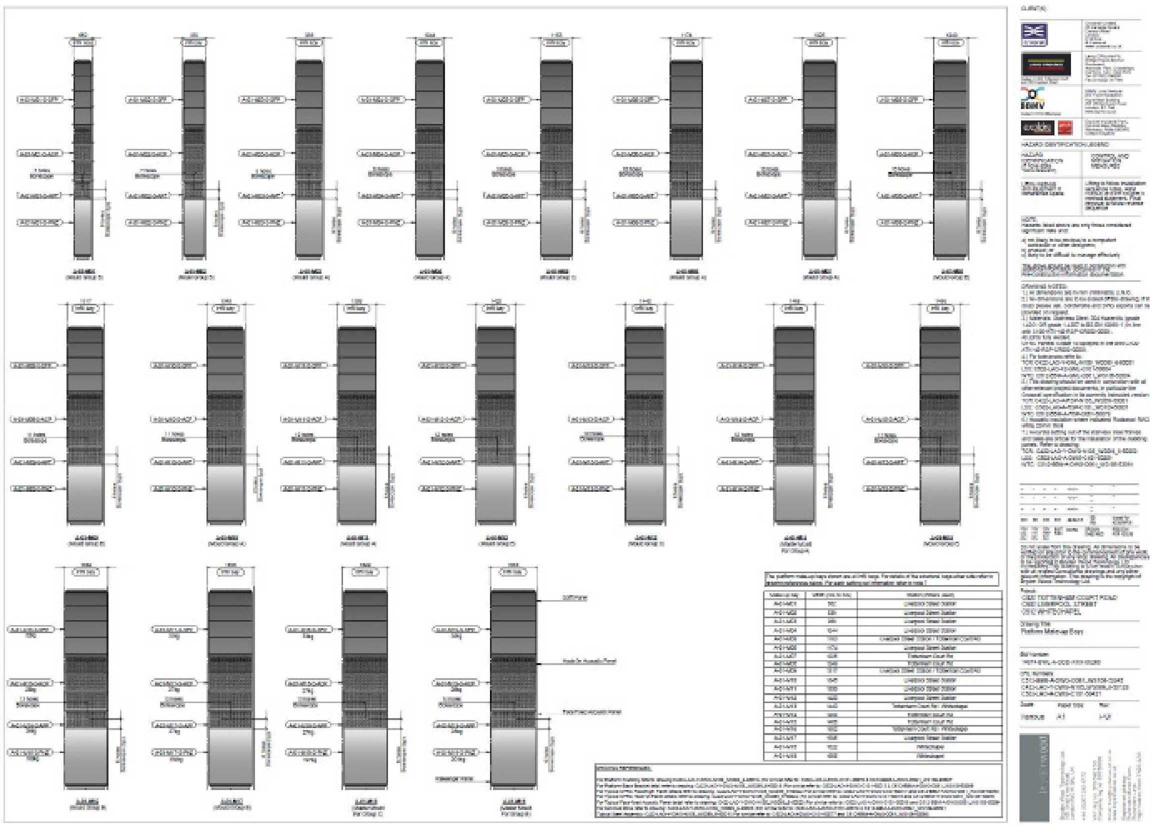
PT4 JUNCTION
Option 4

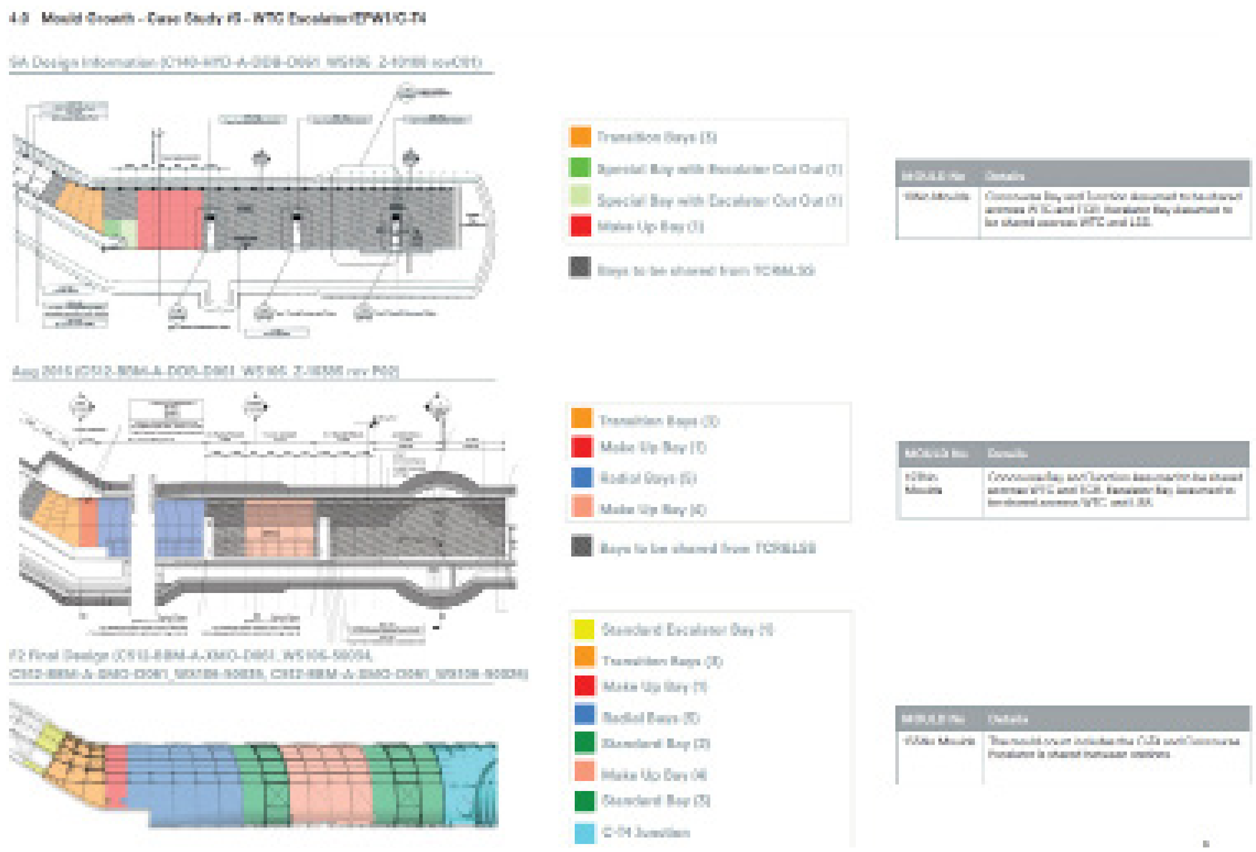


2.21 Crossrail

Rationalisation

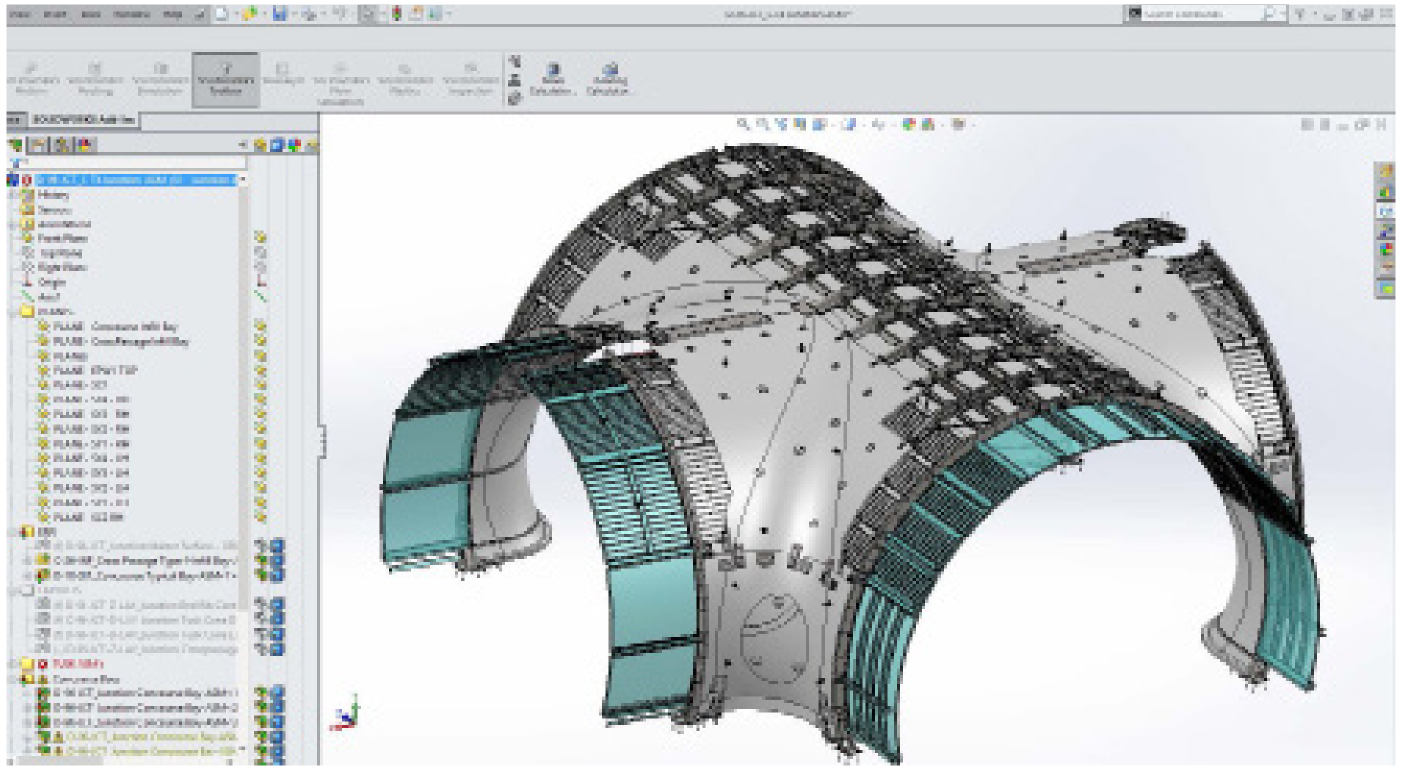


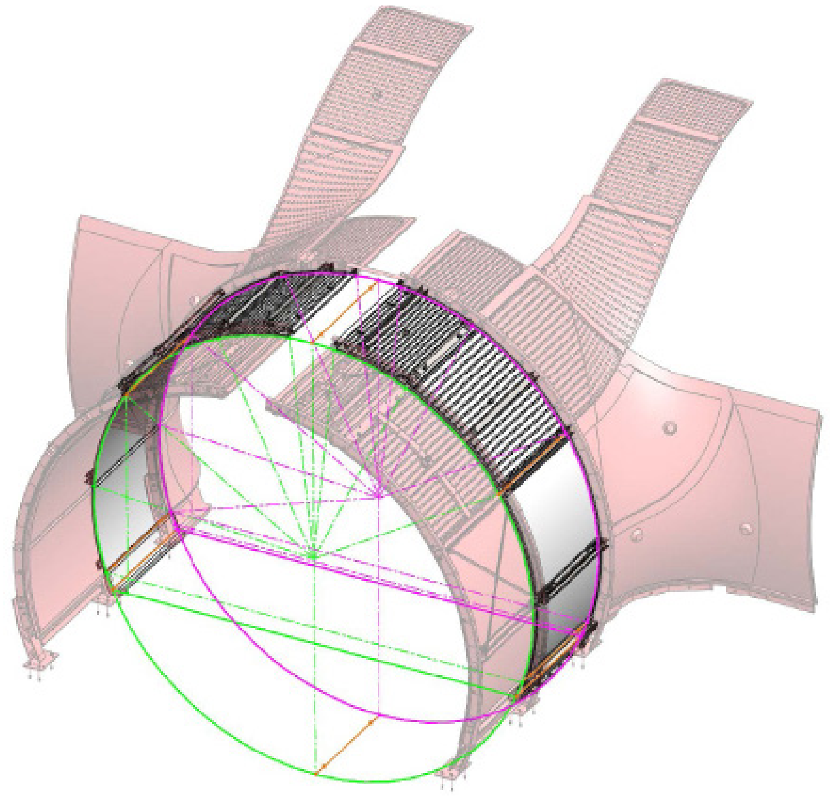


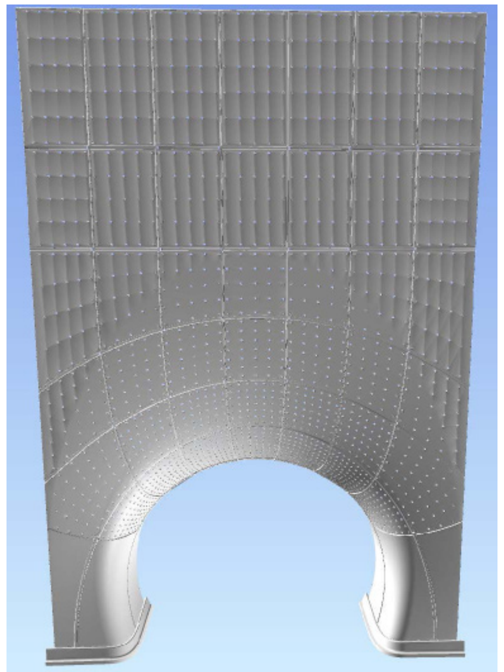


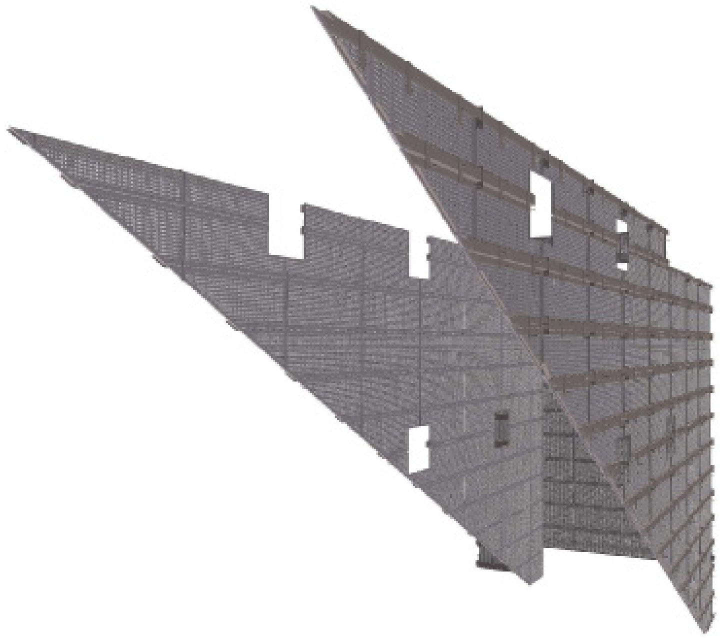
2.21 Crossrail

Solidworks Modelling and parametrics



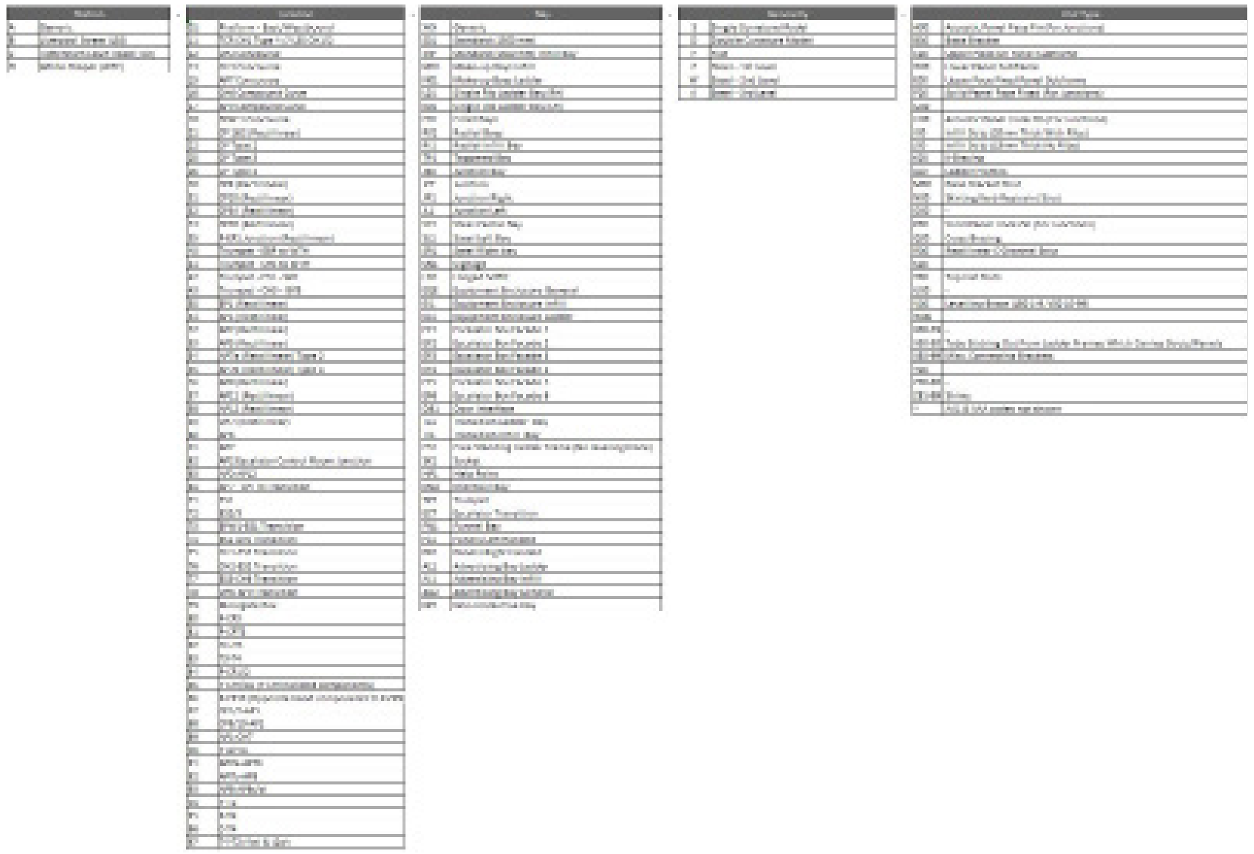


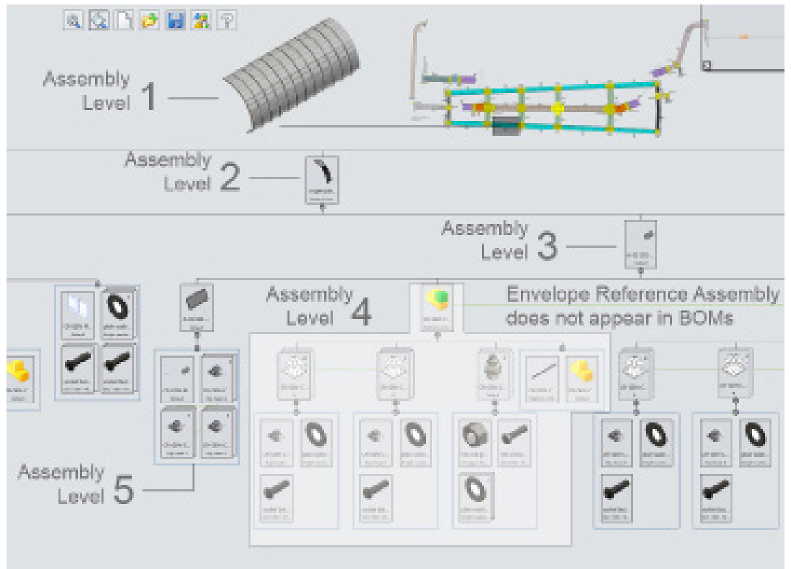


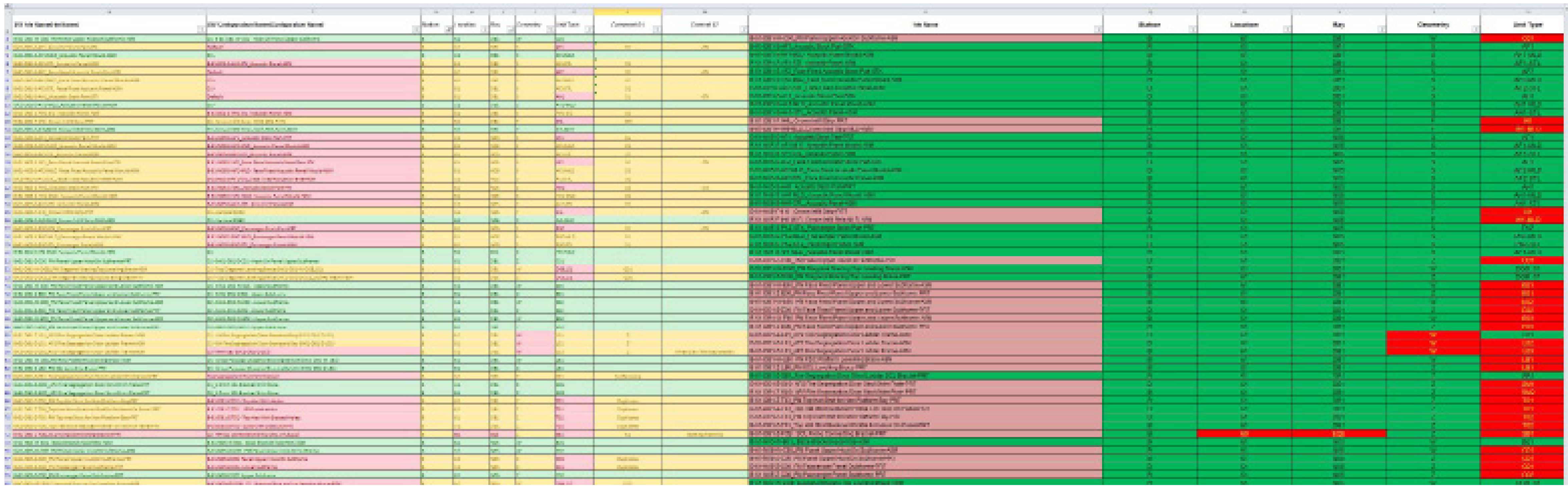


2.21 Crossrail

Meta-Data / Coding

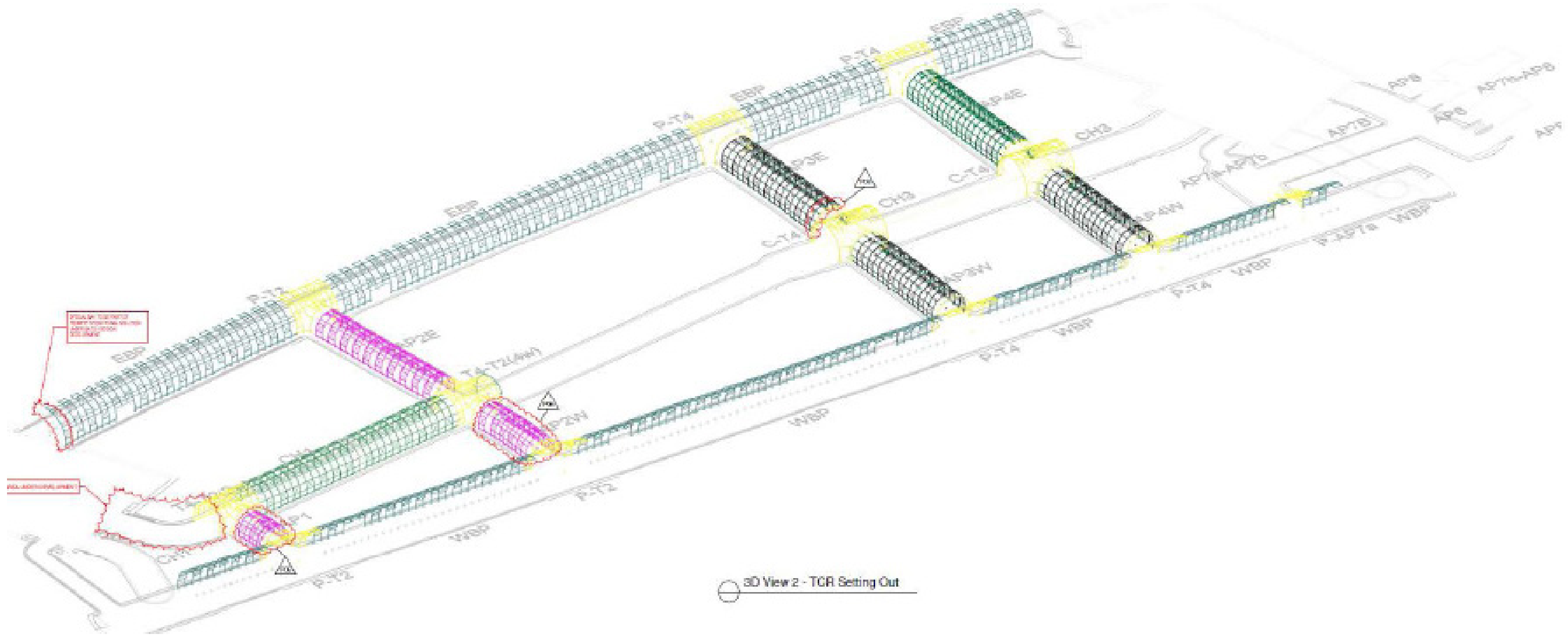


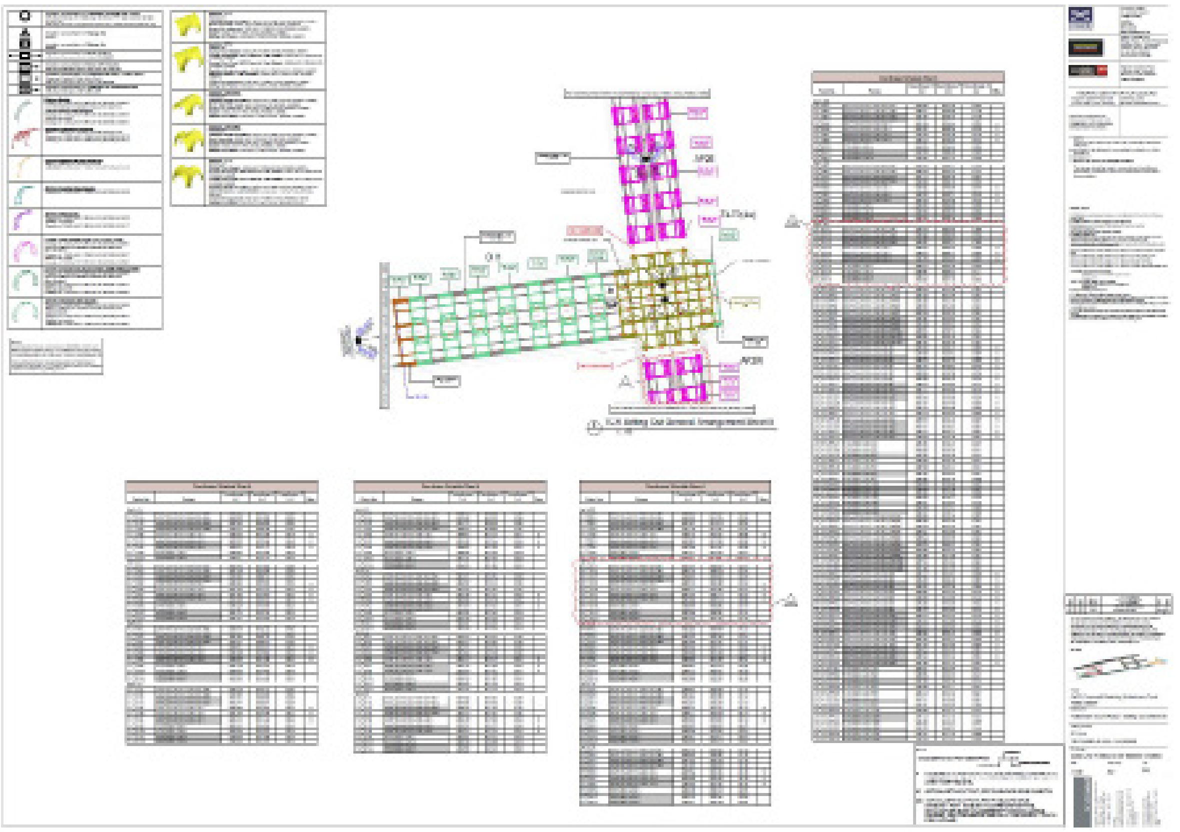




2.21 Crossrail

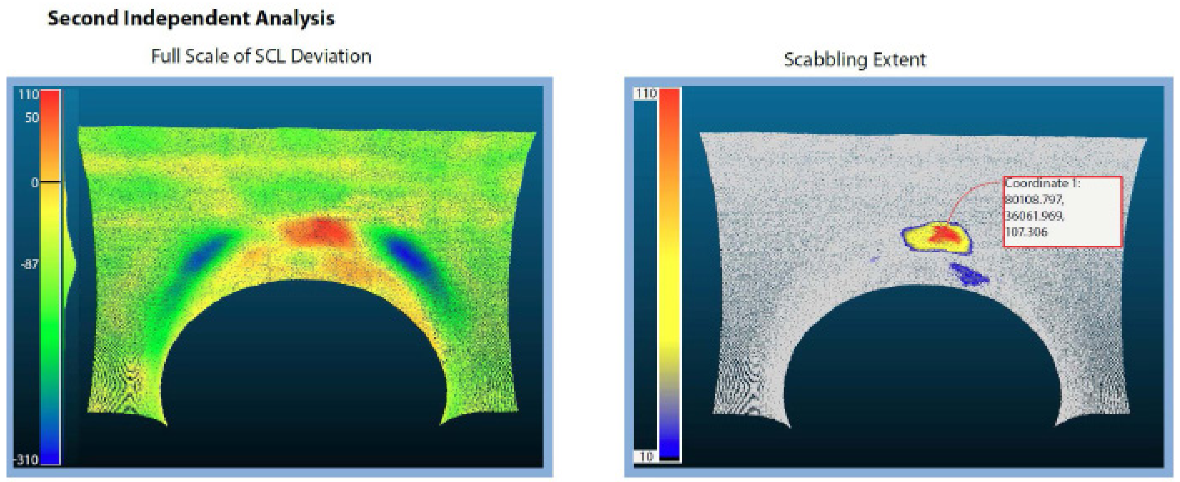
Setting Out

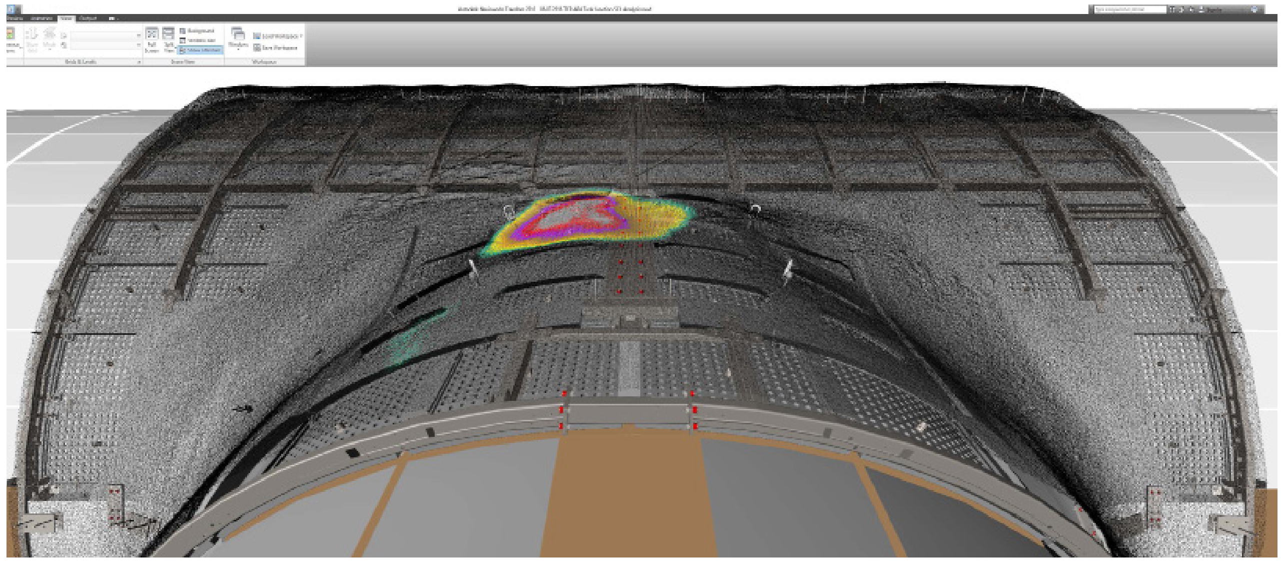


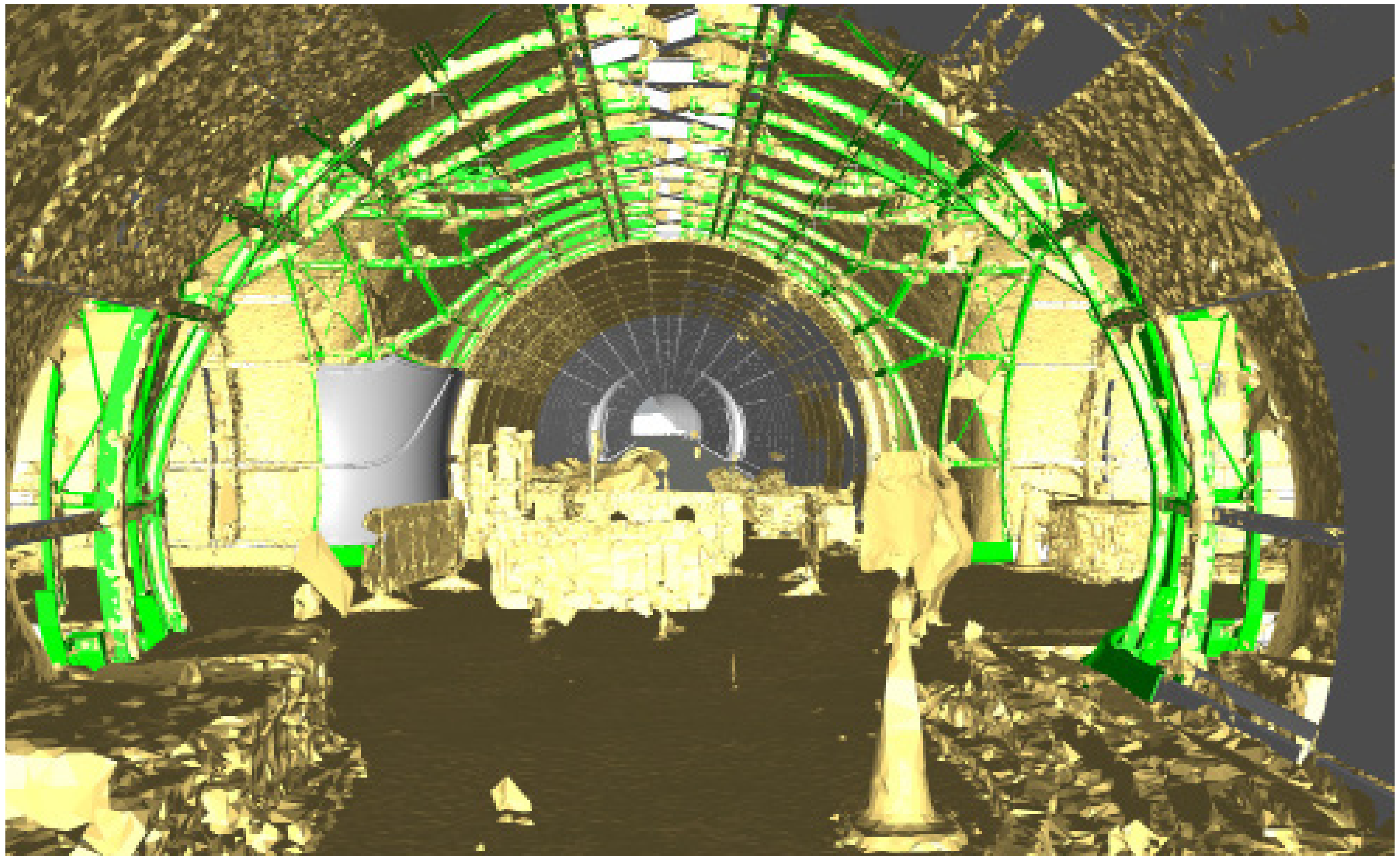


2.21 Crossrail

As-Built Coordination







2.21 Crossrail

Fabrication

2.21 Crossrail

Installation

2.22 Birmingham New Street Station

Project Summary

Client: Network Rail
Our Partners: NG Bailey
Status: Completed

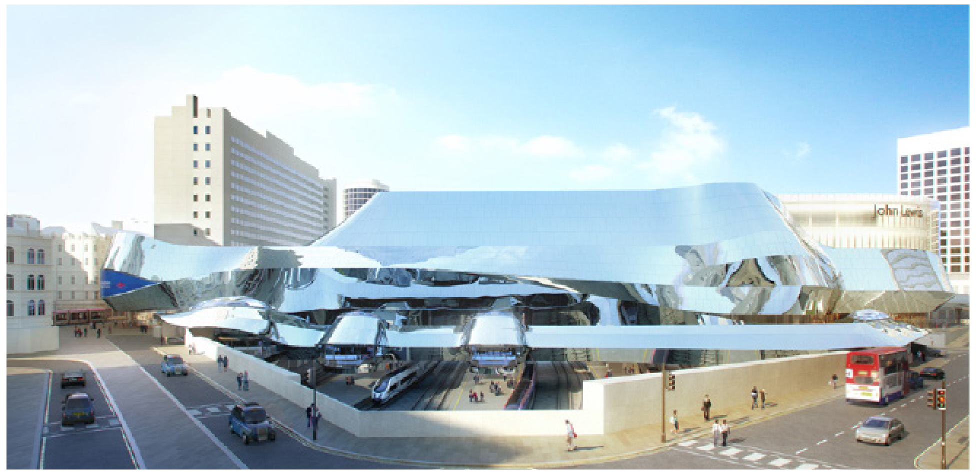
How we added Value:

- The use of prefabricated modules enabled services to be installed with no disruption to train movements into and out of the station.
- Time on site was greatly reduced, improving site safety while reducing overheads and waste.

Prefabricated services corridor for a major rail terminus

Bryden Wood and NG Bailey worked together to create a prefabricated services corridor to house all of the services for the station's 12 platforms. The installation of the new services corridor needed to be complete without causing any disruption to train movements into and out of the busy New Street mainline rail station, which remained open for the entire duration of the works.

Nicknamed "The Spine", the services corridor measured 8m wide, 3m high and 126m long. At more than 300 tonnes it spanned the width of the station. It took a team of eight just three working weeks to install, reducing time on site, improving health and safety and cutting down on transportation and waste.



2.23 Northern Line Battersea and Nine Elms

Project Summary

Client: LUL
Our Partner: GRCUK
Main Contractor: FLO
Construction Value: £1 billion
Status: Pre-construction

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

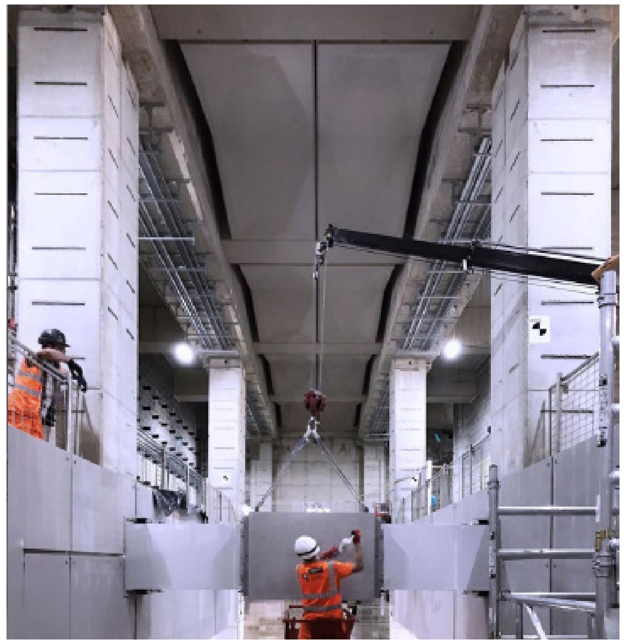
GRC design development for London underground

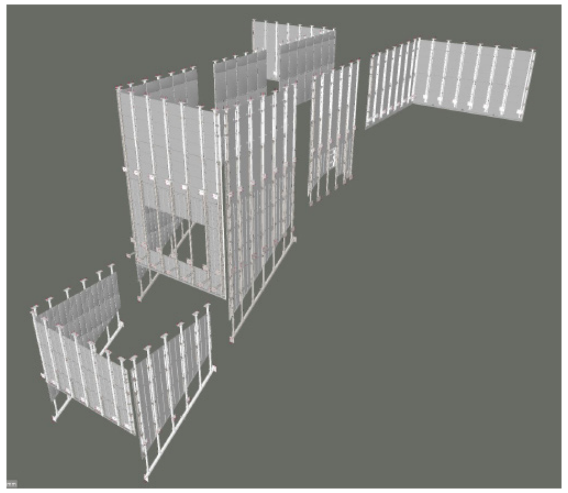
Bryden Wood have been appointed to develop the RIBA stage 4 GRC internal cladding and supportive steel for the new Battersea and Nine Elms stations of the Northern Line Extension development. Working closely with all stakeholders including London Underground and FLO, Bryden Wood have developed the station 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.

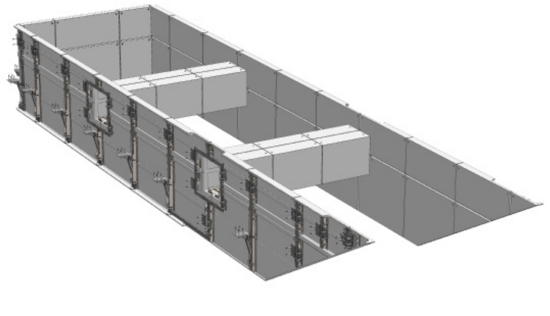
Developed design information is delivered to the client 100% digitally and is processed directly from the 3D CAD data to the CAM manufacturing process without the production of drawings or additional intermediary process. This workflow guarantees the manufactured products geometric details are precisely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







2.24 Tuen Mun - Chek Lap Kok Tunnel, Northern Connection

Project Summary

Client: Gammon

Status: Under construction (alternative proposal)

How we added Value:

- Compressed site construction/install programme due to off-site fabrication.
- Fast site installation of hook on panel cladding system.
- Cladding system provides easy access to road level services with integrated cable tray modules.
- Below road services modules comprise of a chassis skid solution with beam trolleys which are rolled along beam sections to their final positions for optimal efficiency of movement.
- Fast connecting pipe couplers offer speed of site connection over bolted flanged pipe connections. The couplers also allow for expansion and small angle changes (up to 1.5 degrees) along the tunnel length.

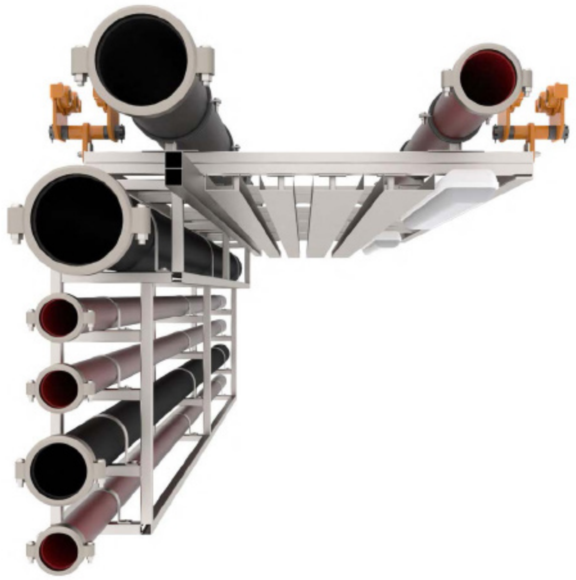
Prefabricated cladding system and horizontal services distribution system

Bryden Wood were approached by Gammon to review the tunnel cladding and services strategy for the Tuen Mun-Chek Lap Kok Link and give input on alternative modularisation and Value Engineering potentials. Tuen Mun-Chek Lap Kok Link northern connection is a dual two-lane sub-sea tunnel approximately 5 km long.

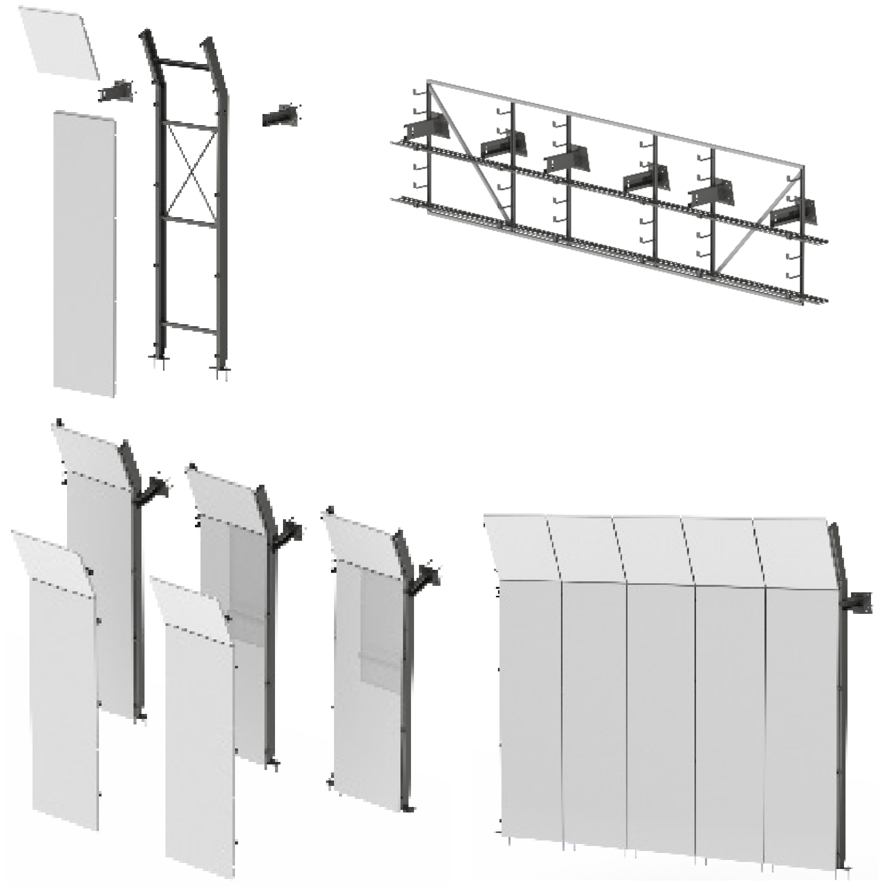
Bryden Wood proposed a modularised pre-assembled steel chassis skid solution for both the horizontal and vertical pipe modules. Our solution combines the horizontal and vertical modules into a single assembly and incorporates a number of key components which enable rapid deployment of the modules into the Service Gallery.

Each module contains 4 beam trolleys attached to a horizontal skid which engage a set of UC beams fixed the concrete ceiling in the Service Gallery. We also proposed using non-flanged pipes and fast connecting pipe couplers which offer a number of advantages over bolted flanged pipe connections.

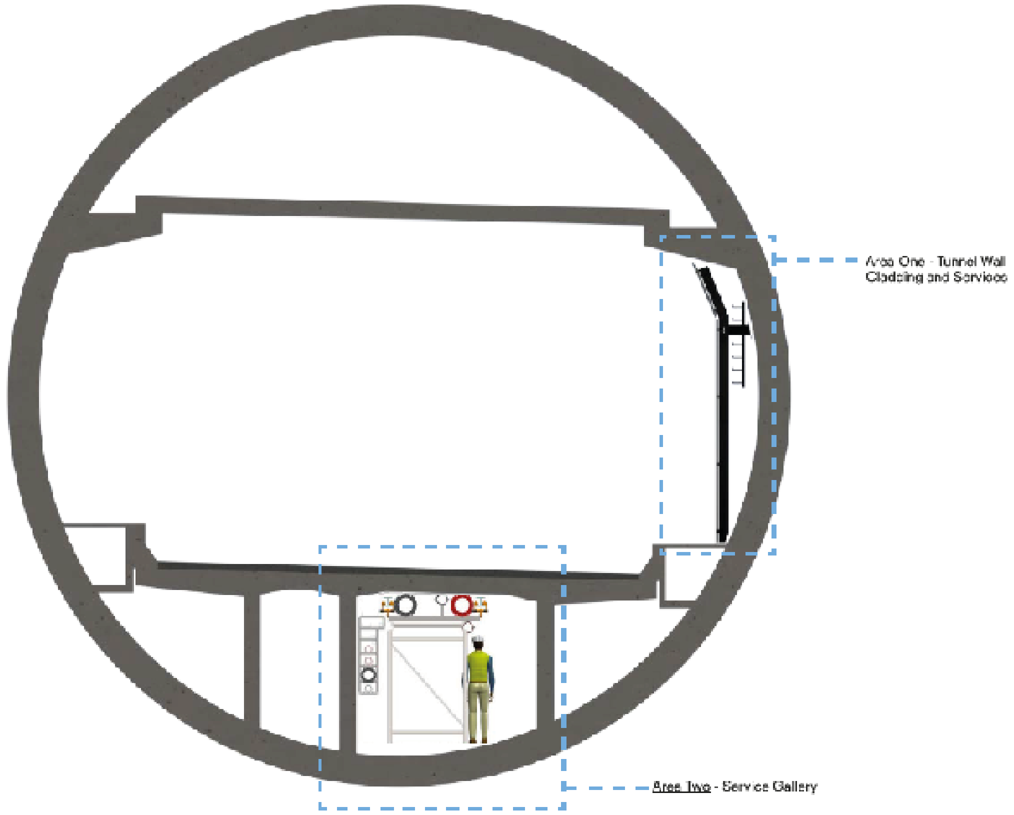
The road level prefabricated cladding system comprises of folded sheet metal hook on panels, ladder frame assemblies and integrated cable tray modules. Minimal tunnel lining fixings are used for ladder frame fixing brackets.



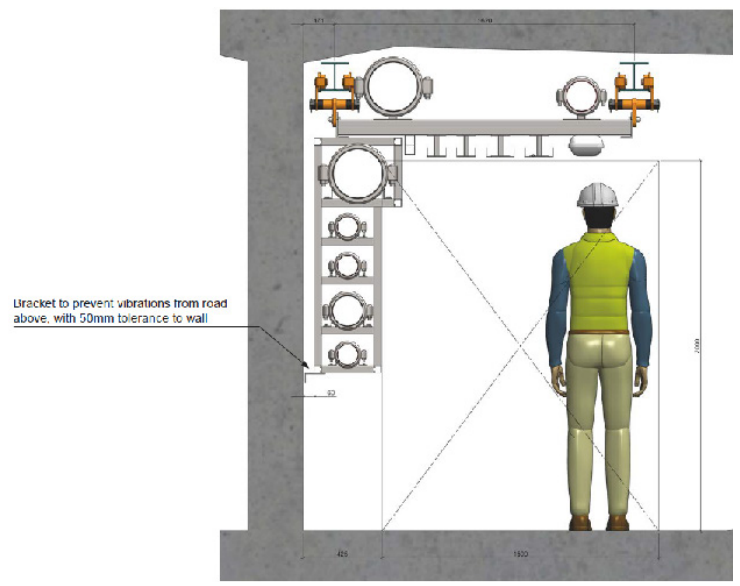
3D view of prefabricated service gallery module



Prefabricated cladding system comprises of folded sheet metal hook on panels, ladder frame assemblies and integrated cable tray modules.

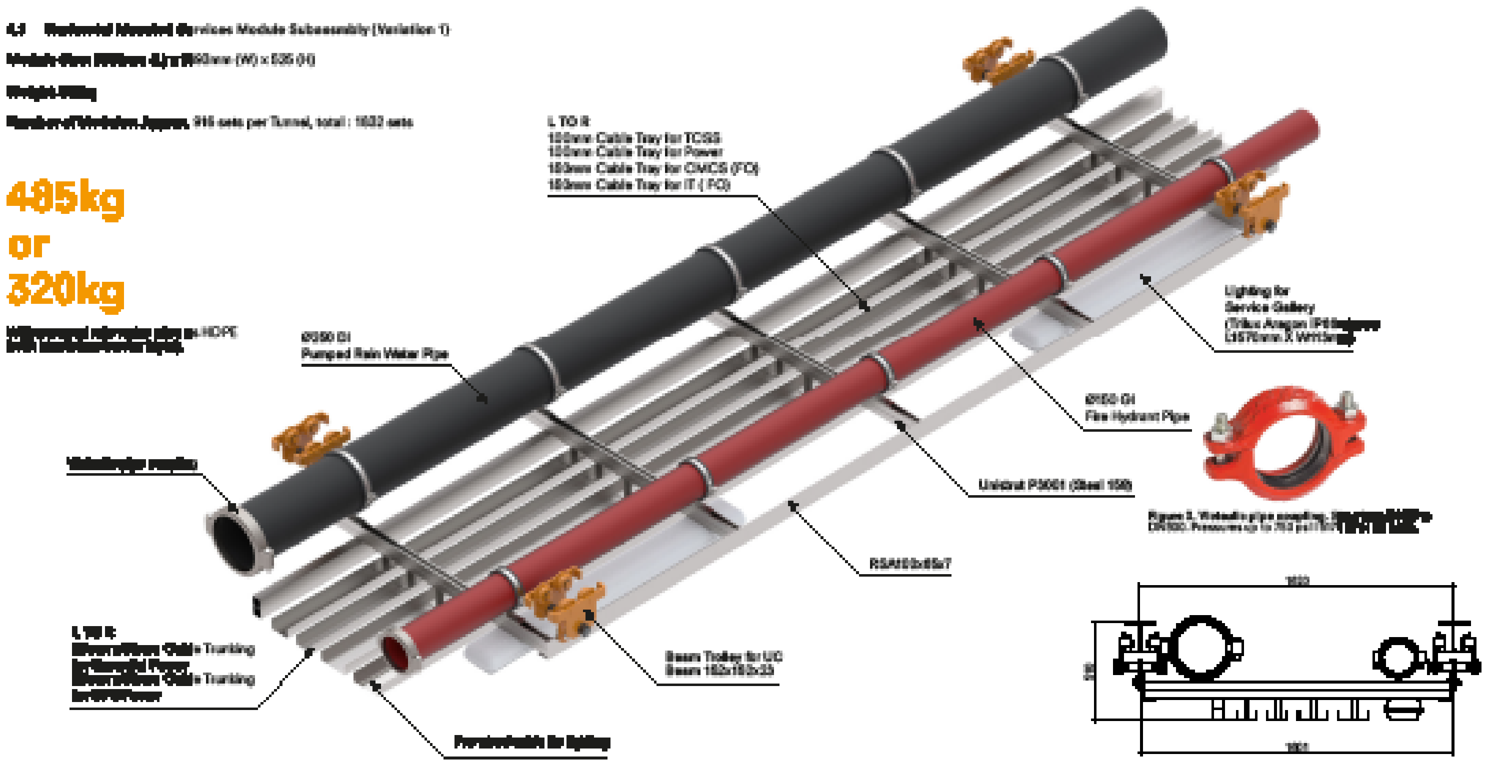


Cross sectional view of tunnel showing location of study areas

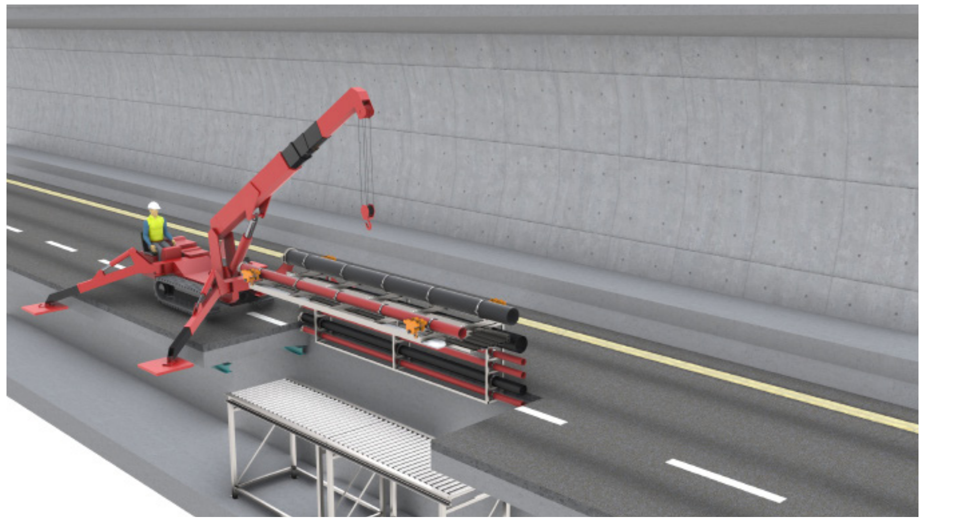


Detail showing the required clearance zone for electrical vehicles and emergency escape (1500 W x 2000 H)

2.24 Tuen Mun - Chek Lap Kok Tunnel, Northern Connection

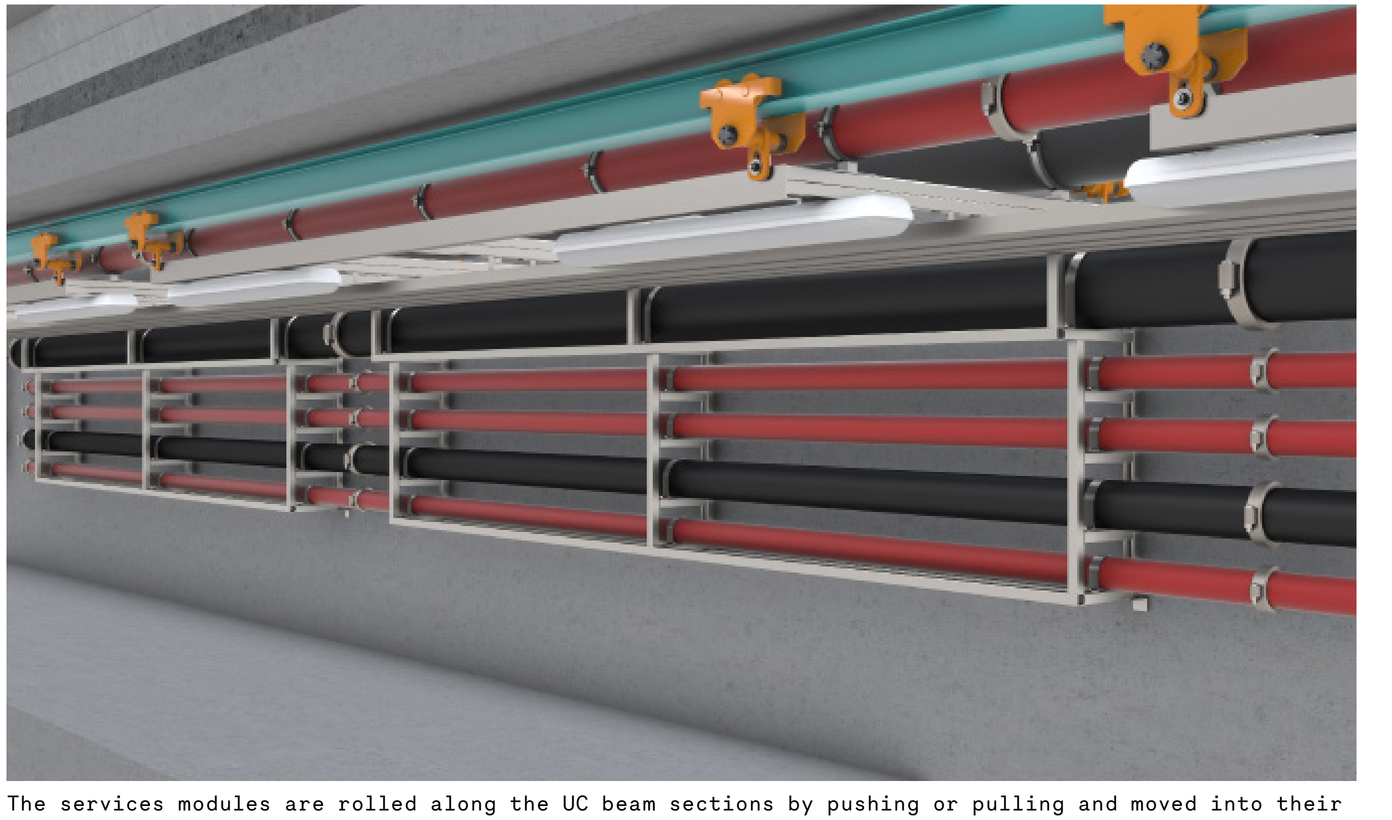


Horizontal mounted services module subassembly (Variation 1) with Victaulic pipe couplers.



The services module is lifted off the electric transfer vehicle and lowered onto a roller platform for optimal efficiency of movement into the Services Gallery.

Transport by truck to tunnel site



The services modules are rolled along the UC beam sections by pushing or pulling and moved into their final positions within the Services Gallery.

2.25 Anglian Water, Uttons Drove

Project Summary

Client: Anglian Water

Our Partners:

Construction Value: £10m

Status: Completed October 2013 (commenced March 2013)

How we added Value:

- Above ground assets resulted in improved accessibility for maintenance.
- No major ground excavation required resulting in significant time, cost and carbon savings.
- Modular offsite construction resulting in accelerated on site programme.
- The scheme was delivered with 48% reduced embodied carbon and 15% lower capital cost.

Prefabricated steel wastewater treatment system

The Uttons Drive project was a component-based prefabricated construction system approach to an Anglian Water wastewater treatment plant.

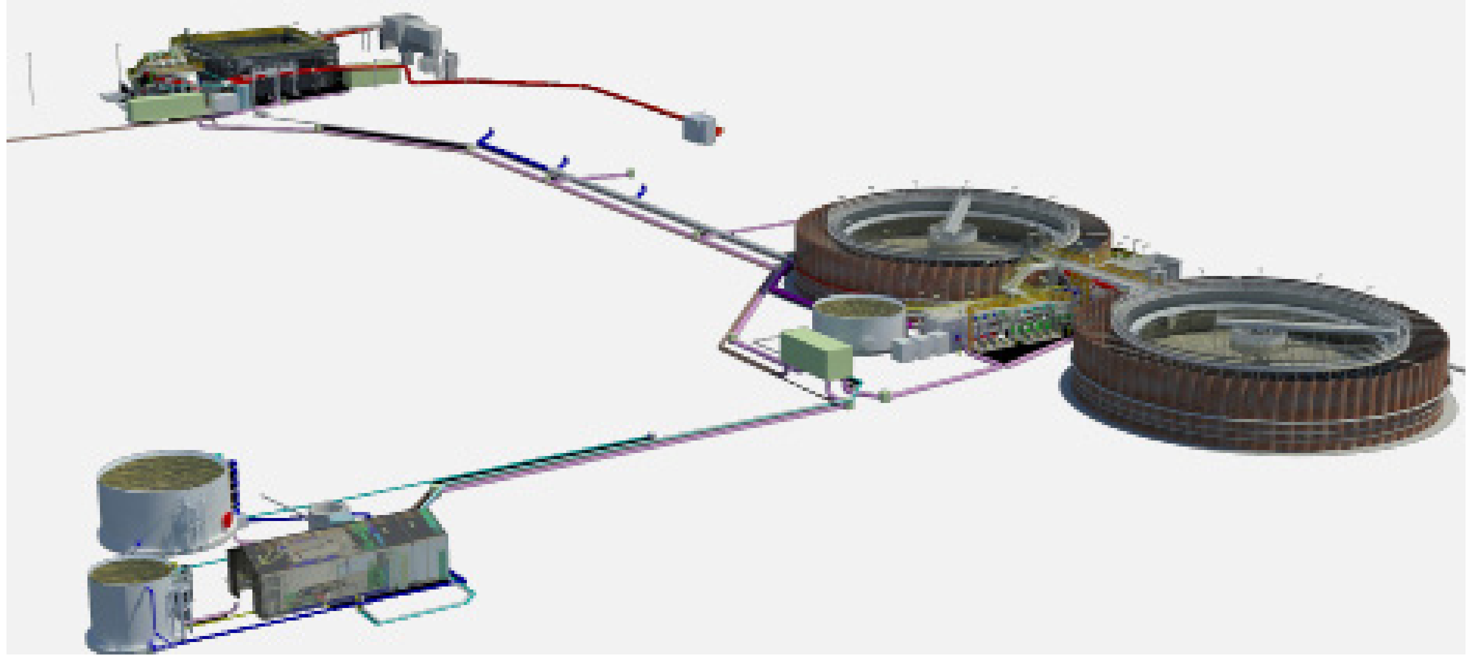
Bryden Wood were appointed to provide multidisciplinary consultancy services for the Anglian Water Uttons Drove Wastewater Treatment Works. This included structural and civil engineering, DfMA, architectural and mechanical and electrical engineering (roads and pavement design by others).

The project included the construction of two large circular tanks, one large square tank and several smaller support structures. One of the major objectives was to transfer as much of the construction as possible off site with the intention of significantly reducing time on site and accelerating the overall programme.

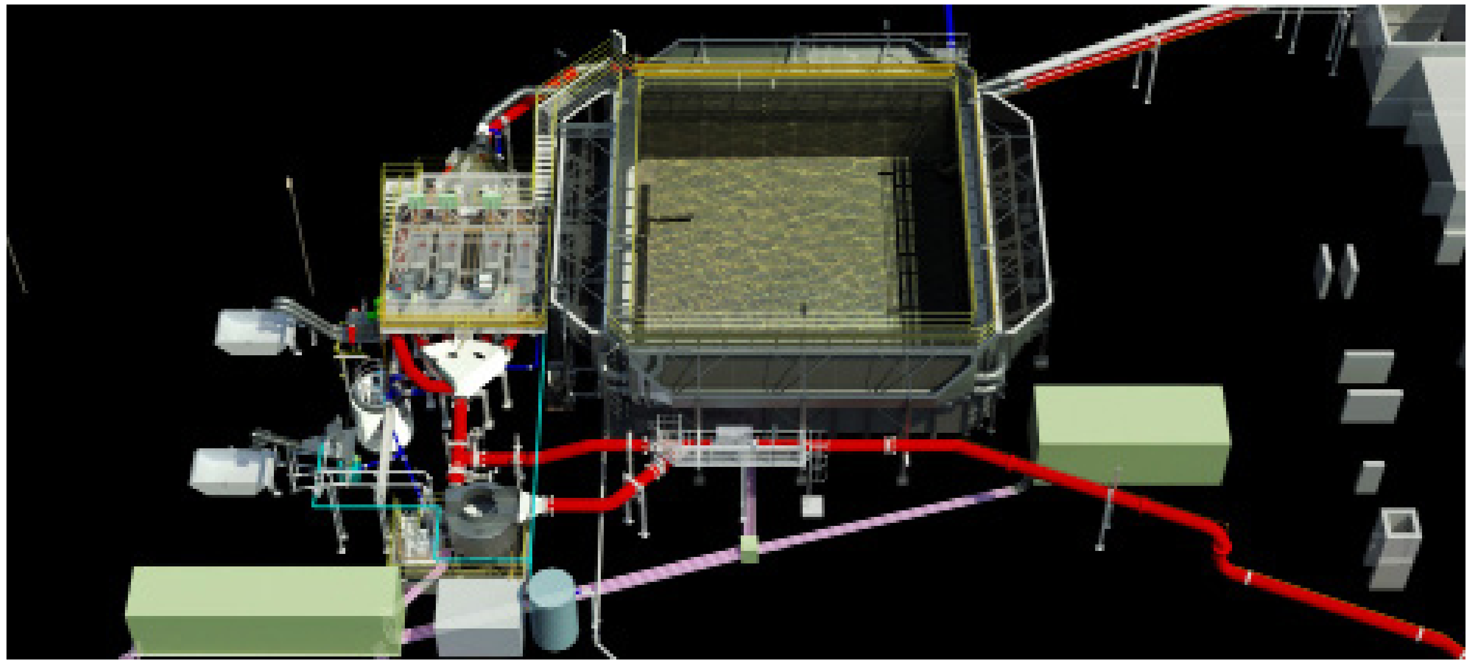
Instead of using a traditional civil engineering approach (i.e. 'digging a large hole and filling it with concrete') the assets were located above ground and delivered using DfMA techniques, as would be typical in an oil and gas facility. The extra cost of pumping the water over the life-cycle of the asset is a fraction of the cost of creating a large submerged concrete facility

Storm Surge and Balancing Tanks (background), Hydro Grit King hydrodynamic vortex separator (left). Raw water intake is a mixture of combined sewers, dedicated foul water sewers and commercial waste water. On low flow volume days all inlet water is processed through the Grit King. During storm days a proportion of water is diverted to the storm tank for settling.

2.25 Anglian Water, Uttons Drove

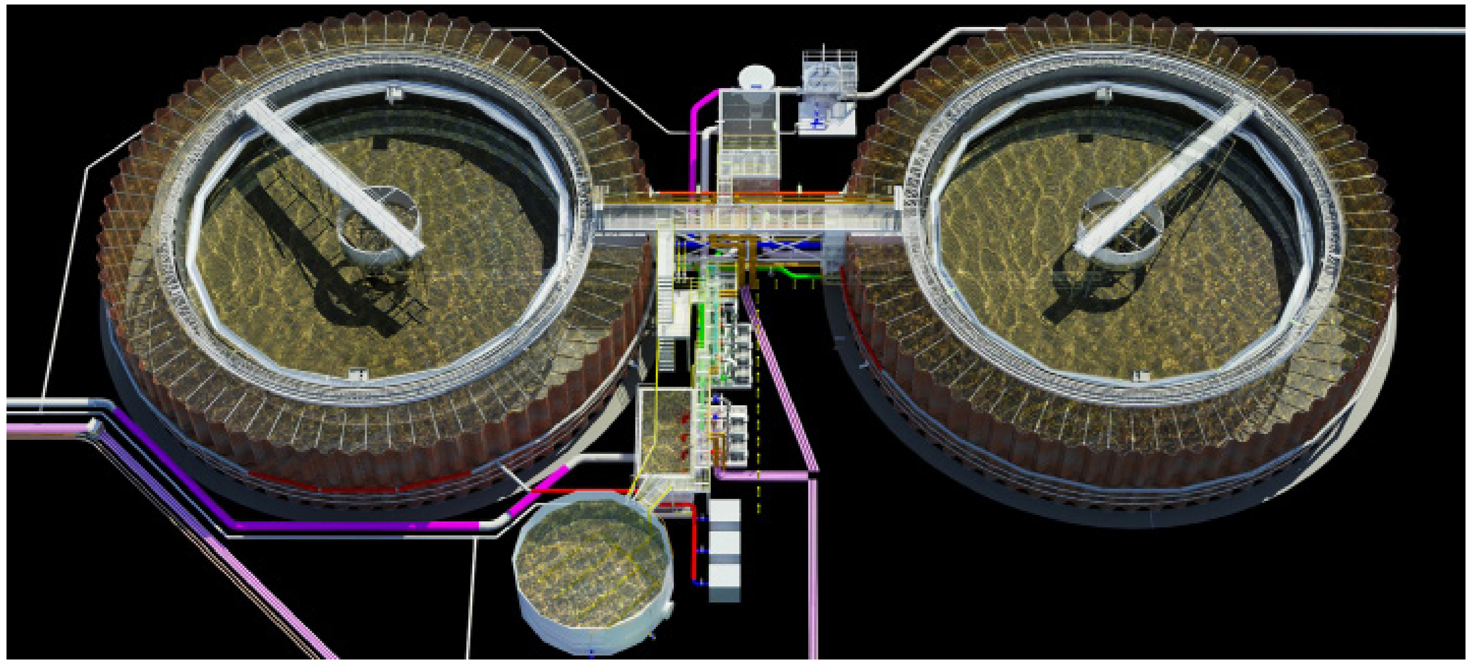


Instead of using a traditional civil engineering approach (i.e. 'digging a large hole and filling it with concrete') the assets were located above ground and delivered using DfMA techniques, as would be typical in an oil and gas facility.



The Inlet Works consists of a central square Storm Surge Tank, 4 Balancing Tanks, Inlet and Outlet Screen Chambers with 4 De-watering Belt Escalators (first stage rag, grit and silt removal) and the Hydro Grit King (a hydrodynamic vortex separator for secondary stage grit and silt removal).

A circular Final Settlement Tanks during construction showing the inner steel plate wall.



The circular Final Settlement Tanks share their external walls with the aeration lanes. The structure of the Final Settlement Tank consists of outer steel sheet pile wall and inner steel plate wall stiffened by steel columns. Sheet piles and plate walls with columns are supported directly on the ground bearing slab. The inner wall is stiffened by a ring truss which has radial bracing system connected to the outer wall at the top of the structure. Rectangular Selector Tank and Washwater Supply Chamber (centre top), rectangular Interstage Sump Tank (centre bottom).

2.26 Swansea Tidal Lagoon

Project Summary

Client: Tidal Lagoon Power

Construction Value: £1.3 billion (estimate as proposed)

Status: Not built (original proposal rejected by the UK Government 2018)

How we added Value:

- Prefabricated steel & precast concrete modules maximise offsite construction & minimise onsite operations.
- Shortened & de-risked construction programme achieved through standardisation & offsite construction.
- Less civil engineering works required in the bay.

Prefabricated steel tidal power system

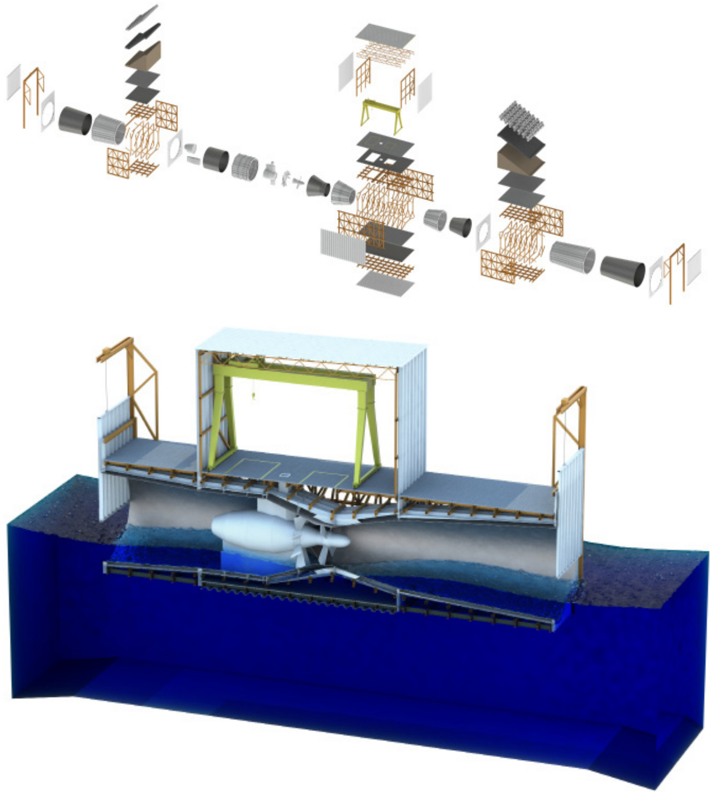
Bryden Wood were approached by Tidal Lagoon Power to review the Swansea Tidal Lagoon project and give input on alternative modularisation and Value Engineering potentials for not only the Pathfinder project in Swansea but also future other projects which have not gone through planning.

By incorporating DfMA, standardisation and offsite construction Bryden Wood developed a set of alternative modularisation and VE potentials to better facilitate mass production efficiencies in a controlled environment while also de-risking site and construction critical path activities.

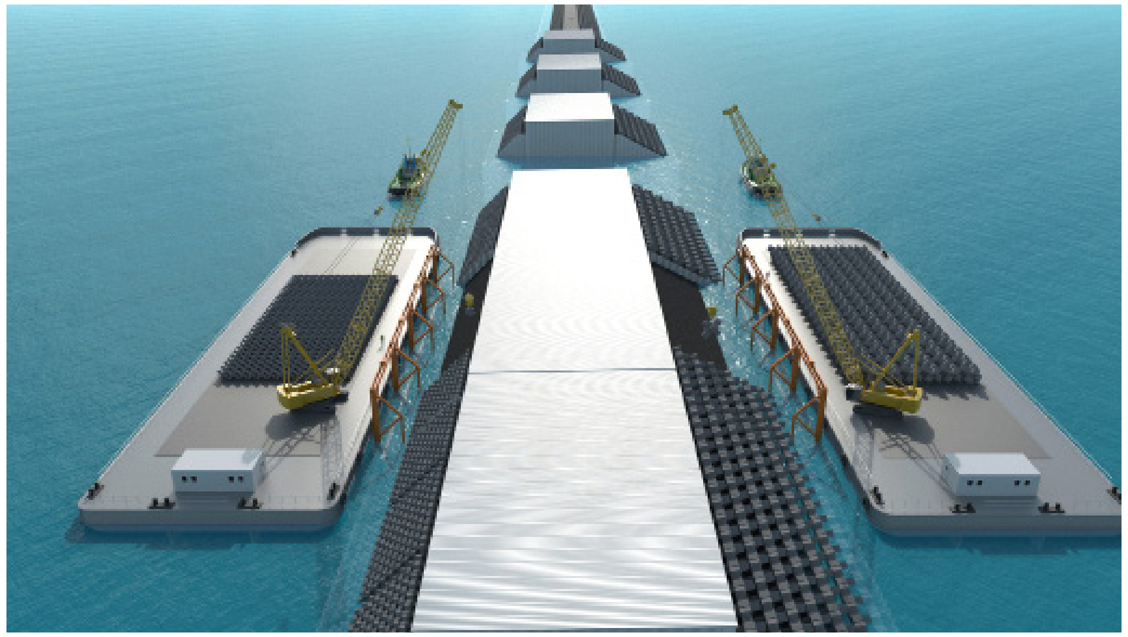
Bryden Wood developed a modularised pre-assembled steel chassis solution for both the turbine housing and caissons which incorporates prefabricated steel and composite concrete elements to maximise the efficiencies of offsite construction and minimise onsite operations.

The solution proposed the following 3 main groupings of standard sections for prefabricated and pre-assembled structural components:

- Standard steel sections for both the turbine house and Caisson chassis (Tata).
- Standard sheet piles for both the turbine house and Caisson chassis (ArcelorMittal).
- Standard metal deck floor profile for all pre-cast and pre-assembled floor cassettes (Tata).



Exploded view of turbine housing unit (above). Section view of turbine housing unit before sinking (below).



The original scheme's single array/group of 16 turbine house units changed to 4 separate arrays each containing 4 turbine house units with an adjacent 50 metre long dam section in between each group.

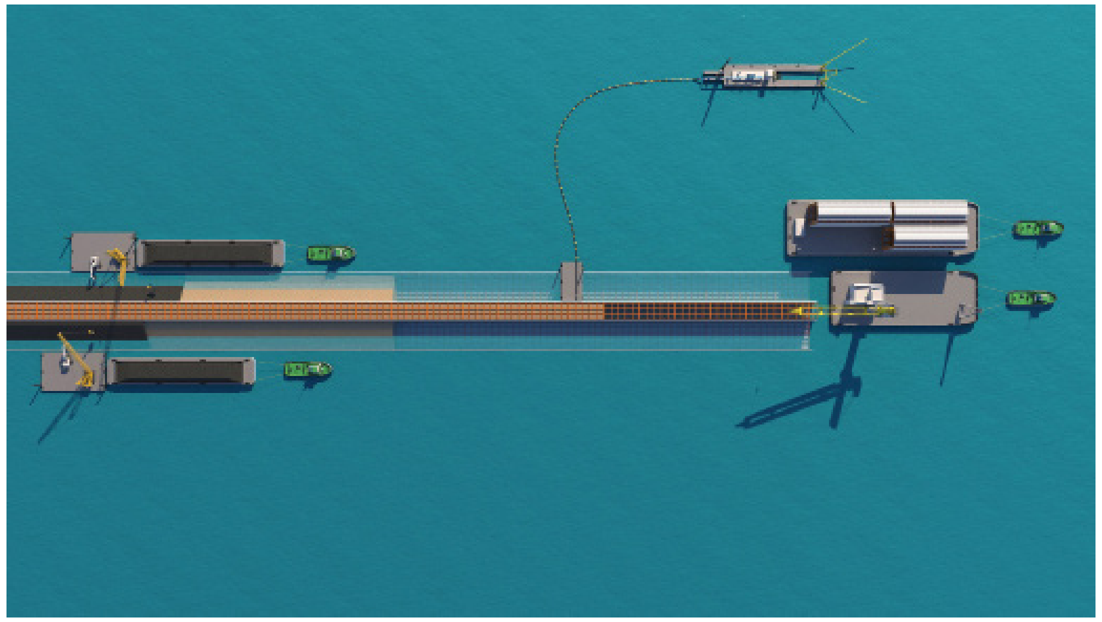
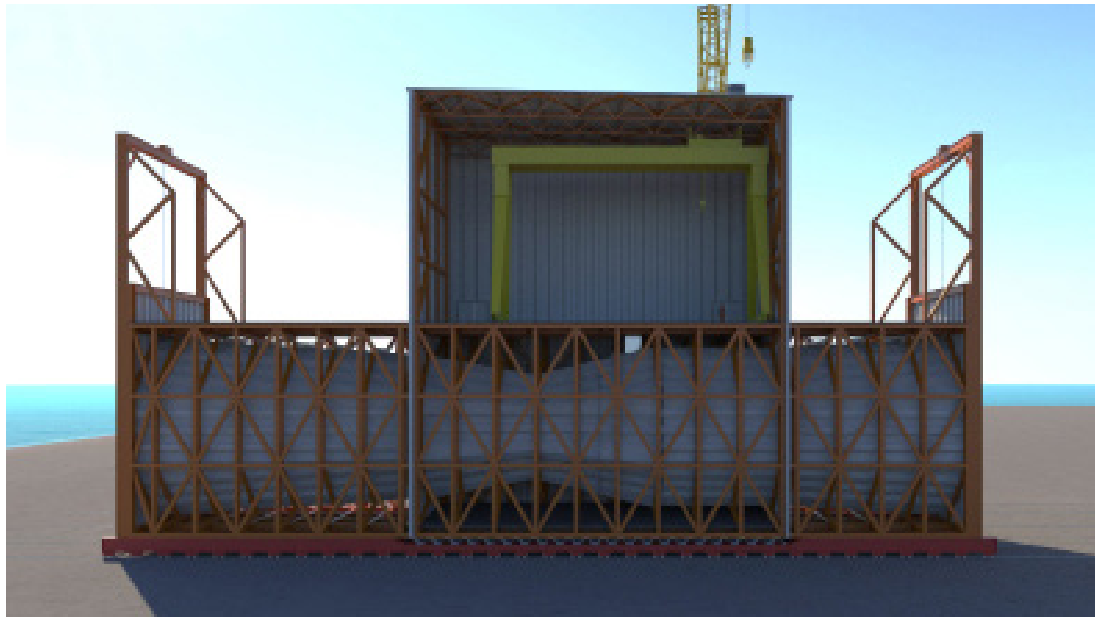


Image showing the linear progression of the prefabricated caisson site assembly stages.



Prefabricated Turbine House before floating and transporting by tug boat to it's lagoon power station location.

2.27 Howick Industrial Building System

Project Summary

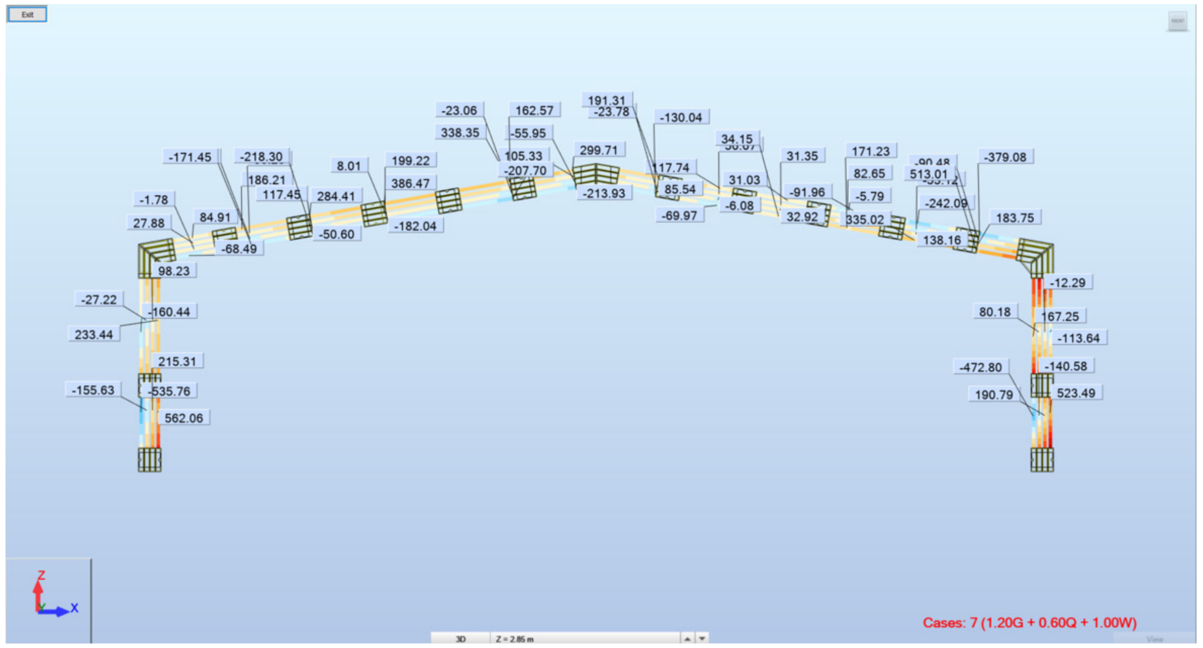
Client: Howick Ltd

Status: Design Stage

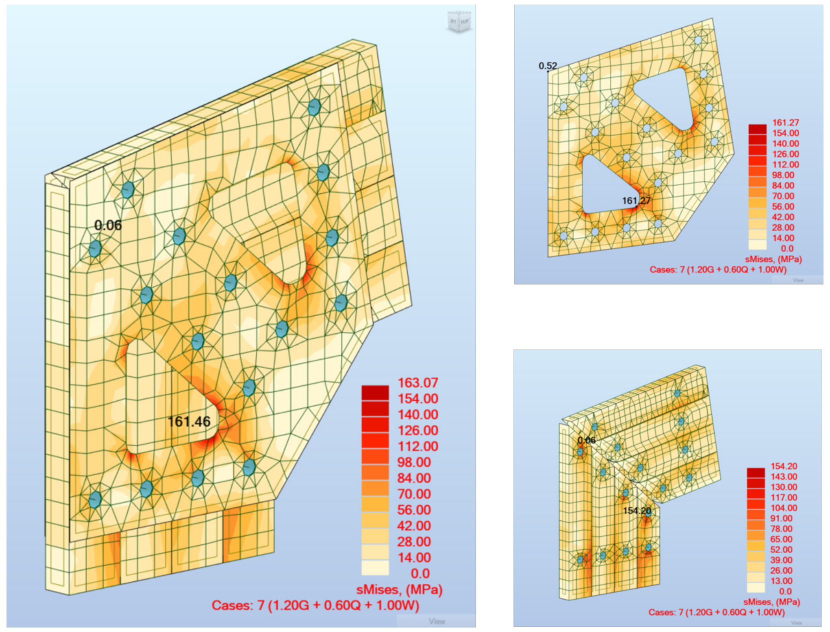
Prefabricated industrial building system

BWT were appointed by New Zealand-based specialist fabricator Howick Ltd to undertake design and analysis of a proposed new construction system for industrial applications. Howick are pioneers in cold-formed or light gauge steel fabrication. They supply a wide range of cold-formed steel products around New Zealand and abroad, and also produce roll-forming machinery. Howick's product range is defined by innovation, using cold-formed steel to accelerate construction processes, reduce labour hours on site and improve the safety and quality of buildings. The company is constantly searching for new applications for cold-formed steel to deliver benefits over conventional construction.

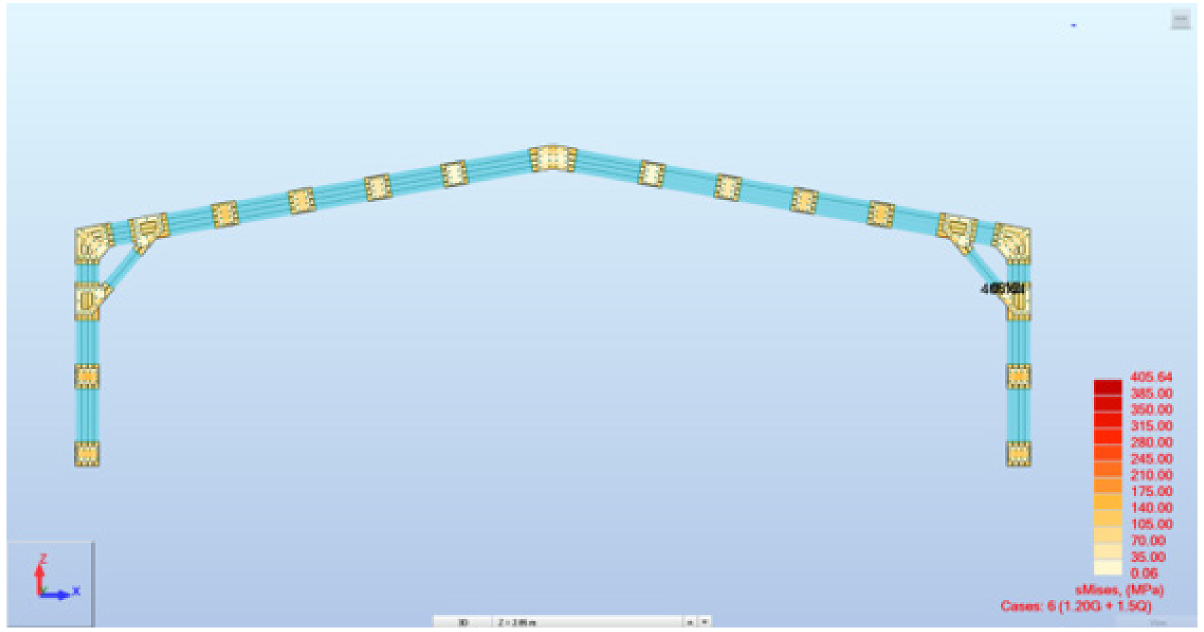
One of the new construction systems under development by Howick is intended to allow the rapid erection of large-scale industrial structures. Physical stress tests of the components were carried out under factory conditions to determine likely maximum loads however further analysis was required to determine the real-world performance of the system. BWT produced a finite element analysis of the structure to precisely determine at which point it was likely to fail, and proposed design changes to improve its structural performance and meet the client's requirements for a strong and robust large-span structural system that used less material and labour and could be erected in less time than alternative methods.



Finitie element analysis ofversion 1 member stresses (N/mm2) with a load combination: 1.20G + 0.60Q + 1.00W.



Finite elment analysis of version 2 column and beam joints (with load combination: 1.20G + 0.60Q + 1.00W).



Finite element analysis of version 2 with bracing added,profile thickness of lipped channel increase to 2.40mm instead of 1.90mm (with load combination: 1.20G + 0.60Q + 1.00W).

2.28 Westgate

Project Summary

Client: Sonn Group

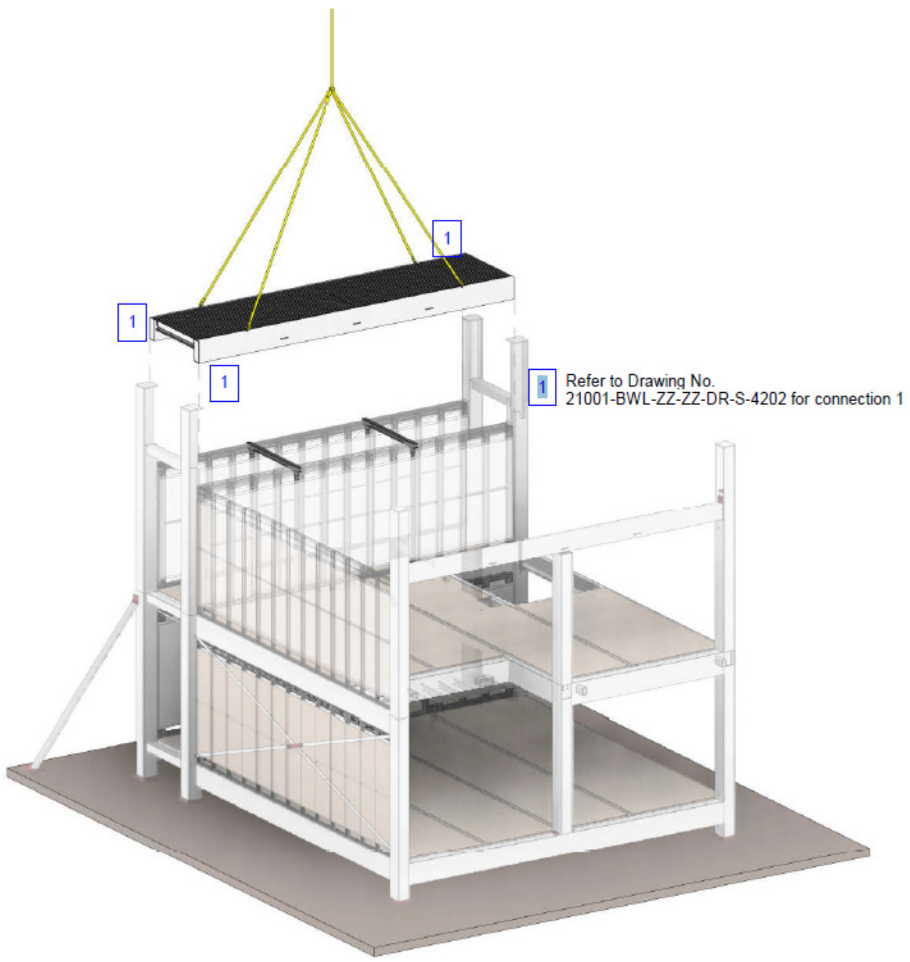
Status: Prototyping

Prefabricated residential building system

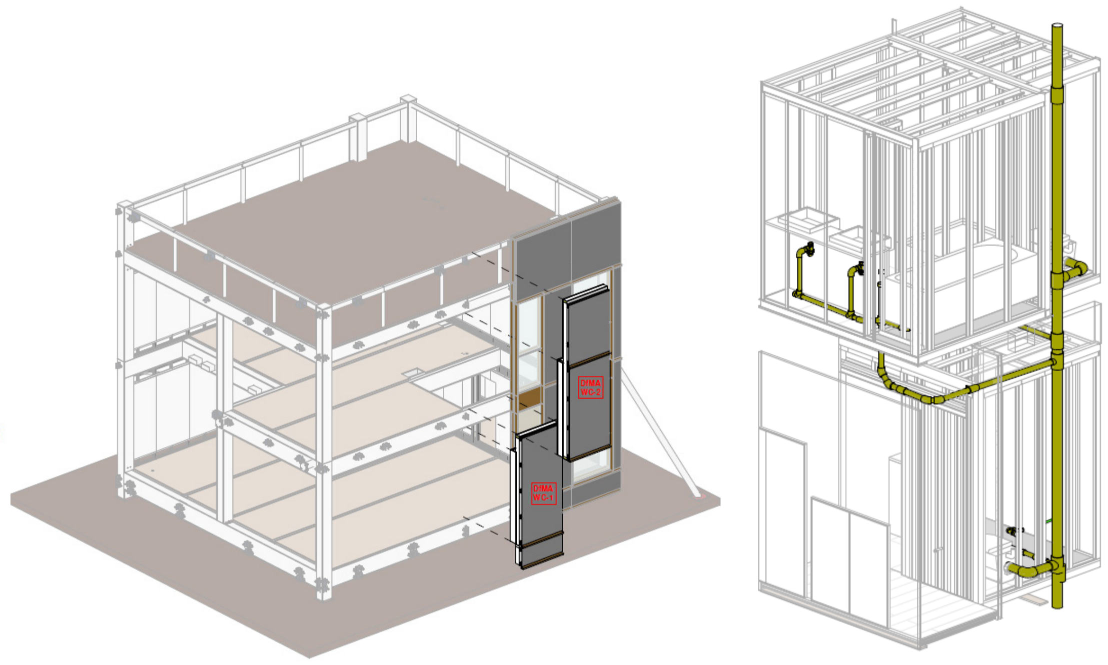
Sonn Group are a leading Hong-Kong based developer with an extensive portfolio of projects in mainland China and international markets. They are committed to utilising world-leading BIM and digital design coupled with modern methods of construction (MMC) to deliver cost-effective, rapid build projects that are high-performing, aspirational and set a new standard of quality.

BWT were appointed to develop a new construction system for Sonn Group's Westgate residential project in Auckland, New Zealand. BWT applied a Design for Manufacture and Assembly (DfMA) approach in close collaboration with Sonn Group's technical and commercial stakeholders to develop a system that utilises a range of MMC including volumetric, flat-packed and componentised elements to enable architectural flexibility to be created from a standardised and limited component library. The residences in the scheme will set a new standard for medium-density living in Auckland and showcase Chinese capabilities in prefabricated construction and digitisation.

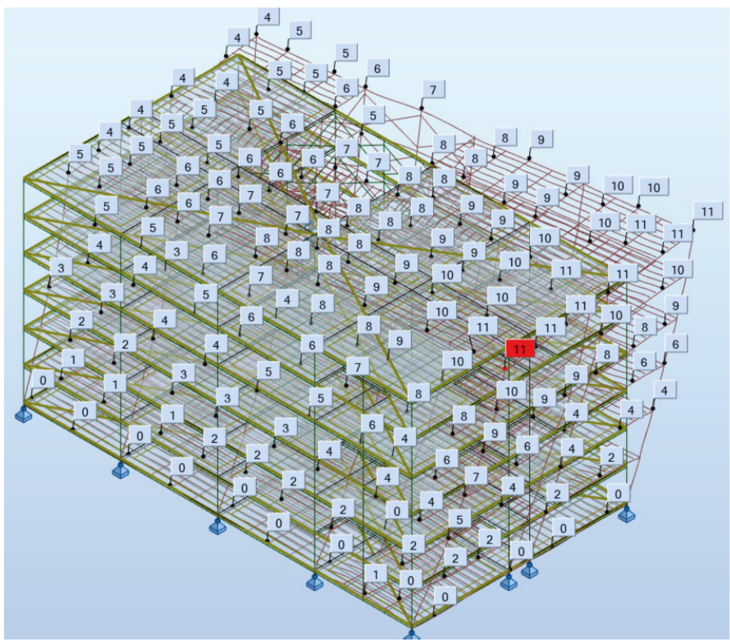
The design development of the Westgate system to date has been a collaborative effort between BWT as lead designers, the client and local consultants. This has ensured the system blends BWT's vast expertise in DfMA and the requirements and vision of the client while remaining feasible and appropriate in a New Zealand context. In order to validate the DfMA system BWT have designed a full-scale mockup of a single apartment. This will allow component fabrication, assembly and disassembly to be fully tested and lessons learned incorporated prior to full-scale implementation. A data-rich 3D BIM model of the mockup was developed by BWT including phasing to demonstrate the assembly and disassembly approach. The model is intended for use by the component supply chain to allow fabrication directly from the model. Benchmarking of the proposed system against alternative methods will ensure that the project delivers on its value promise.



3d model showing the roof cassette assembly lowered by crane onto column end plates.



Left: facade panel sequence. Right: volumetric pods.



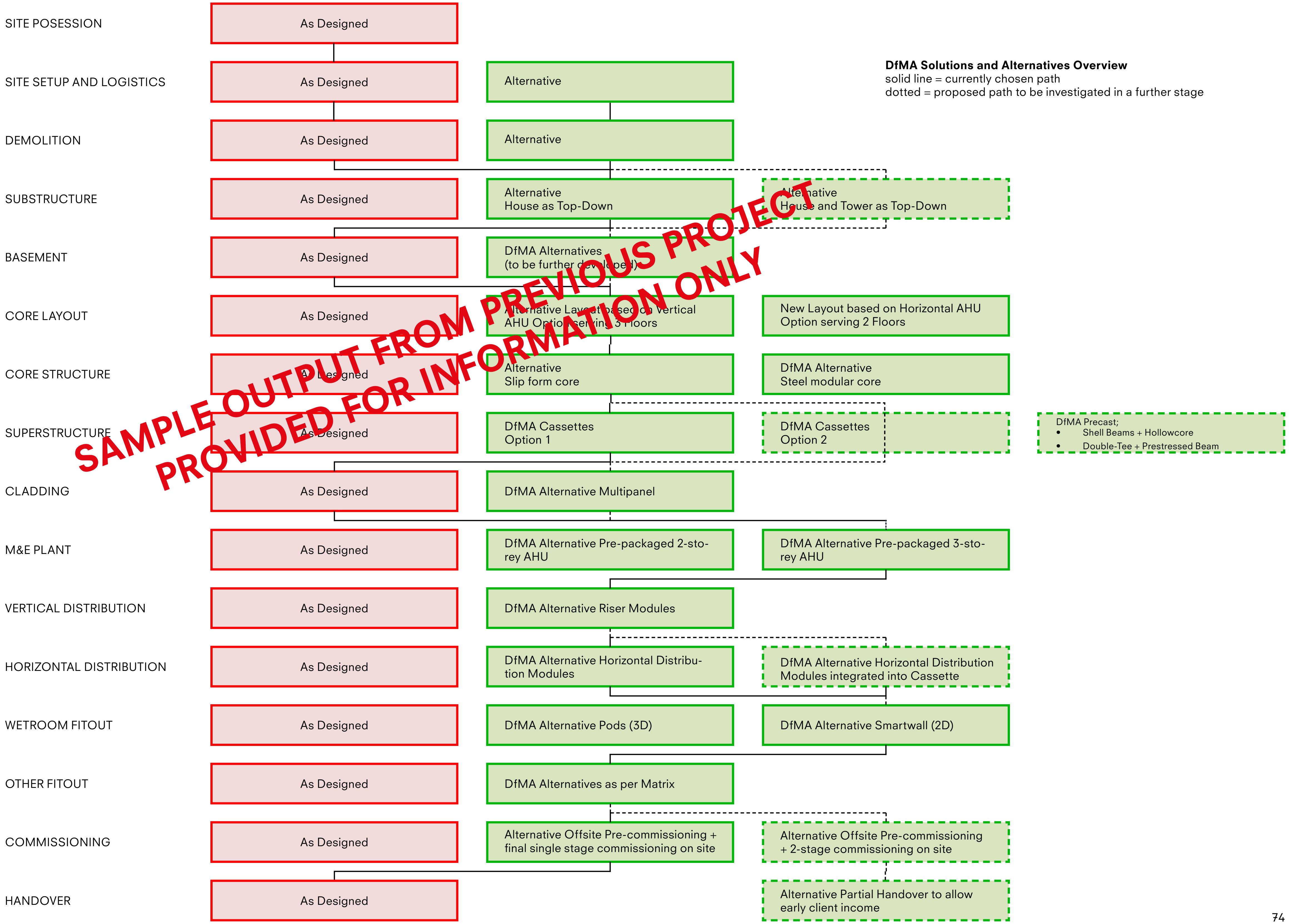
Structural analysis of building elements for a typical residential block.

Architectural visualisation showing 2 storey height 3d model.

ANNEX 1: Sample Conversion Excerpts

DfMA solutions and alternatives overview

The following table captures the different DfMA alternatives considered under each different design aspect. The currently chosen path is shown and analysed in the main sections of this report. The alternative options explored are described in the appendixes of this report.



Structural opportunities

Integrated floor cassettes

The preferred alternative to traditional slab construction is the use of integrated floor cassettes.

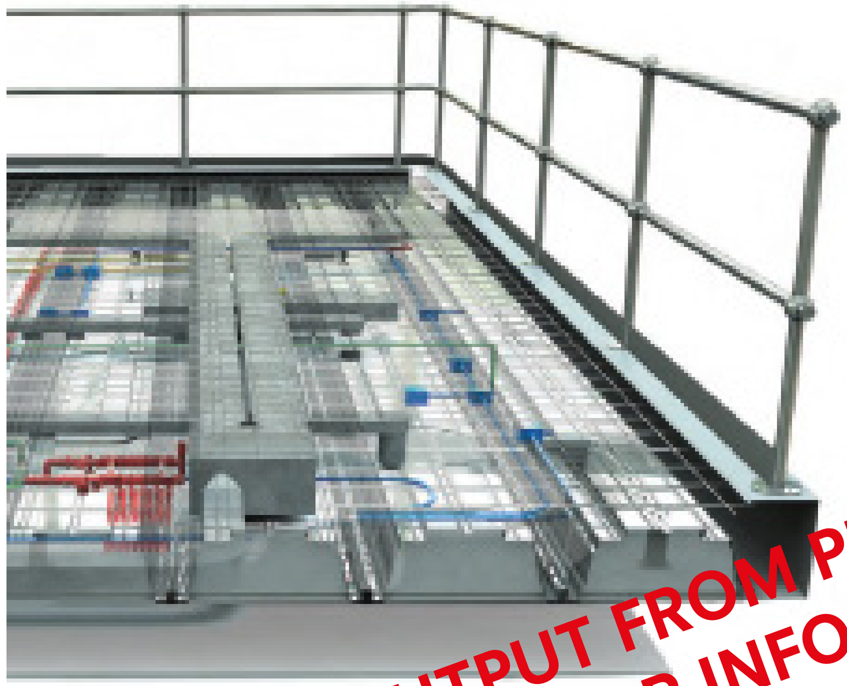
The term 'cassette' refers to a prefabricated floor unit that includes the steel deck, edge and/or perimeter cold formed lipped L-sections and reinforcement. The cassettes are made lightweight by excluding concrete - the concrete is efficiently poured on site as an in-situ operation and the cassette is in effect a permanent shutter. While this does retain the in-situ concrete pouring operation, the transportation logistics are efficient (as a large volume of concrete can be transported to site per vehicle) and the site pouring is highly streamlined.

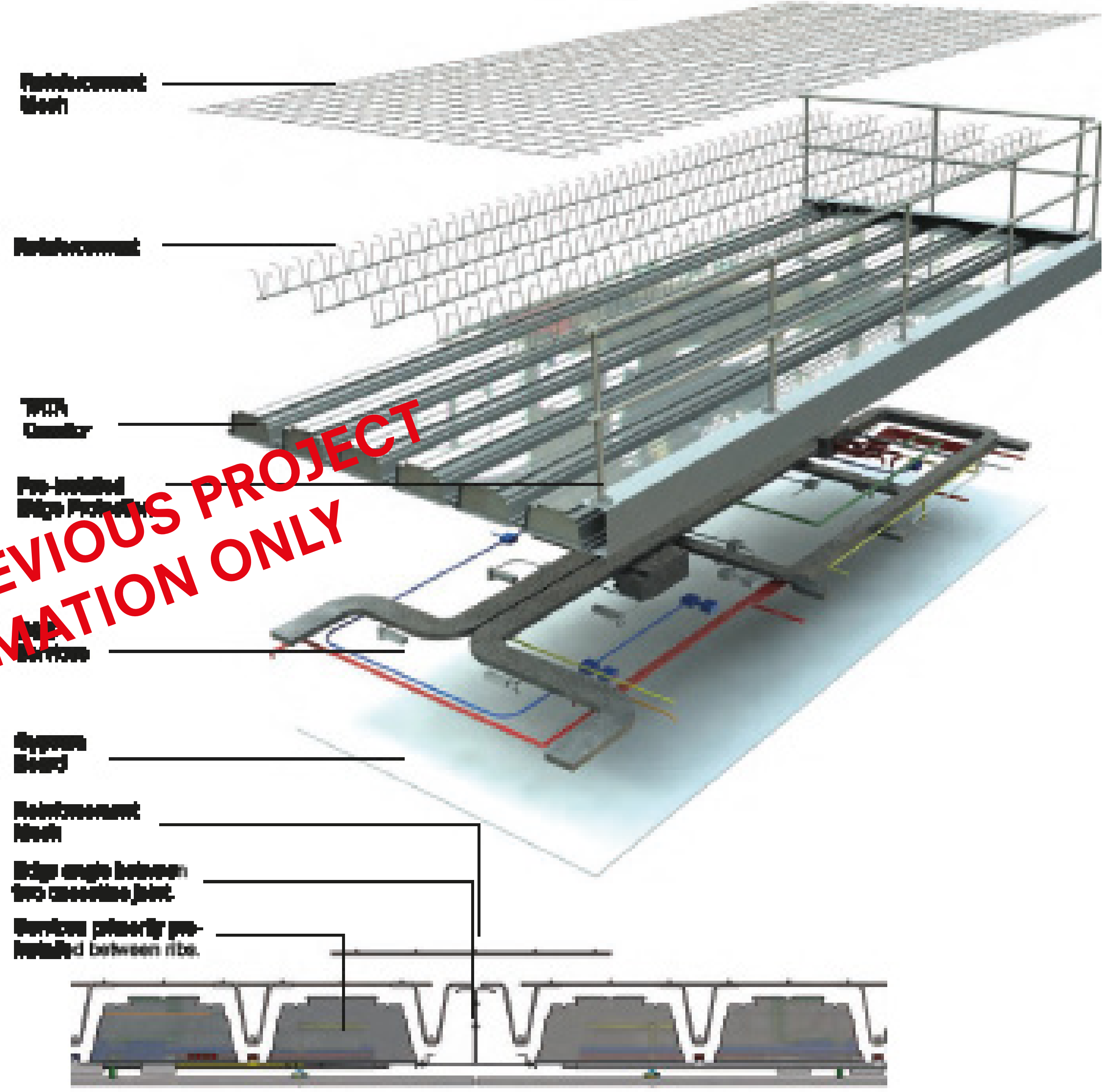
The integrated cassette requires minimal structural material (structural depth is optimised). The cassettes can be provided with pre-installed edge protection to ensure operative safety on site. Ceiling finishes can be pre-installed. Depending on the characteristics of the building the secondary distribution of the services can be also pre-installed running between ribs of the deck.

This concept has been developed within Bryden Wood taking into consideration the requirements of structural, mechanical, electrical and architectural disciplines.

The geometry of the cassettes has been adjusted to suit the specific characteristics of the building, transportation and lifting criteria. An overall slab depth equal to 345mm (including the 20mm plate welded at the bottom of the square hollow section) with a steel deck (Comflor 225 1.25mm thick gauge) is proposed in order to achieve the 6m span between secondary beams and to provide the required 120min fire resistance.

Once the standardisation of the spans is carried out it is expected that a typical floor can be covered with slight modifications of two standard cassettes. We propose transporting the cassettes and connecting them on site into assemblies of 2 or 3 units to cover each single bay. Additional cold formed sections can then be installed at the edge of the building in order to span the limited distance between edge columns. Cassettes are connected to each other by rivets through the perimeter cold formed sections at 500mm centres.





Structural opportunities

Tower crane lifts

One of the goals of the DfMA floor strategy is trying to reduce the number of lifts required compared to the traditional as-designed option. An indicative number of lifts for each of the DfMA options and the traditional option has been developed.

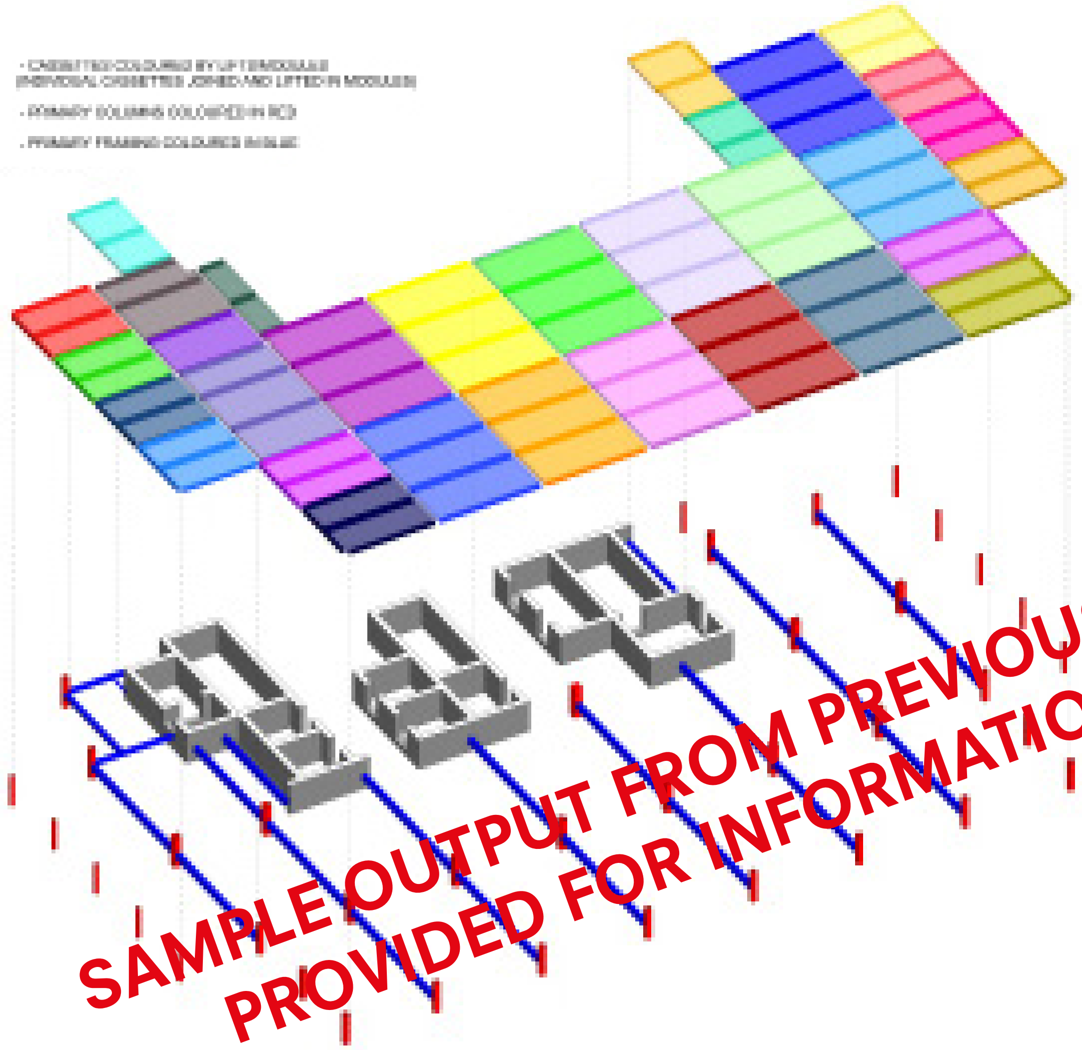
In the below table the number of lifts needed for the DfMA options are shown compared to the traditional option. Note that the only steel elements that need to be lifted for these alternatives are shown in the adjacent image in dark blue. The rest of the framing, reinforcement and steel deck is integrated within the cassettes.

Lifts per Floor

	DfMA Option 1	As Designed
Beams	22	68
Bay cassettes	31	N/A
Reinforcement	N/A	2
Steel deck	N/A	5
TOTAL	53	74
Reduction to traditional:	**29%**	**N/A**

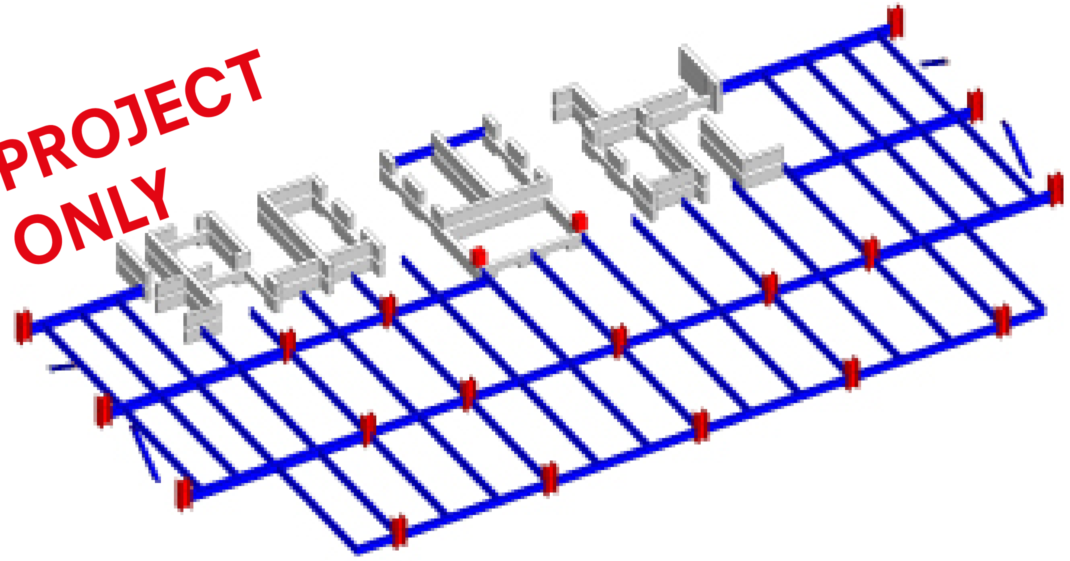
Notes:
Maximum lift = 3.7T
Reinforcement for DfMA included in the cassette
Assumed A395 mesh for all options
1mm thick Comflor 51 as per AKT GA

As can be seen in the above table there is a reasonable reduction in the number of lifts needed. This is directly related to the lower number of beams used. Note that reinforcement and 'secondary' services can come pre-installed for both DfMA options.



Proposed framing and cassettes modules (2/3 unit each) for DfMA Cassettes Option 1.

Each module and beams is considered to be lift independently.



Traditional ('As designed') Option. Note the high number of beams needed, each one independently lifted.

Façade and cladding opportunities

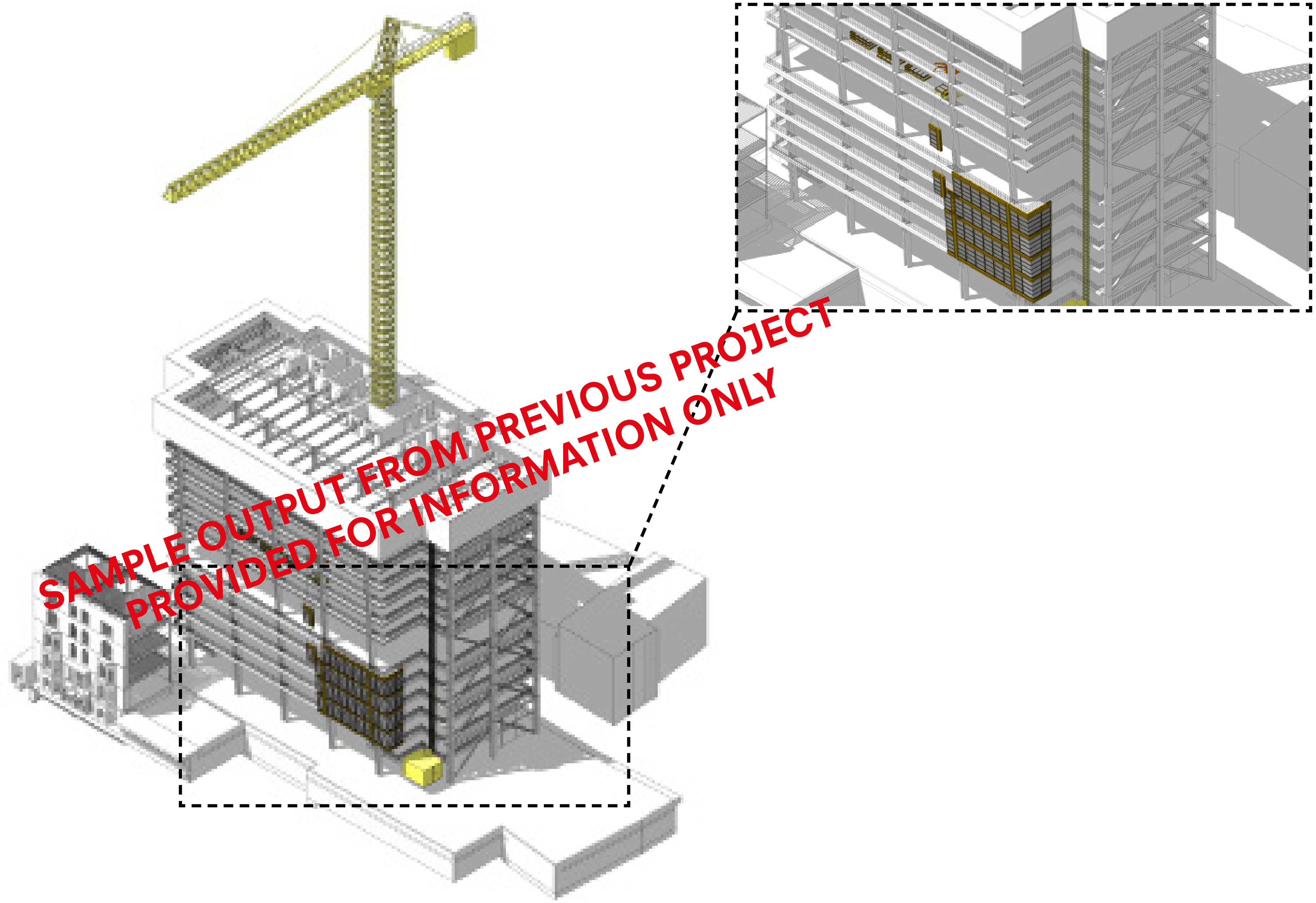
Installation of Unitised Facade Panels

The glass will be pre-installed within the glazing panels. No site glazing will be required following the panel installation.
- For panel installation on e.g. Level 4: The panels will be manoeuvred onto a launching tray which will be cantilevering, retractable and situated on Level 5 (the floor above the installation floor of the panels) and offset horizontally from the panel installation location; The panels will be lifted by a spider crane situated on Level 6; The panels will be installed on Level 4; Meanwhile superstructure erection can continue above (on Level 8). - Once the unitised glazing panels have been installed they can be sealed for temporary waterproofing. Once temporary waterproofing is in place, internal fit-out and M&E works can continue closely behind the structure erection.

Panel installation can continue up the building following the methodology set out in Stages 3 and 4: Spider crane situated 2 storeys below the structure erection; The launching tray situated 1 storey further below; Panel installation 1 storey further below the launching tray.

6 levels further below the launching tray, a full width safety net to be used for providing cover in case small parts i.e. bolts fall of the building during installation or construction works.

Temporary waterproofing allows internal Fitout/ M&E to follow closely behind structure as well.



MEP opportunities

Vertical AHU

This design review period has explored the potential for systems to be optimised with the aim of providing value engineered solutions without comprimising on system performance and exploring the potential for DfMA methods of design and delivery.

This option considers the provision of a vertical orientation Air HandlIng Unit (AHU) in lieu of a horizontally orientated AHU as proposed.

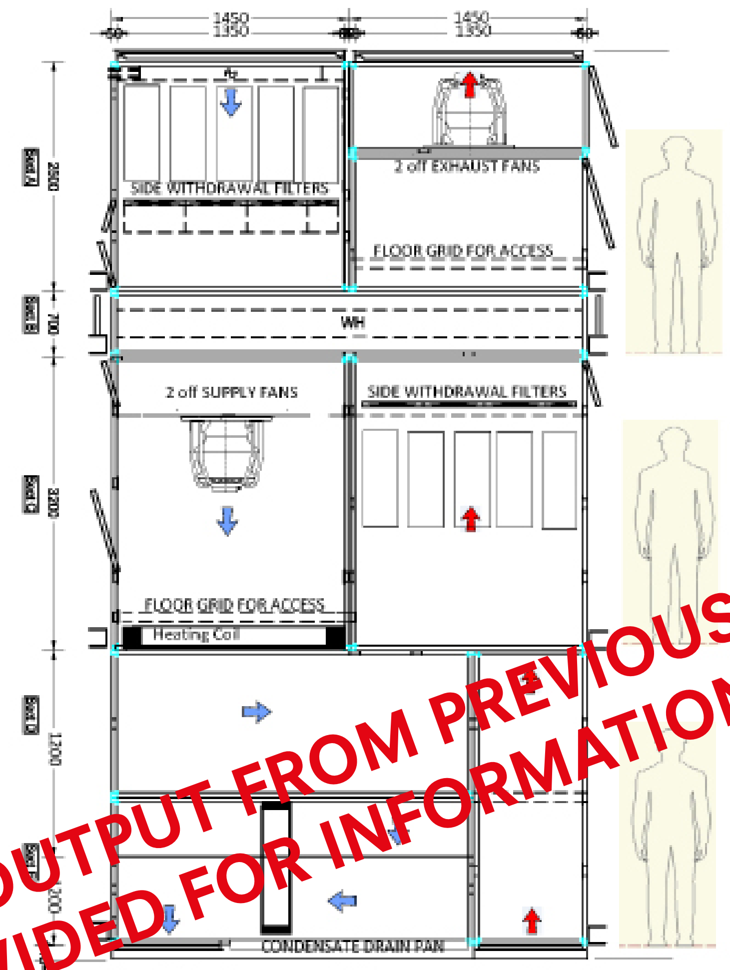
This strategy as illusttated as illustrated in adjacent images, would merge the ventilation requirements of 3 commercial office floors into a single consolidated unit in a vertical orientation.

To enable its adoption, there would be modifications required to the core layout with the need to position the AHU plantroom in an area which optimises ductwork connections and both vertical and horizonatal air distribution routes.

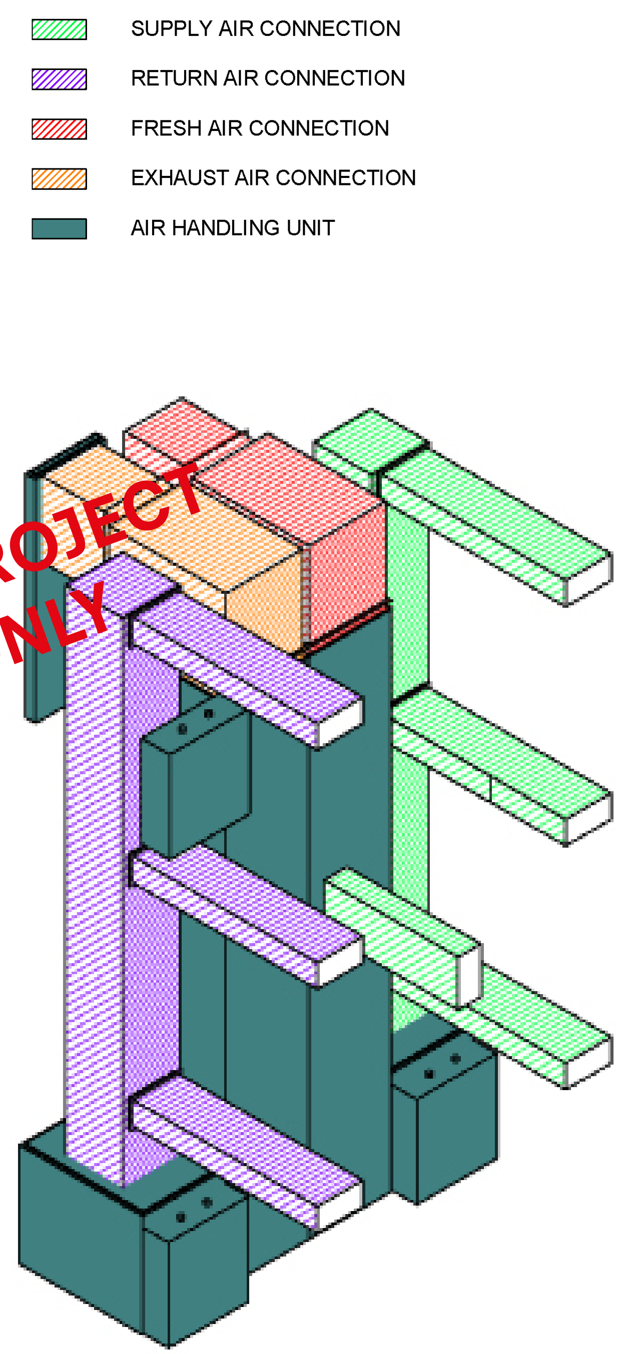
Our initial high level assessment has confirmed that this strategy has the potential to reduce the number of installed units to 11, offering a 60% reduction in the number of installed units (12.5% reducation in capital costs for AHU units) and when this is considered against programme benefits inlcluding transportation, lifting, installation and commissioning, coupled with life cycle costing associated with maintenance and plant replacement strategies, this method of design and delivery has potential to offer significant value during construction phases and throughout the buildings life.

Unlike the horizontal ventilation strategy there would be a requirement for plantrooms on every floor. Our Initial estimates suggest a 40m2 plantroom would be required on each floor which would be an overall increase in plant area of 145m2; however, this strategy has greater potential for a DfMA approach as the design progresses to the next stage.

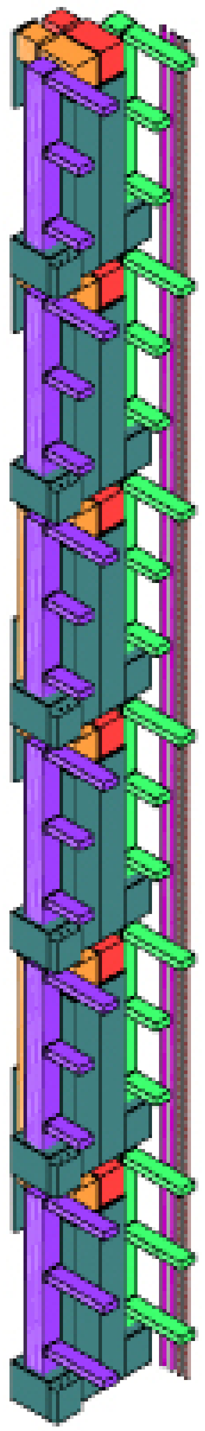
The above figures consider plantroom area implications associated with this philosophy. As highlighted in the archictural section of this report, through the reorgansiation of the core, an additional are saving of 33m2 can be gained on each floor, therefore nett impact with this proposal is an additional 28m2 on each floor plate.



Vertical AHU arrangement



Typical vertical plantroom



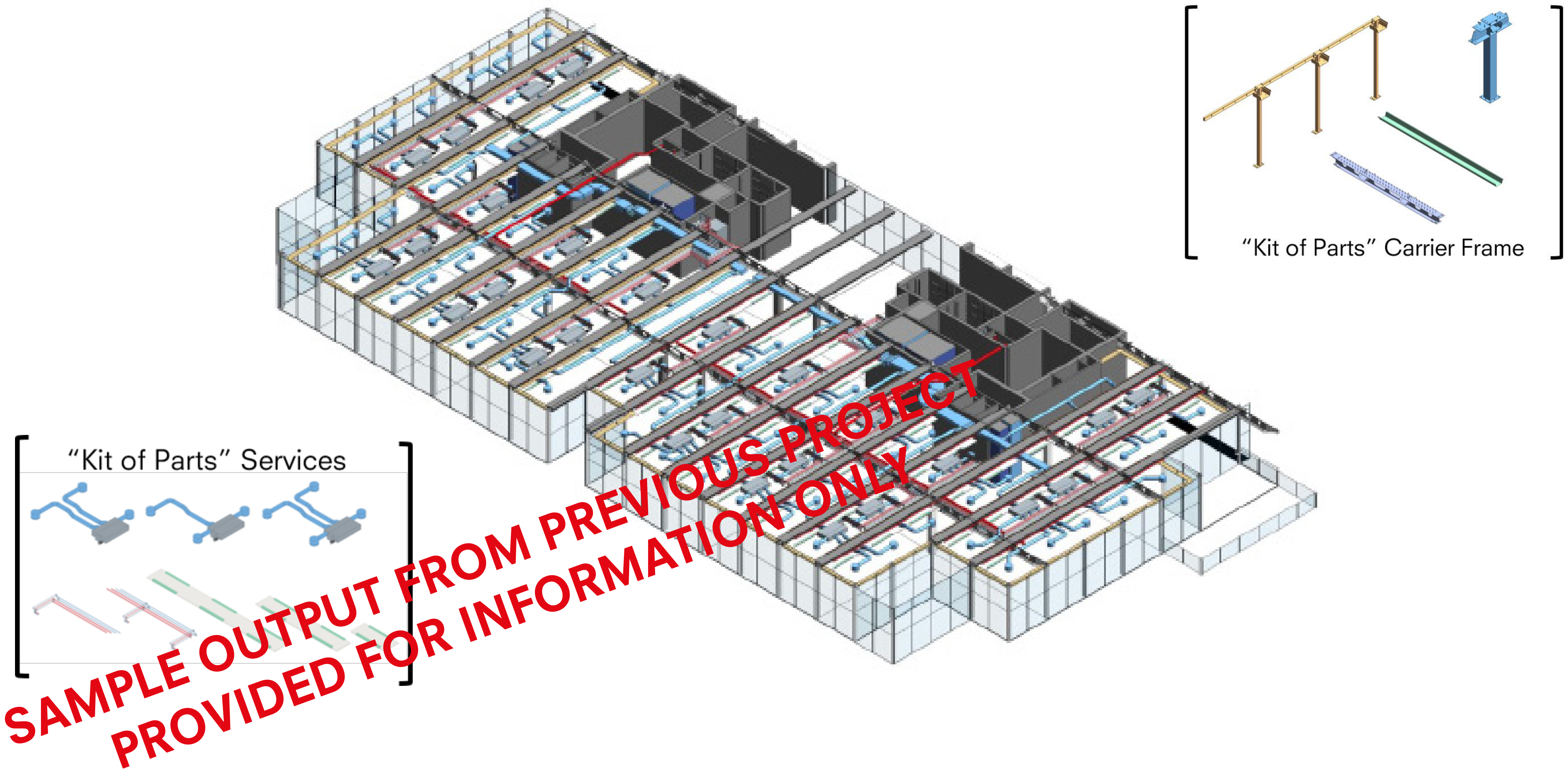
Vertical ventilation distribution

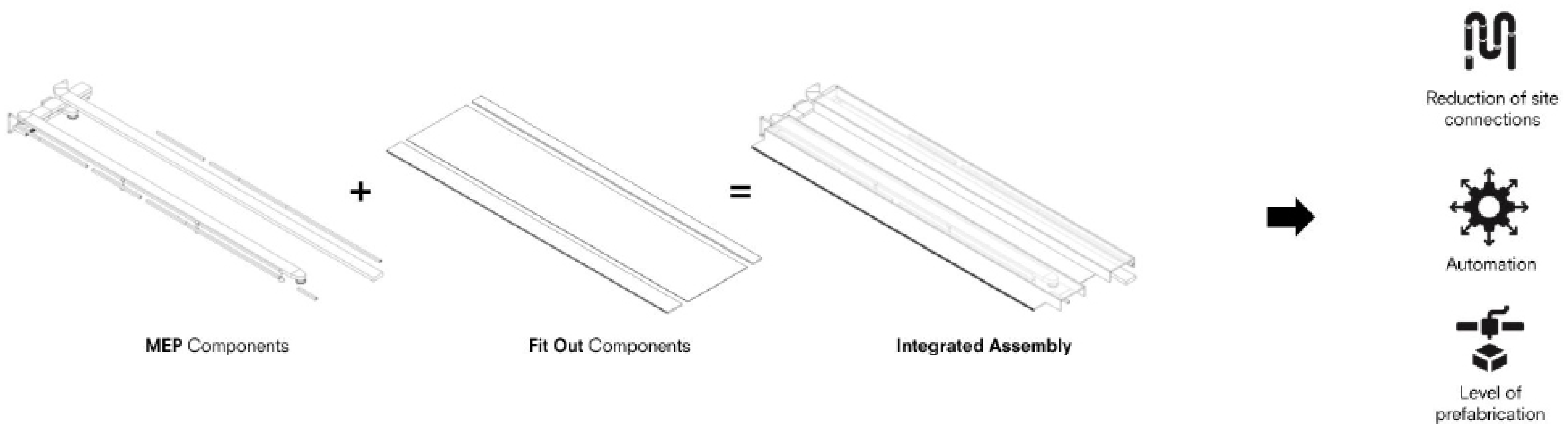
MEP opportunities

Prefabricated MEP ceiling modules

The use of integrated DfMA ceiling modules that are designed to fully coordinate with the structural and fit out elements of the project have the potential to bring benefits in terms of increased levels of off-site factory prefabrication (along with all the associated quality benefits that come from working in a controlled environment), reduction in the number of connections that need to be made on site, and the potential for increased assembly automation.

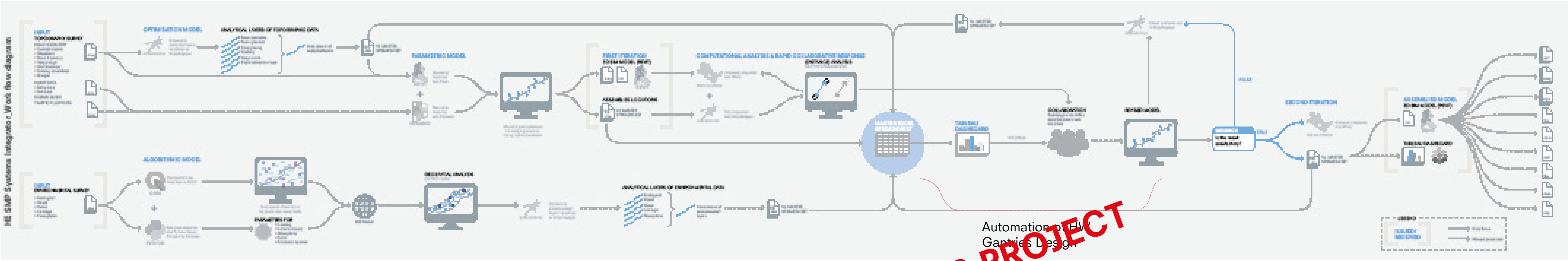
The modules would be comprised of two complementary kits of component parts - the services elements themselves, and the supporting carrier frame elements. Both kits of parts, aggregated together, would form part of the overall integrated floor and ceiling cassette.





ANNEX 2: Automated Tools: Configurator + Structural Design & Optimisation + Fabrication Detail Output

System Workflow



Integration between BIG DATA + BIM + API Structural Design + Solidworks for rapid engineering

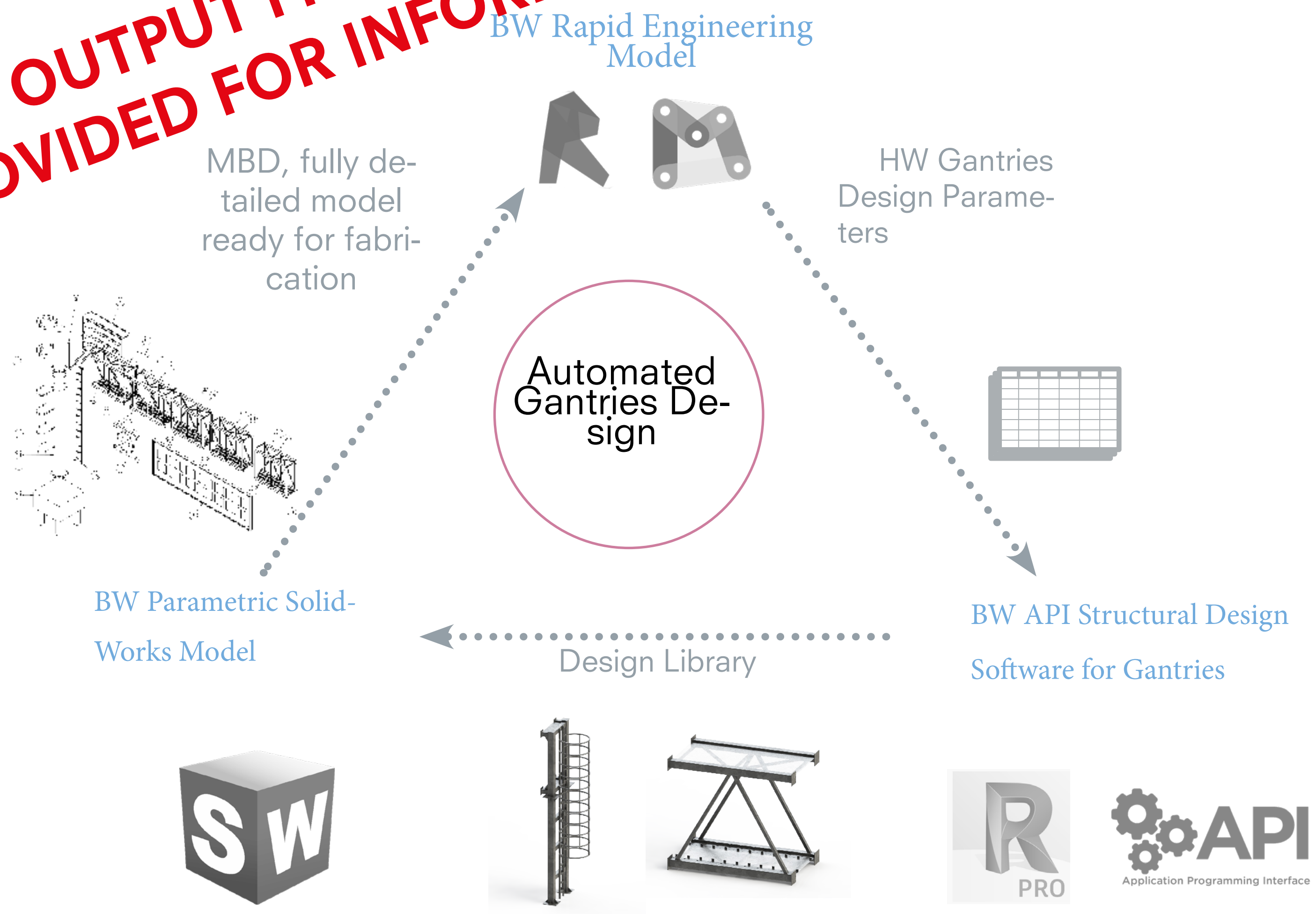
Big infrastructure projects, massive in scope and man-hour needs as they currently are, face new challenges even after the implementation of streamlining design techniques for its many structures and elements.

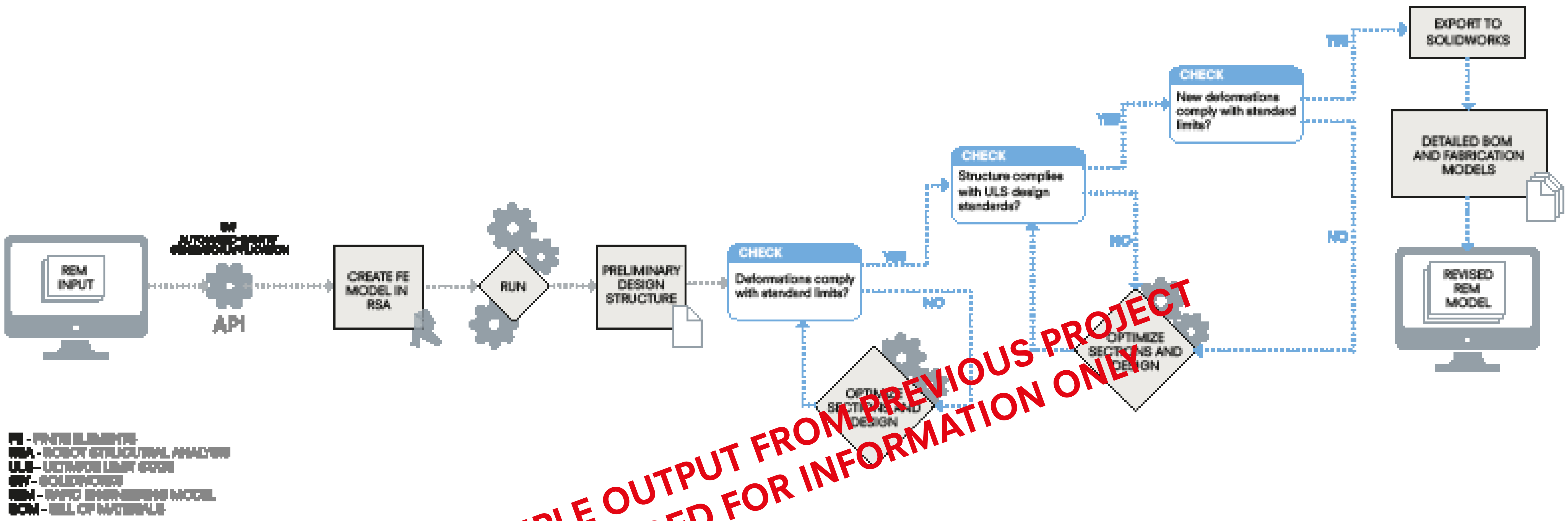
Rapid Engineering Models generated by previously plotted road paths and terrain assessment provide valuable data that can be utilized to determine where and which gantries should be used in a future roadwork. That same information can in turn be integrated into structural engineering software, automatically specifying which kinds of components will be used on each individual gantry.

The automated structural design using an in-house application will speed-up the process by designing different types of gantries with variations of signs, loads geometries, etc.

Finally, when all gantries have had their individual structural and component composition determined, dedicated parametric modelling software such as Solidworks can create the final production models using a previously generated modular structure database, adapting it to each individual need of every gantry with minimal, if any, human intervention and verification.

Traditional 2D fabrication information is not needed as all details including dimensions, geometric tolerance, materials, bill of materials and annotations are parametrically created with the 3D model with Model Based Definition (MBD). However, should the supply chain continues to rely on traditional 2D fabrication drawings, they can be produced in an automatic fashion from parametric models.





BW In-house Software scheme

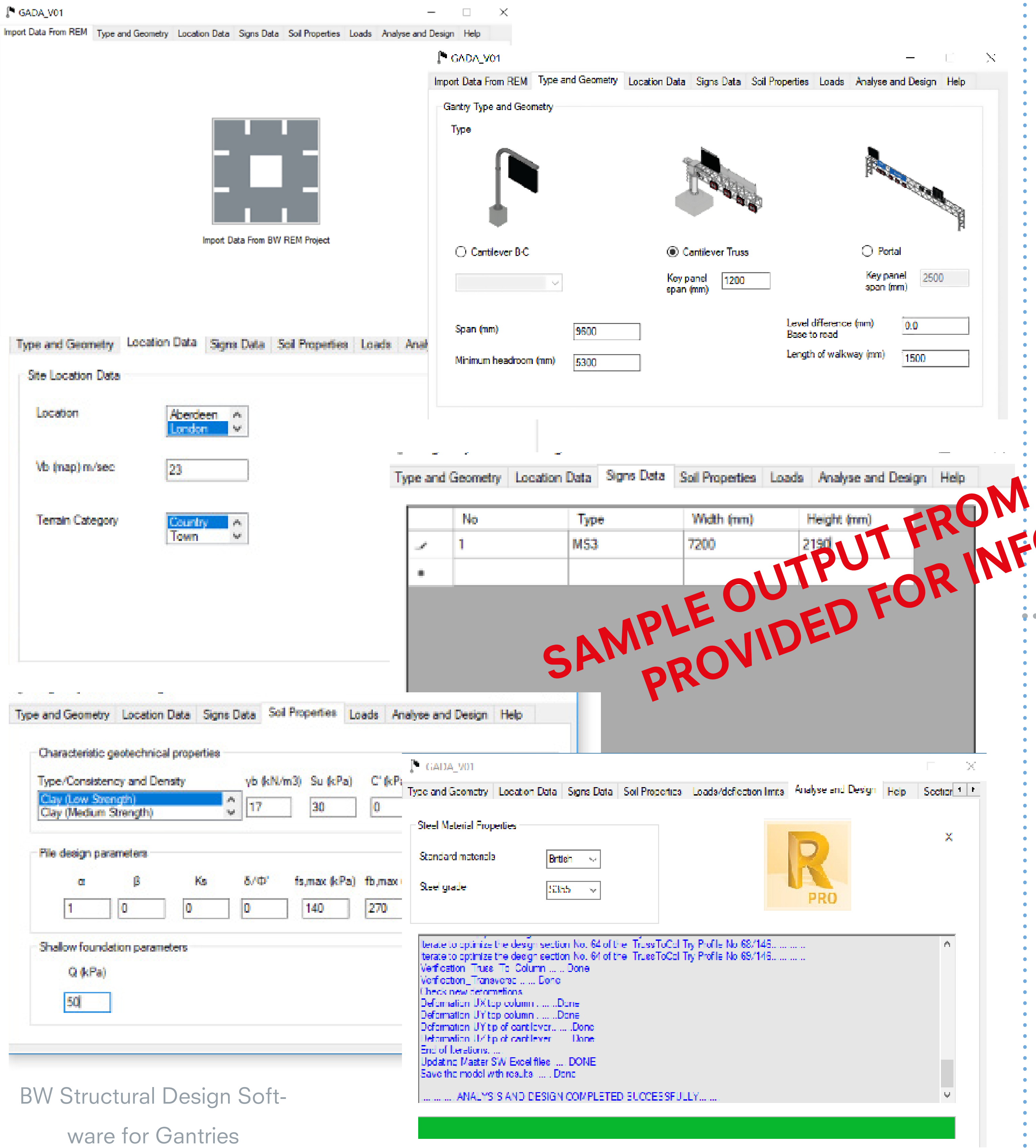
The scheme of the developed In-house software is presented in the Figure above. The solution uses the open Application Programming Interface Technology (API) in the Finite Elements Software ROBOT to automate the structural design in just ONE Click.

From REM input, the developed software reads and processes these inputs, creates the Finite Elements model in ROBOT and starts a preliminary design in order to get the initial sections. Subsequently, the software enters the model in an iteration process to comply the standard deformations limits and ultimate limit strength. This iteration continues until the optimal design is reached in terms of cost and structural performance ..

With the end-result data, Solidworks template files are edited with the required construction information that are exchanged automatically from ROBOT through the developed application. General assembly, sections profiles and tolerances, all can be exported to Solidworks program from the analytical model.

At this phase, the definitive models of fabrication are generated automatically in Solidworks, relevant data such as the bill of material, technical drawings, and the 3D fabrication model are incorporated in the REM database.

BW Structural Design Software for HW Gantries



BW Structural Design Software for Gantries

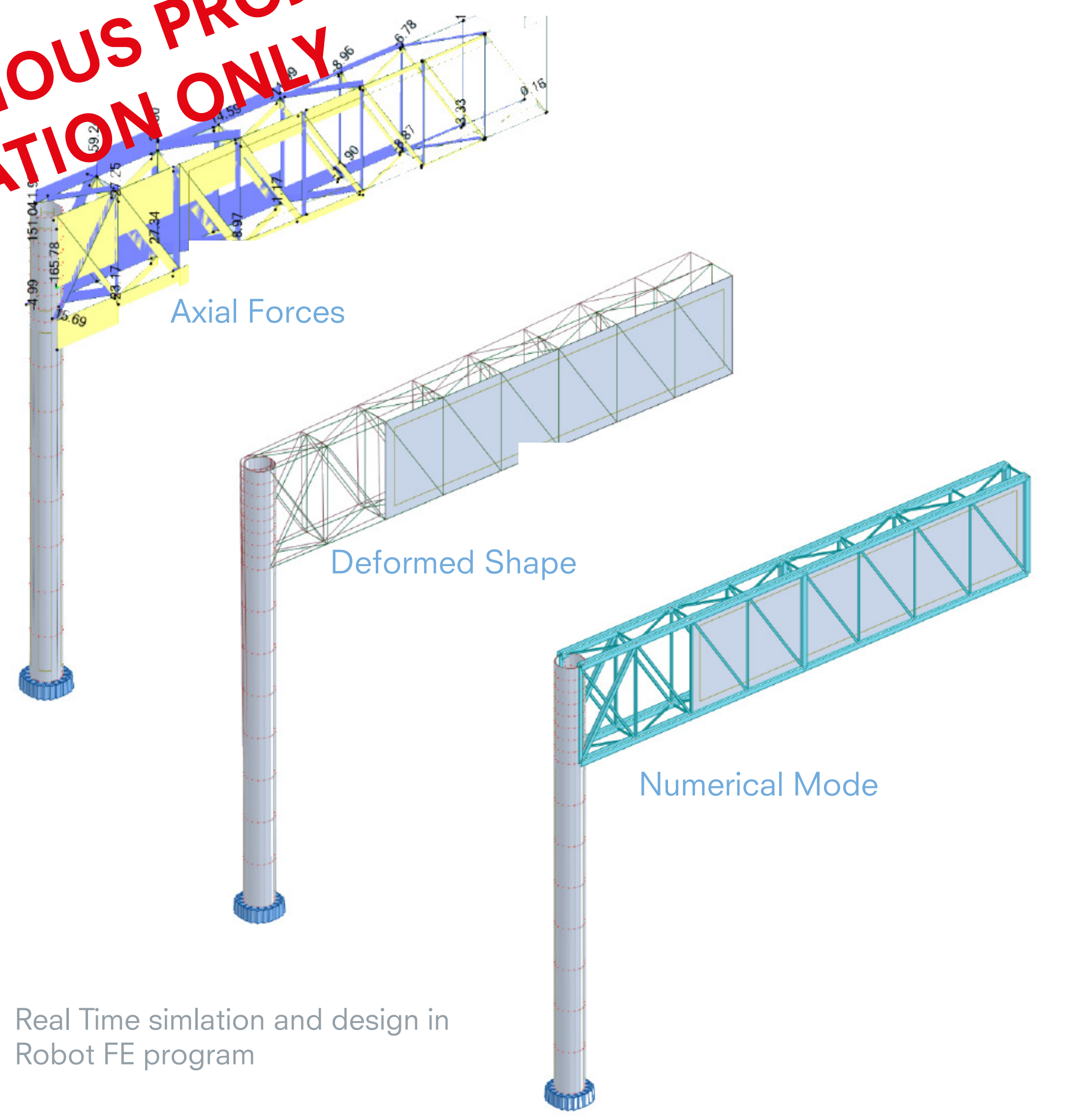
BW in-house Software interface

Three families of gantries have been implemented in the developed software:

1. Simple Cantilever: Consists of a beam and column with moment connection.
2. Truss Cantilever: Consists of truss rafter connected to a circular column with moment connection. This model is developed in two forms, 2D truss for short span up to 7.2m, and 3D truss for long spans up to 15
3. Portal Truss: for long spans up to 50m: Consists of 3D steel truss beam supported on tow steel posts. Each post consists of two columns connected transversally with several element along its height.

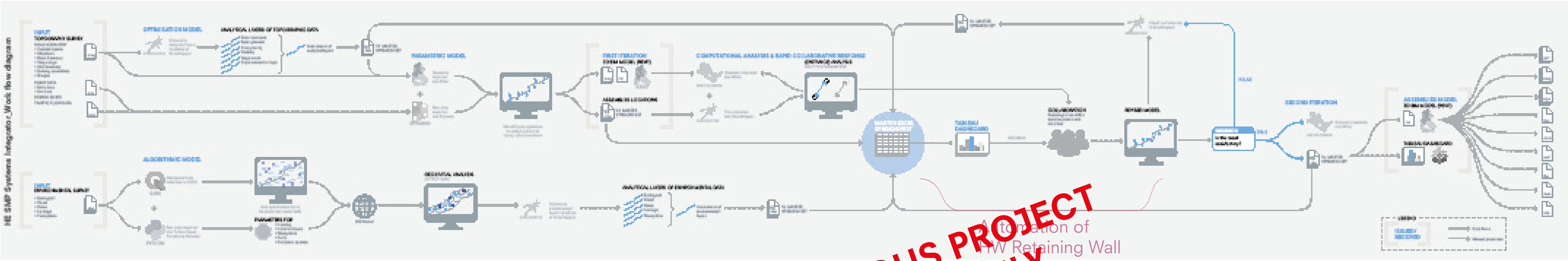
The software at this state of the project, only supports the automated design of the cantilever truss model. This can be extended to other models in case there is an interest for a future phase by Highways England.

The developed software provides a user friendly interface which allows the data to be imported directly from REM, as well as the option of individual inputs. Real-time modelling and optimization in ROBOT program is also supported. The framework of the developed software can be easily enhanced by a built-in scheme for foundations design. This scheme will extract the supports reactions for different load cases, and carries out the design based on the soil conditions imported from REM.



Real Time simlation and design in Robot FE program

System Workflow



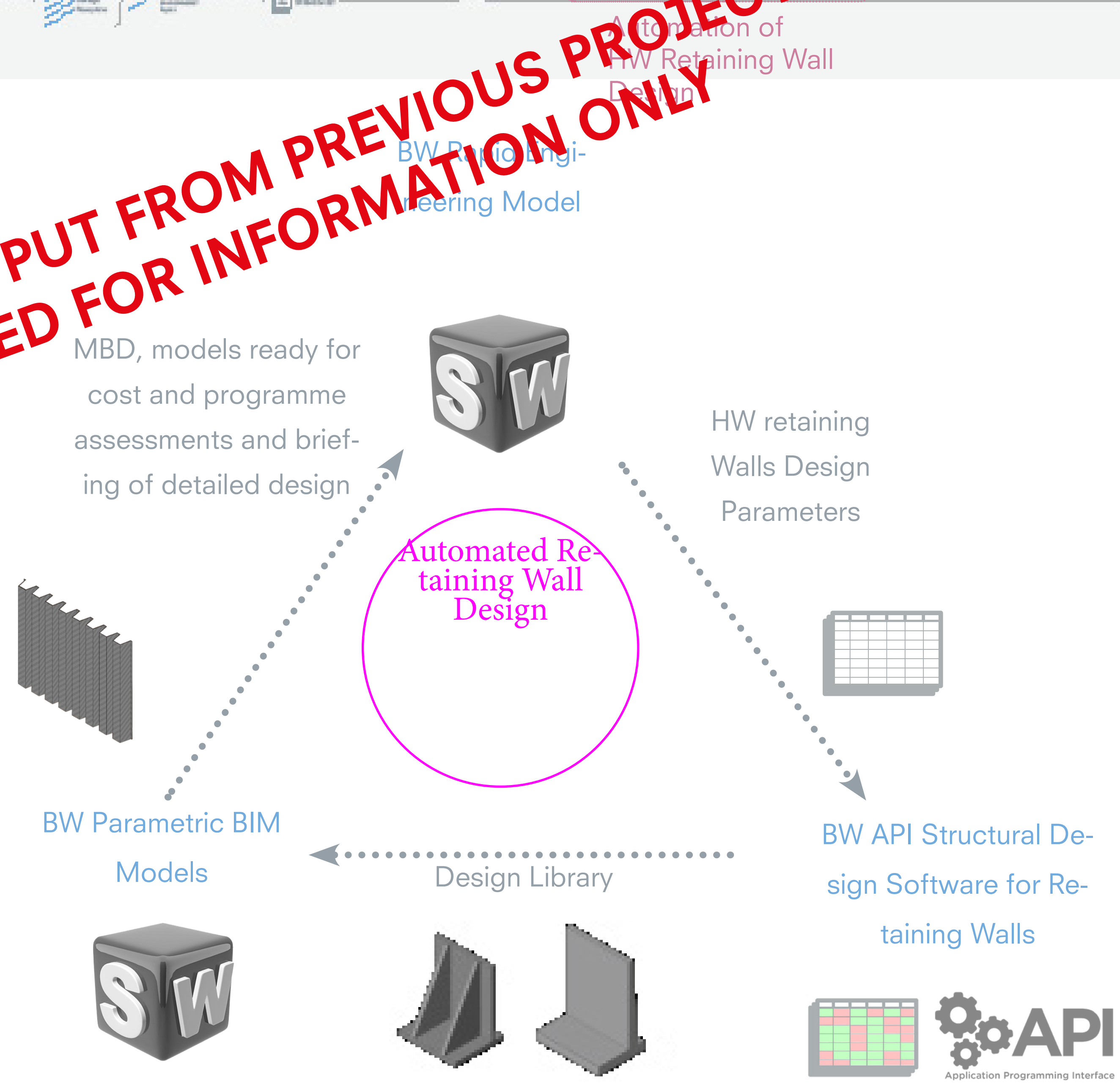
Integration between BIG DATA + BIM + API Structural Design + Solidworks for rapid engineering

Big infrastructure projects, massive in scope and man-hour needs as they currently are, face new challenges even after the implementation of streamlining design techniques for its many structures and elements.

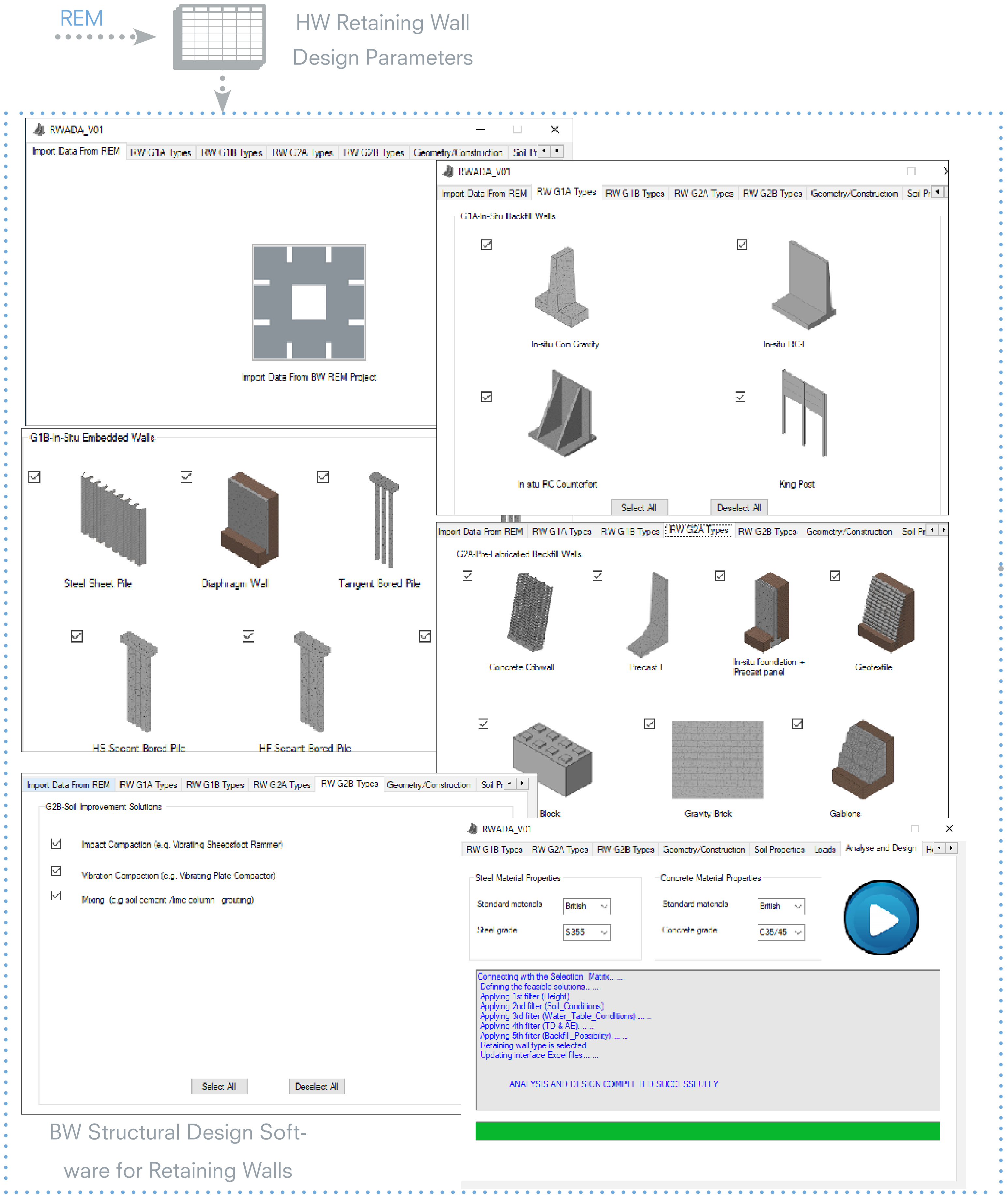
Rapid Engineering Models generated by previously plotted road paths and terrain assessment provide valuable data that can be utilized to establish positions where retaining walls are necessary.

Finally, when all retaining walls have had their individual structural and component composition determined, dedicated parametric modelling software such as Solidworks can create concept models using a previously generated modular structure database, adapting it to each individual retaining wall position.

Should there be an interest by or benefit to Highways England, the automatic retaining wall design could be further developed in the future to output detailed design or in some cases construction stage design.



Structural Analysis and Design Workflow

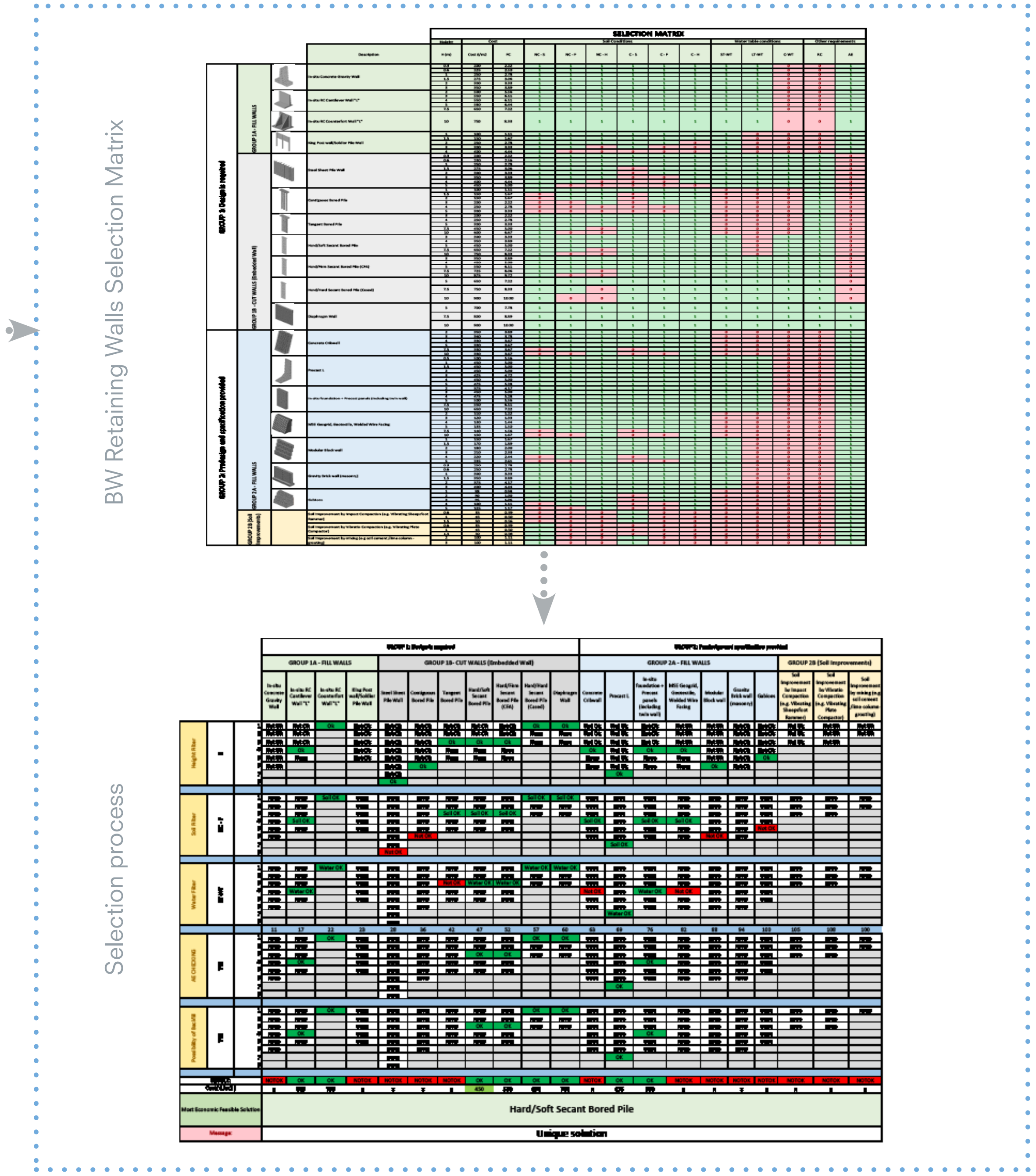


In-House Development For Automated Analysis and Design of HW Retaining Walls

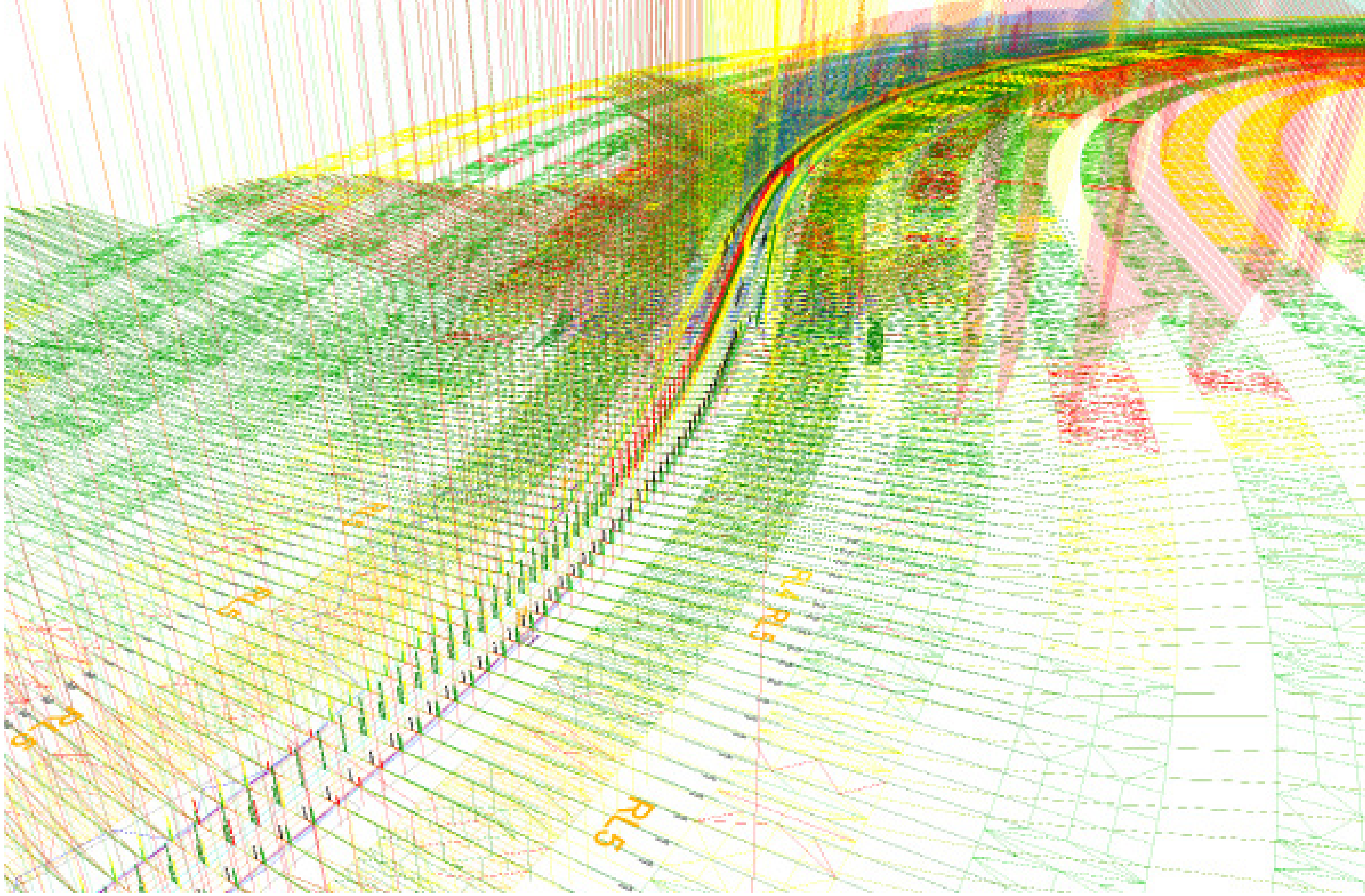
An In-house software is developed for automating the structural selection as well as the structural analysis and design of HW retaining walls. Developed software plays the bridge role between the REM platform and the final BIM models in Solidworks, providing the required sections, materials, geometries and elevations.

The software is enhanced with a selection matrix which narrows the selection based on several filters (e.g. Soil conditions, water table conditions and construction conditions). After defining the feasible RW types based on the filters, the final selection is conducted according to a pre-estimated prices and a pre-defined weight factors (e.g. Durability, Impact risk and Special equipment required). Each of these factor is amplified by an interest factor defined by Highways England for each case.

Once the RW type is selected, the software will carry out the structural design using principle of mechanics and RW calculations schemes. For pre-fabricated wall types (e.g. Pre-cast L, Gabions and Crib Walls), the software will use a pre-defined models and geometries selected from available data in the market. These data can be modified in the future by Highways England in case there is an interest of a future phase.

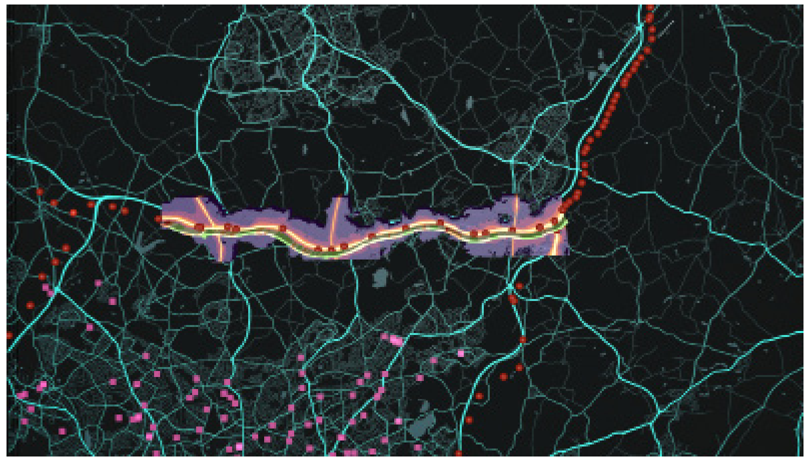


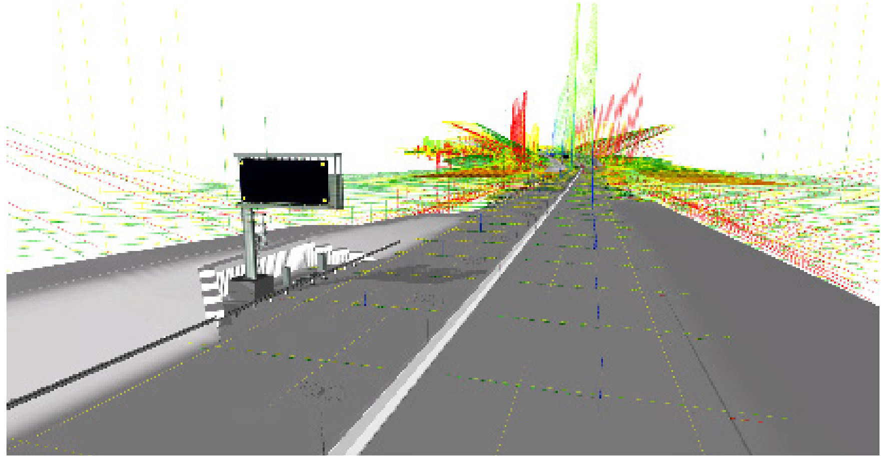
Rapid Engineering Model (REM)



The Rapid Engineering Model (REM) is a radical and disruptive new digital approach to automated design for Highways England, developed by Bryden Wood Technology Ltd for the Smart Motorways Programme (SMP).
REM is a digital workflow, rather than a single piece of software, that is digitally driven and collaboratively enabled and means that SMP schemes can be designed automatically much faster than by traditional means. Central to the functionality of REM is the design guidance documentation that has been already developed for the Smart Motorways Programme. This guidance has been encoded into a rules engine that drives two key aspects of REM – data analytics and automated design. Topographic data can be analysed alongside environmental data to help identify opportunities and risks within a specific project, or along an entire asset in the network. Using this data, design layouts of major roadside assemblies (such as gantries) can be automatically generated, in accordance with the SMP guidance. The layout can then be optimised according to a variety of different design and performance criteria.
The step-by-step Rapid Engineering Model process is as follows;

1. Analysis of digitally captured topographic and environmental data.
2. Evaluation of suitability of topographic data analysis.
3. Automation of design layout, following SMP design rules.
4. Optimisation of design layout according to project specific criteria.





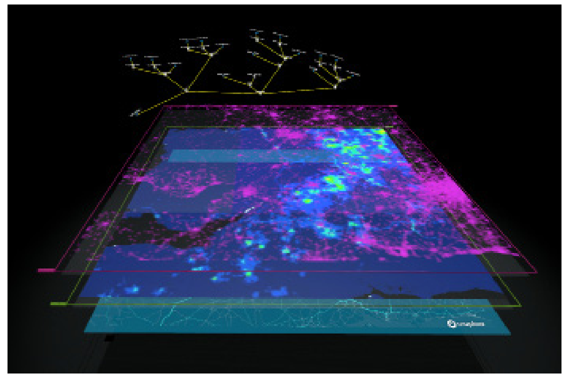
The REM workflow is organised around a 'master data set' – a single source of the design truth - which captures the analytics, evaluations and optimised layouts. From this, REM can generate many different outputs types and formats, including;

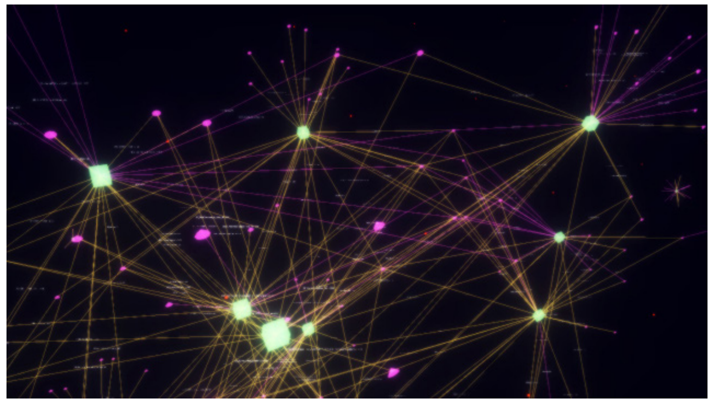
- GIS data layers
- HE compliant BIM models
- Interactive, browser based data dashboards
- 'Drive through' visualisations

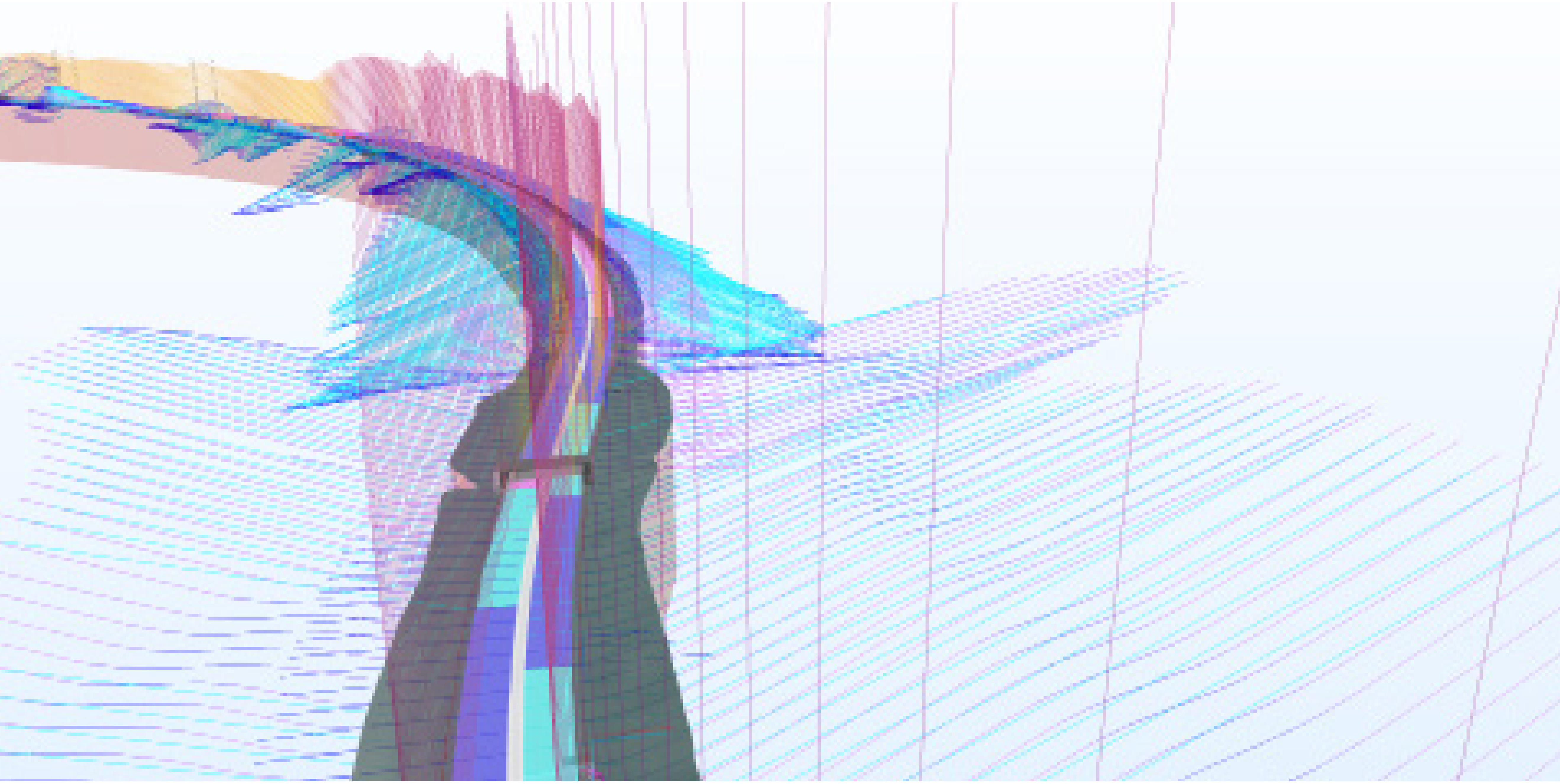
Furthermore, the REM data set can be viewed in 'virtual reality' as well as through web and mobile apps that have been developed specifically for SMP. All of these outputs are consistent in structure and format across each design iteration, as well as each scheme, allowing for easy comparison and evaluation. This directly supports a data-driven and evidence-based approach to SMP design.

REM has been developed with the SMP innovation team for 12 months, initially in parallel to the ongoing design work, but has recently been used to assist design teams in the development of the early stage 'Operations Concept' information for a number of SMP projects.

The functionality of the Rapid Engineering Model workflow continues to be expanded. Features are currently being developed and tested focusing on 'design in the verge' for the automatic configuration and self-design of the major road side assemblies themselves. A further development will see elements of quantification such as cost incorporated into REM that will further extend its capability and impact.







Appointment:
Construction, Innovation consultants
Programme:
July 2015 - ongoing
Client:
Highways England

Select Client List

A
ACT Foundation
AF Gruppen
Amazon
American Airlines
Anglian Water
Ardmore

B
British Airways
BAA Limited
BG Group
Bovis Lend Lease
Balfour Beatty
Basepoint
British Airways
British Land
BT Group
Buckinghamshire County Council
Building and Construction Authority, Singapore
Bupa
Buro Four
Byrne Group

C
Cabinet Office
Capgemini
Carillion
Chorus Group
Costain Group
CircleHealth

D
Durkan Group

E
Essex County Council
Equinix
Explore Living
Explore Manufacturing

G
Gammon Construction Limited
Gatwick Airport Limited
GlaxoSmithKline
Global Switch
Graham Construction
Great Western Studios

H
Henderson Global Investments
Heron International
Hertfordshire County Council
Heathrow Airport Holdings Limited
Highways England
Hinchingbrooke NHS Trust

I
ICES
Igus GmbH
Integrated Building Products
Investec
ISG PLC

J
Johnson Matthey
Jones Lang LaSalle

K
Kent Institute of Medicine and Surgery
Kier Group

L
Laing O'Rourke
Land Securities
Legal and General Modular Homes
Lendlease
London Borough of Barking and Dagenham
London Borough of Bromley
London Borough of Kensington and Chelsea
London Borough of Lewisham
London Borough of Redbridge
London School of Hygiene and Tropical Medicine
Loromah Estates
Lufthansa

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

N
NG Bailey
North Manchester General Hospital
Norstead

O
Oxfordshire County Council

P
PM Property Services

Q
Qatari Diar Delancey

R
RAF
Royal Holloway University of London
Royal Mail
RG Group

S
Sainsbury's
Schneider Electric
SEEDA
SES
Serco
Shangri-La
Shepherd Group
Sir Robert McAlpine
Skanska
SnoozeBox
SPb Renovation
Spie Matthew Hall
Stanhope
Swire Properties

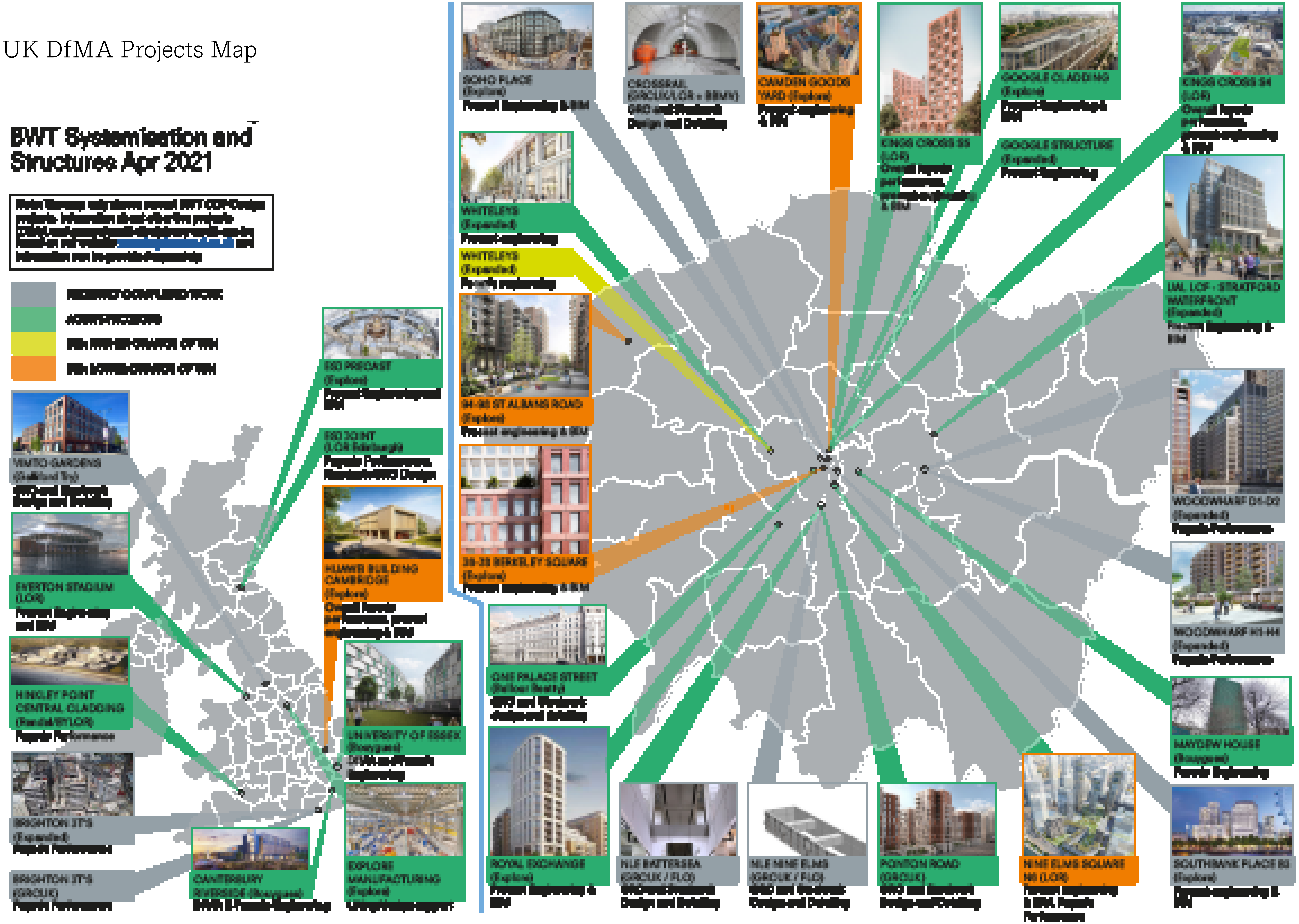
T
Tate Modern
Tesco Stores Ltd
The London Clinic
Three Valleys Water
TRE Global

U
University College London (UCL)
University of Southampton

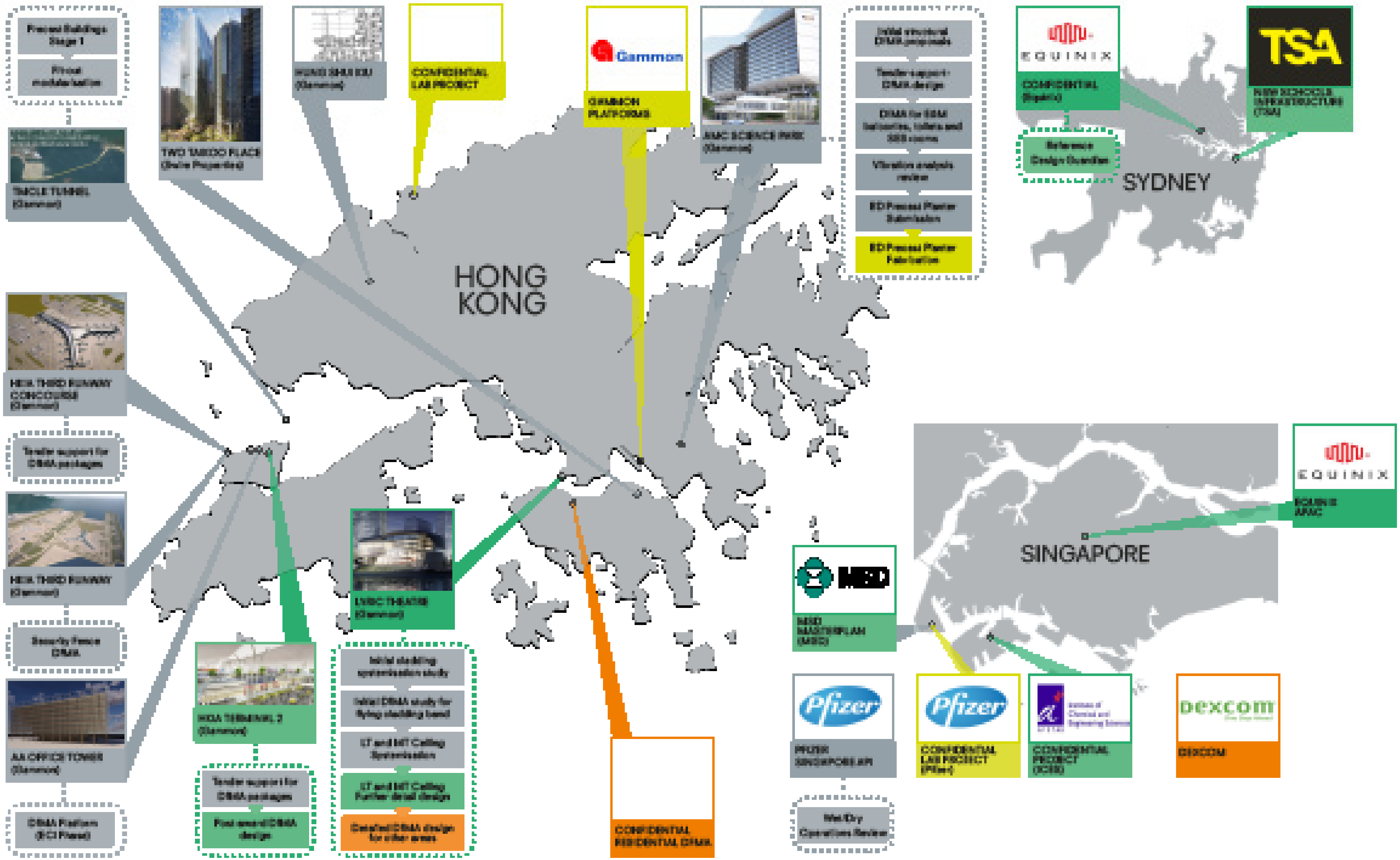
V
Vastint
Vestfold Hospital Trust - Norway
Vinci PLC

Y
Yotel

UK DfMA Projects Map



Hong Kong/Asia Projects Map



Thank You

Bryden Wood @BrydenWood @brydenwoodtech

Markus Huber
Board Director
Head of Systemisation, Civil &
Structural Engineering
mhuber@brydenwood.co.uk
+44 7889 402 531

Adam Jordan
Asia/Pacific Lead
ajordan@brydenwood.co.uk
+61 420 989 903

Thomas Nunn
DfMA Director
tnunn@brydenwood.co.uk
+1(780) 964 7724

Ionut Hapaianu
Director
IHapaianu@brydenwood.co.uk
+44 7711 036 001