Structural design of Te Pae Christchurch Convention Centre

B.D. Galloway, A.G. Brown & A.T. Eyles

Holmes NZ LP, Christchurch.

ABSTRACT

Te Pae is inspired by the Māori creation story and reflects the unique and natural beauty of the Canterbury region. The exterior façade emulates the fluidity of the Canterbury region's braided rivers while the interiors reflect the diverse culture, community and values of Ōtautahi.

The convention centre comprises multi-purpose, flexible spaces interconnected by concourses, kitchens, serveries and plantrooms built above a drive-through truck dock. The structural connection of these spatial requirements proved one of the key project challenges while the elaborate finishes of Te Pae conceal layer upon layer of complexity. Solutions were developed to extend the façade 'braids' across several levels without compromising the architect's vision for a flowing, layered facade.

The complex geometry also required innovative technological solutions, with significant benefits found from integrating the analysis, modelling and documentation workstreams. Development of bespoke software to automate the façade design and documentation process enabled delivery of high-quality documentation in an efficient manner with an accuracy the fabricators used as the basis for the steelwork shop drawings.

Figure 1: Te Pae Christchurch Convention Centre (Image credit: Lightforge)

INTRODUCTION

Te Pae Christchurch Convention Centre is an important anchor project for the rebuild and revitalisation of Ōtautahi following the 2010-2011 Canterbury Earthquakes. The central city site was designated to attract new and exciting events to the city and to reactivate surrounding streets and public spaces. The brief to create a world-class boutique venue led to the unique architectural design by Woods Bagot and Warren and Mahoney which embraces local cultural values and breaks away from the conventional big box typology.

This unique project has a 1400 seat tiered auditorium, 2800m^2 of exhibition space (which can expand to 3300m^2 if required), 24 meeting rooms, can accommodate up to 1800 people for a seated banquet, and has 28,000m^2 of highly flexible and adaptable design.

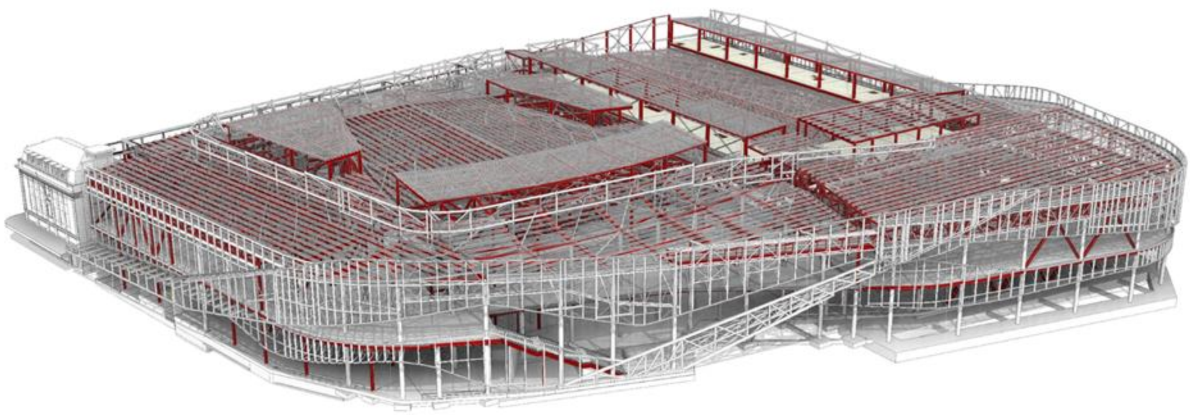

Figure 2: Structural BIM Model of Te Pae Christchurch Convention Centre

The project was initially tendered as a public private partnership, with masterplanning design carried out for a larger precinct incorporating accommodation and retail offerings integrated into the convention centre design. Following Ōtākaro's decision to take back control of the project, the design was subsequently revised to deliver a stand-alone convention centre on part of the site. At completion of the developed design phase, the design team was novated to CPB Contractors to complete the project under a design and build contract.

CONNECTING SPACES

Te Pae is a building of complex geometry and intricate finishes. An early challenge was turning the creative concept into a realistic proposition in an environment where the seismic loads are more than 50 times the wind loads the international project team was used to working with. Complex voids, interposed floor levels and irregular roof geometries were carefully arranged to produce a coherent building structure that is functional, buildable, safe and resilient.

Space is one of the more complex things to build and Te Pae is full of it. An important feature of the facility is the interconnection of the auditorium, exhibition hall, banquet rooms and flexible meeting room spaces by concourses used for pre-function activities. These key spaces required clear heights ranging from 4.5m to 14m and are also serviced by kitchens, serveries and plantrooms built above a drive-through loading dock capable of simultaneously unloading two semi-trailer trucks. Figures 3 and 4 illustrate the complexities of the stacking arrangement of spaces within the facility. The structural connection of these widely varying spatial requirements proved one of the key project challenges

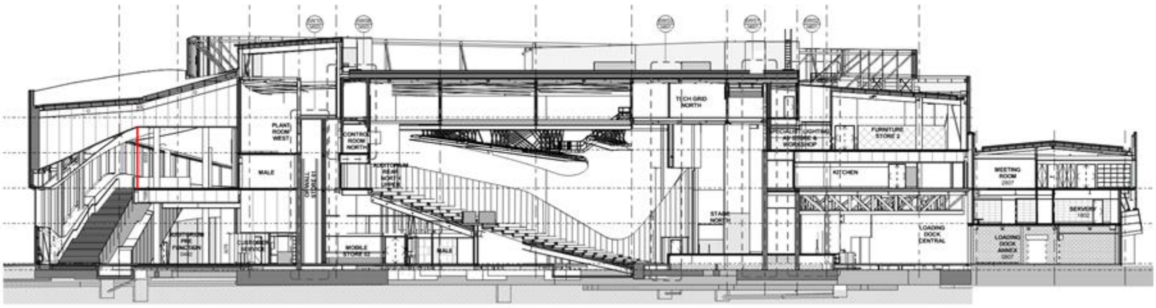

Figure 3: Typical long section

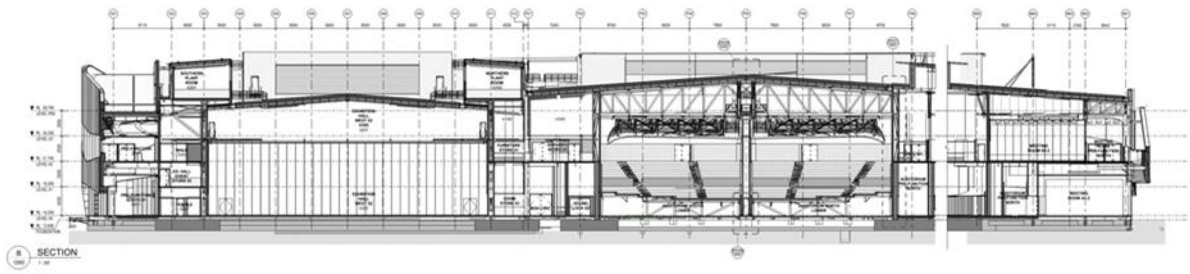

Figure 4: Typical cross section

During the concept phase we guided the architects in arranging these key spaces—enabling them to be structurally tied together while maintaining large brace-free volumes. The facility was separated into three structurally independent but interconnected buildings across the 15,000m^2 footprint. Structural bracing lines were typically located at 30-40m spacings, with the discontinuous roof and floor plates required to transfer loads between these bracing lines.

Creative approaches were found to isolate undesirable floor plates and create structural planes within the complex roof geometries – such as connecting the bottom chord of one roof system into the top chord of another and creating warped structural planes to connect adjacent roof forms of different geometries. Buildability was central to the design, with the erection sequence and staged analysis for the auditorium developed to allow for un-propped construction of the roof (Fig. 5) while maintaining the benefits of two-way spanning capability for permanent loads.

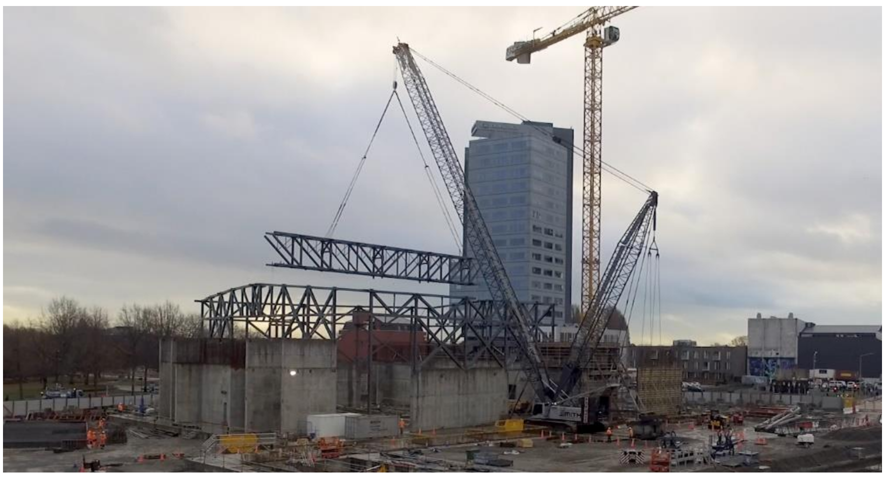

Figure 5: Erection of the Auditorium spine truss

The coherent loadpaths negotiated through the concept phase were key to being able to meet the highly accelerated structural design programme for the project. With foundation design being completed during the developed design phase and all five primary structure consents and construction packages being issued and under construction or fabrication prior to completion of the detailed design phase, staying in control of the building geometry was a real challenge as the architectural and services designs developed.

DEVELOPING STRUCTURAL SOLUTIONS TO COMPLEX FACADE

The elaborate finishes of Te Pae conceal layer upon layer of complexity. Overlapping braided ribbons seemingly flowing uninterrupted over the height of the façade are an example of creative engineering at its best.

The façade design draws inspiration from the braided rivers of the Canterbury Plains and comprises 42,058 herringbone fibre cement tiles assembled on 1604 separate panels. These façade panels are in turn supported by a complex steel structure that follows the curve of the façade between primary structural elements. Figures 6 and 7 illustrate the complexity of the overlapping façade form and the degree of variation as the façade wraps around the perimeter of the building.

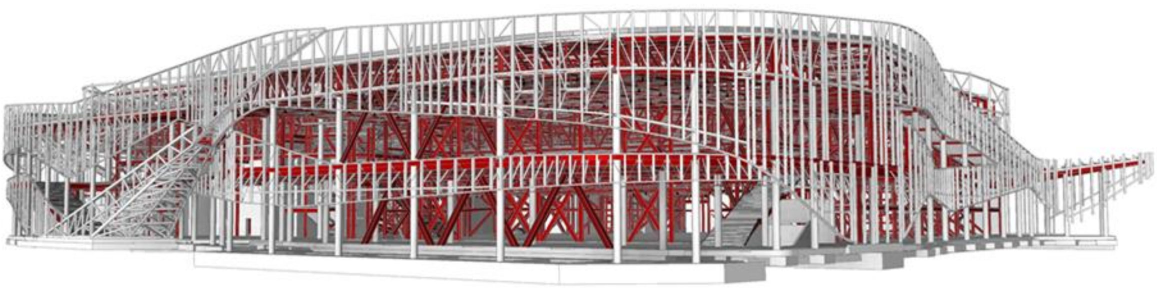

Figure 6: Façade complexity

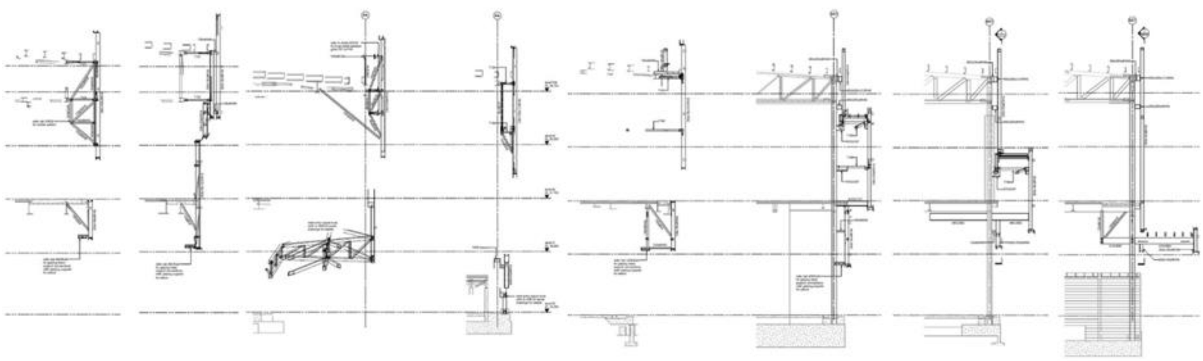

Figure 7: Illustration of variation in façade form

Adding to the complexity of the facetted, layered façade was the traversing of façade ribbons over several structural floor levels. Typical prefabricated façade systems have slip joints provided at floor levels to accommodate the inter-storey seismic movements. However, to realise the architectural and cultural intent of the flowing braided ribbons, creative structural solutions were developed that avoided the need for these horizontal joints.

Vertical movement joints could be hidden within the herringbone tiled façade areas, but the glazed areas posed significant challenges. While glazing at ground-floor level utilised a conventional movement head detail to accommodate in-plane movement, the steelwork supporting these glazing heads was required to cantilever up to 7m down from the first-floor level.

The upper-level glazing was more challenging again as the larger glass sizes necessitated structural steel mullions for support which in turn needed to accommodate vertical movements as well as horizontal racking under in-plane loads. An innovative detail was developed for these steel mullions (Fig. 8) using pairs of carbon steel balls in deep rectangular pockets to allow the mullions to rotate both in and out of plane whilst being rotationally fixed and allowing for the significant lengthening/shortening resulting from vertical deflections and in-plane racking.

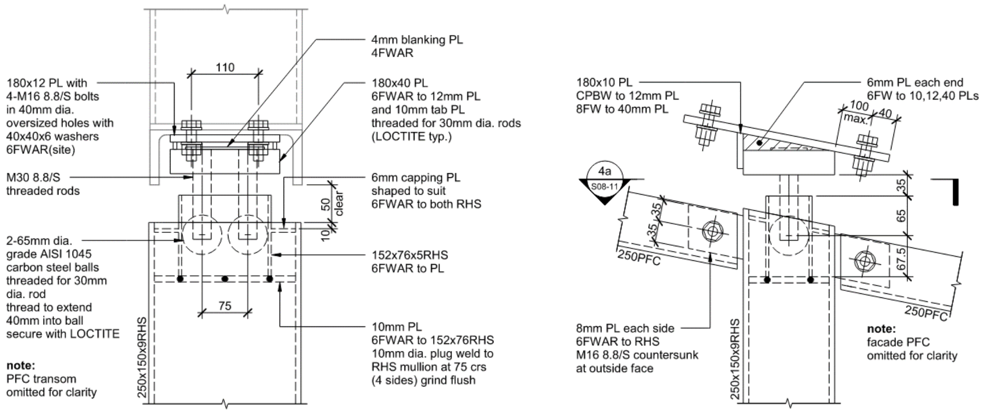

Figure 8: Upper level glazing façade mullions

Epitomising the challenges faced in providing structural support to the complex façade arrangement, a slender three-dimensional eccentric space truss (Fig. 9) cantilevers some 30m out of the ground to support the upper-level glazing above the main entry to Te Pae.

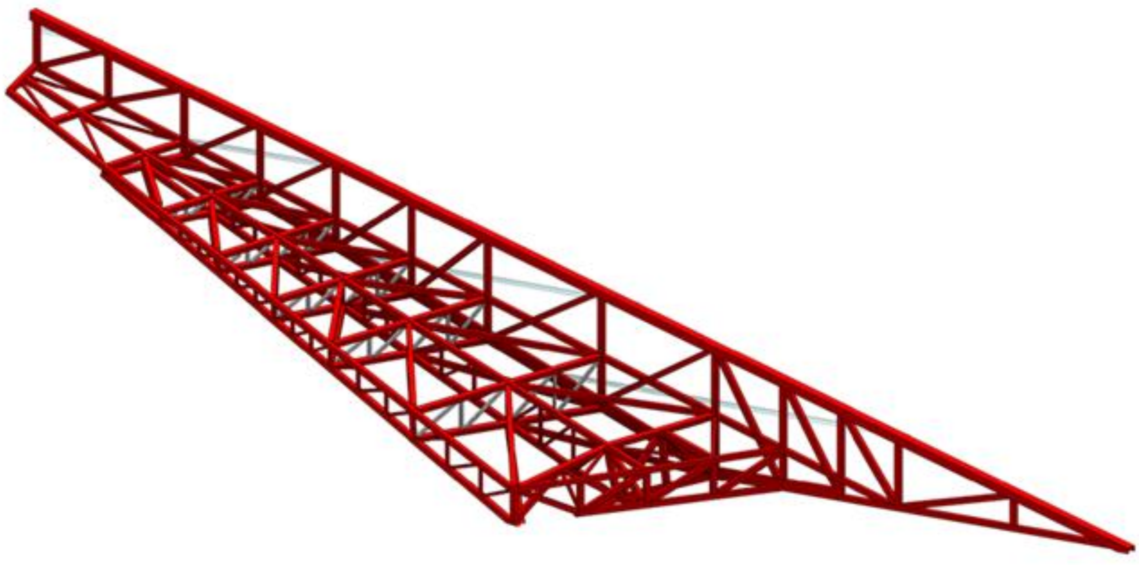

Figure 9: Space truss concealed above the main entry to Te Pae

FAÇADE AUTOMATION

Having communicated the vision to solve the technical challenges through a comprehensive sketch package in the preliminary design phase, the complex façade arrangement needed to be analysed, modelled and documented. The irregular architectural geometry required an innovative technological solution, with significant benefits found from integrating the analysis, modelling and documentation workstreams. To achieve this Revit was used in combination with Dynamo, Excel and Microstran, to automate the development of the structural model of the support system for this complex façade.

Using the facetted and multi-layered architectural skin model developed in Rhino by Woods Bagot as a base, Dynamo graphs were created to query the architectural model. Then, based on specified parameters, the placement and layout of the steel façade mullions and supporting truss/frame arrangements between primary structural support points were automated within the structural Revit model.

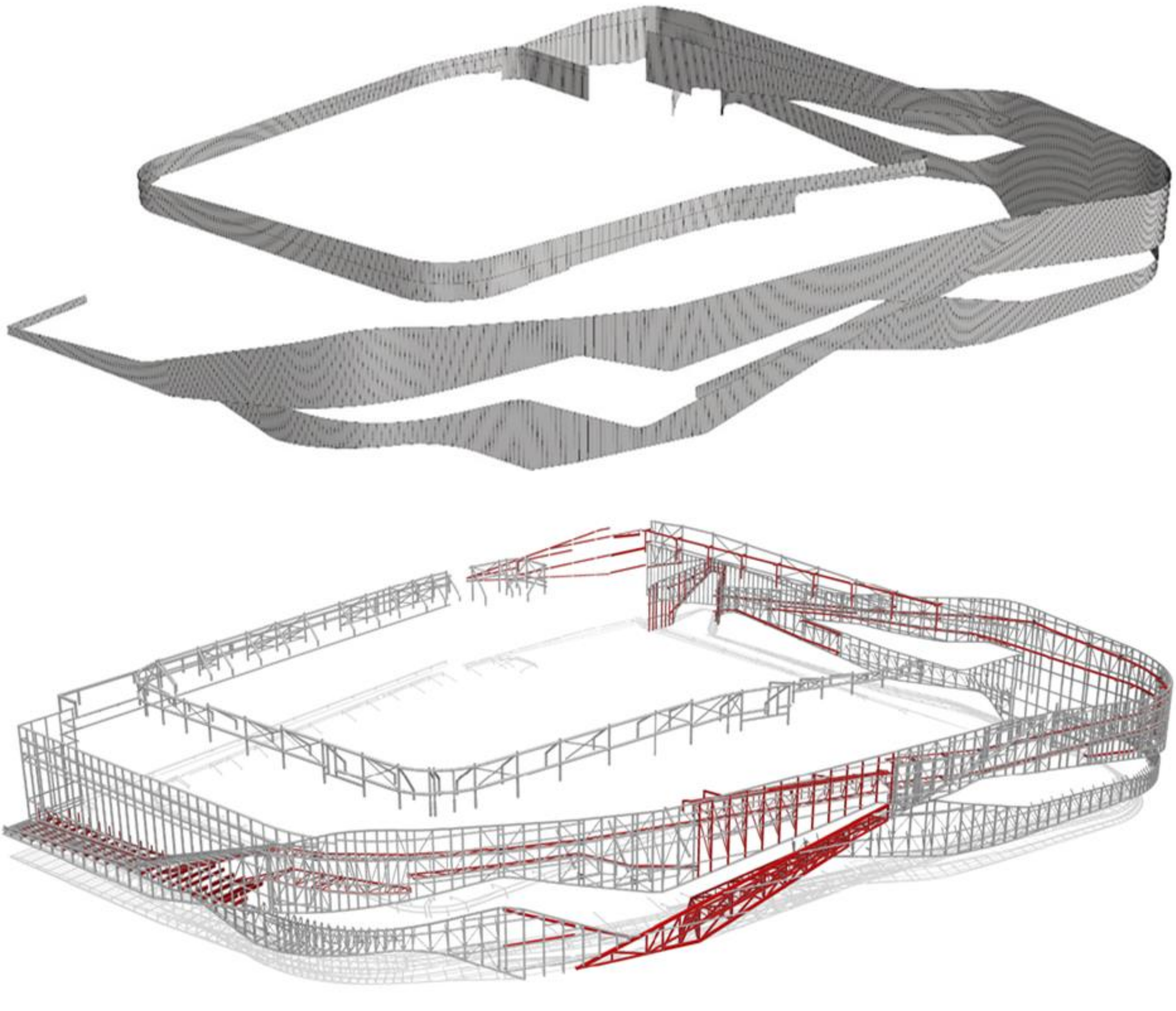

Figure 10: Façade ribbons – architectural and structural models

This process translated the basic architectural skin into the complex arrangement of structural steelwork (Figs 10, 11) with an accuracy that would end up being used by the steel fabricators as the basis for the steelwork shop drawings. Doing so helped ensure the project stayed on programme and also minimised the risk of steel fabrication having errors and causing budget blowouts for the contractor.

Figure 11: Erection of multi-layered façade ribbons

As part of this process Dynamo was used to simultaneously create the structural analysis model from the Revit model. Dynamo graphs were created to logically number and export all of the structural elements along with their properties and coordinates from Revit to the analysis software, Microstran, in conjunction with the applied wind, seismic and gravity loading. The façade sections could then be analysed in the structural design software and the member sizes updated as required. This process resulted in the creation of both the analysis model and structural drawings from the complex architectural skin.

The façade steelwork arrangement and connections were also developed with a systems-based approach in mind. This meant that—in spite of the complex geometry—a systematic steelwork arrangement was able to be documented for the majority of the façade, providing benefits in design, documentation, fabrication and construction.

Within the structural Revit model the Dynamo graphs created metadata that was stored in the façade elements. Because of the systematic approach taken to the façade design, standardised drawing sheets could be rapidly generated for the façade steelwork which inherently reflected the typical connection details required for the system. Given that over 200 structural drawings were required to describe the façade steelwork alone, this process resulted in significant time and cost savings. A graphic illustrating the façade design automation tool is presented in Figure 12.

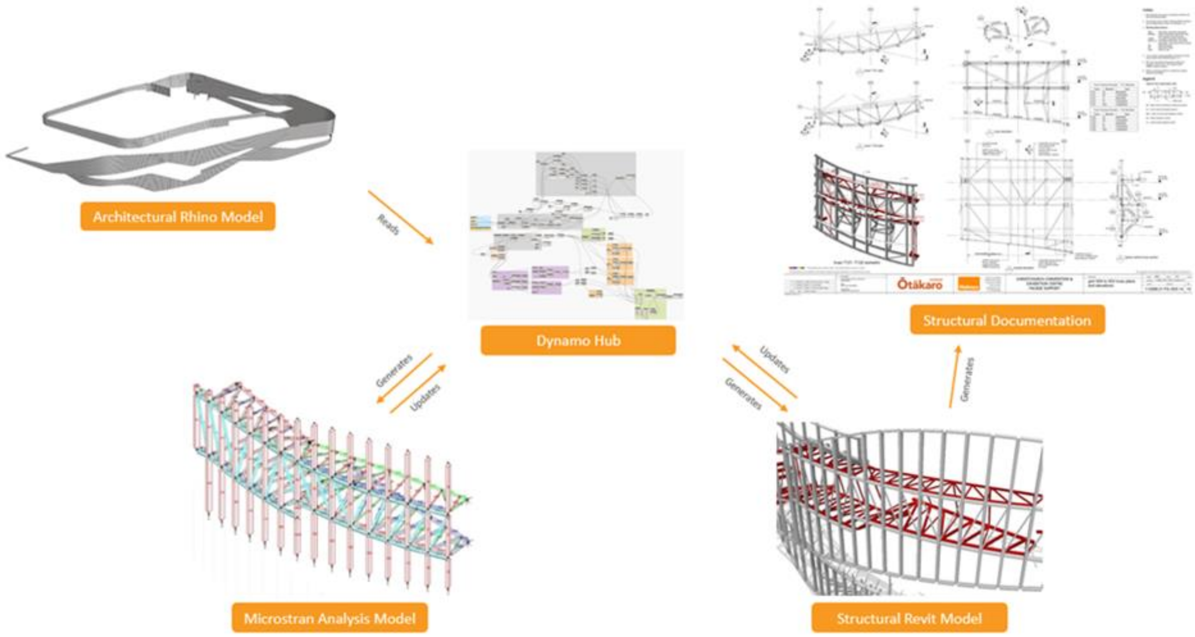

Figure 12: Façade design automation process

SUMMARY

Te Pae is a significant piece of civic architecture for Ōtautahi, with a strong narrative reflecting the culture and values of the local iwi. The complex relationship of disparate internal spaces required careful attention to loadpaths to negotiate a robust structural form. The structural solutions developed to maintain the cultural narrative have resulted in a resilient structure that is discretely hidden behind the intricate architectural finishes.

A carefully considered approach to buildability coupled with comprehensive documentation enabled the contractor to advance the structural elements ahead of the rest of the design with minimal construction issues on site. The development of software to integrate the analysis, modelling and documentation workstreams and automate the design of the façade provided significant cost and quality benefits to the project.

Te Pae is an outstanding public building, reflecting the passion and commitment of the design and construction team.