

Structure as architecture – a collaboration towards a shared vision

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ABSTRACT: Beca and Warren & Mahoney have collaborated on the recently completed Southern Terminal Extension at Wellington International airport. This paper will cover the collaborative journey that the engineer and architect took to fulfil the client's brief and how an architecturally rich scheme incorporated a number of resilient and low damage structural features.

The south and north facades of the south west pier feature full height glazing to maximise views of the apron and southern coastline beyond. To achieve the open expansive views, a novel structural system was developed that incorporated curved glulam timber frames and expressed structural steel connections that also act as replaceable fuses for the lateral load resisting system. Rather than hiding structural systems, the completed structure celebrates structure as architecture and provides a tactile and intimate experience for passengers using the busy airport. This paper will explore the architectural and structural challenges, compromises and successes of adopting a collaborative approach between the engineer and architect on a technically complex fast track project.

1 THE CLIENT'S BRIEF

Wellington International Airport is a significant piece of infrastructure spanning between Evans Bay to the North and the rugged South Coast. Millions of visitors experience their first and last moments of the Capital City here.

Beca and Warren and Mahoney were appointed by the client to design an extension to the Main Terminal Lounge in response to the Airport's 2030 strategic goals particularly and to accommodate future projections for increasing passenger numbers. Wellington International Airport Limited's visions and aspirations for their future and the Level of Service they provide to passengers and visitors also formed an important part of the brief. Functional briefing requirements included increased lounge area, additional passenger amenities and extended and reconfigured operational facilities as needed to support the increasing passenger numbers.

The existing Main Terminal Building lounge space is unique amongst New Zealand airports, with an elevated passenger lounge providing open and expansive view across the apron to the West. Extensive use of steel structure, glass facades and timber finishes in the original terminal design create a lounge like feel, at once connected to the operations on the apron below and yet removed, in the comfortable lounge-like atmosphere.

With the design for the Terminal South Extension, the design team sought to extend the building in a way that respected the established system of exposed structure, expansive glazing and timber finishes, but moved the airport forward, into the future.

Put simply, the brief was to extend the terminal to suit projected passenger growth, noting it would be

nice to “provide a window to the apron and south coast beyond”.

2 THE IDEA

Often a project outcome is defined by the first design team meeting. Understanding of the brief and the problem that needs to be solved together turns a collection of individuals with differing backgrounds, skills and motives, into a team. Individual’s attitude and interaction with others influences everyone and often sets the tone and eventual course of the project.

Having the right people and more importantly the right attitude is critical to the success of design led projects. The architect and the engineer rely upon the skills of the other to achieve the best outcome for the client. They need to get on with each other in order to collaborate, but they also need to challenge one another on predetermined ideas, perhaps even ask some stupid questions.

One simple question was asked of the structural engineer at the first key design team meeting, “do you think this could work?” accompanied by a simple rendered image, it was met with a moment of thought and a simple “yes”. The tone and course of the project was henceforth set. Whilst the answer was backed with many years of practical experience and a gut feel, the answer set a positive environment and a willingness to listen, adopt and create together.

The simple image was of a rhythmical series of timber crosses along the north and south facades of the widened South West Pier link. Initially conceived as ‘X’ forms, connected at two thirds high on the six metre facade, the design team’s decision to promote timber structural elements led to separation of the elements, and the insertion of a curve at the connection point. This also addressed glulam manufacturing constraints.

Airports function best with open and clear views through queue zones and beyond to passenger routes to gates, this functional requirement prompted a parallel conversation amongst the design team to minimise column numbers between facades. Reducing internal columns also enabled greater flexibility for the client, to accommodate future needs.

The glazing system was proposed to attach to the front of the timber framing and take a similar diagonal mullion arrangement to minimise obstruction of the views of the apron and beyond.



Figure 1. Rendered image at concept design stage (Warren and Mahoney)

3 CHALLENGES AND OPPORTUNITIES

3.1 Transverse lateral loads

The X shape provided a readymade lateral load resisting system in the longitudinal direction of the south west pier. During the concept design stage the vision of an X-frame façade was also tested to see if it could resist both the longitudinal and transverse direction seismic lateral loads. This meant a clear span (in the order of 19m) portal frame action using the X-frame assemblies as legs of the portal and either a timber or steel rafter. With the parts and portions loading, Importance Level 3, high seismic hazard factor ($Z=0.4$) and particularly heavy ceiling structure, it became clear that the size of the frame legs would be substantial (circa 1000mm deep). The glazed façade would appear further away and depending on the angle of the observer, more of the view would be obscured.

Despite an initial desire for a clear span space, the functioning of the space dictated that a number of internal obstructions were needed such as, Flight information displays (FIDs), a demarcation between departing and arriving passengers, tensile barriers and so on. This gave us an opportunity to once again use structural elements to perform more than one function.

The seismic and wind lateral loads determined a stiff steel solution and a cantilever truss was put forward for consideration by the architect. A spine truss collects the roof rafters and is supported on three cantilever trusses. These are hidden, clad and used to mount FIDs and provide a support for the glazed wall between arrivals and departures. It was the structural engineer's time to ask "do you think this would work?" The answer was met with a positive "yes".

3.2 Let's 'float' the X-frames

The frames and roof structure sit partially over the existing level 1 concrete frame and floor. A widened south west pier extended the width of the pier with new concrete moment frames in the longitudinal direction and cantilever column action in the transverse action. The X-frames sit on a steel shelf to the side of the floor and extend up to support the roof structure.

The steel shelf was to be as thin as possible to give the impression that the façade floats over the side of the floor. Without mass and resultant stiffness of the shelf plate, the combination of loads on the plate were too great to prevent excessive bending and yielding. This particular challenge led to using the X-frame timber leg connections to stiffen up the continuous steel plate. The stiffeners were set into the thickness of the timber leg becoming inconspicuous to the casual observer, except for the bolted connections.



Figure 2. Installation of X-frames onto shelf plate

3.3 The ‘Kiss’ connection and damage control

Throughout the design process and stemming from the initial idea, it became obvious that God is indeed in the detail. Structurally, the connection at the junction of the back to back curved timber members was key. This connection was also conspicuous and care was needed to maintain a simple, clean and well-presented solution. Timber blocking and architectural finishing was envisaged to cover this connection and create a monolithic joint.

The limitations of timber and adhering to a capacity design approach presented a challenge to ensure the correct mechanisms would form under design level lateral loading. Without stepping away from the carefully selected proportions of the timber frames, the ‘Kiss’ connection (as it became known as), was designed to link the frames and provide higher strength and capacity than the timber. Hence adopting a design capacity hierarchy.

The Kiss connection presented further opportunities for controlled damage and possible replacement after moderate and large seismic events. A carefully sized steel fin plate was designed to focus the potential damage through yielding and protect the non-ductile timber frame elements. To avoid the frames separating and causing a sudden loss of support to the roof, façade and ceiling structure, thread rods are epoxied into the timber to provide strength to the timber and steel plate connection. A further four bolts were added for a total of eight rods in the assembly and feature oversized washers and nuts to provide a mechanical fixing should the steel plate fail and the epoxy bond be broken.

When the principal contractor was appointed, work began on a number of prototypes for the key connections, including the kiss. The timber and steelwork sub-contractors were brought into the team and played key roles in the collaboration of key details. A full size sample of the kiss connection was made and passed between the timber yard and the steel fabricator’s workshop.



Figure 3. X-frames under fabrication

Tolerance for the hole depth, position and diameter, the junction of the curved steel plates and curved timber frames were keenly reviewed by the architect and engineer alike. The loss of gross section at the connections was considerable with 8No. M32 bolts and associated countersinking of the washers and nuts.

On the day of inspection for the first prototype on site, the architectural team studied the prototype connections. A temporary timber blocking and ply cover had been made by the steelworker and placed over the kiss connection, however this was swiftly removed with a borrowed hammer and the steel connection revealed. The connection, subject to some minor tweaks was well received and the passing comment of not covering the steelwork up with timber blocking gained traction. A ‘less is more’ theory, presenting the joint for all to see was a testament to the efforts of both the architect and engineer and further reinforced the philosophy of structure as architecture.



Figure 4. Kiss connection and timber treatment underway

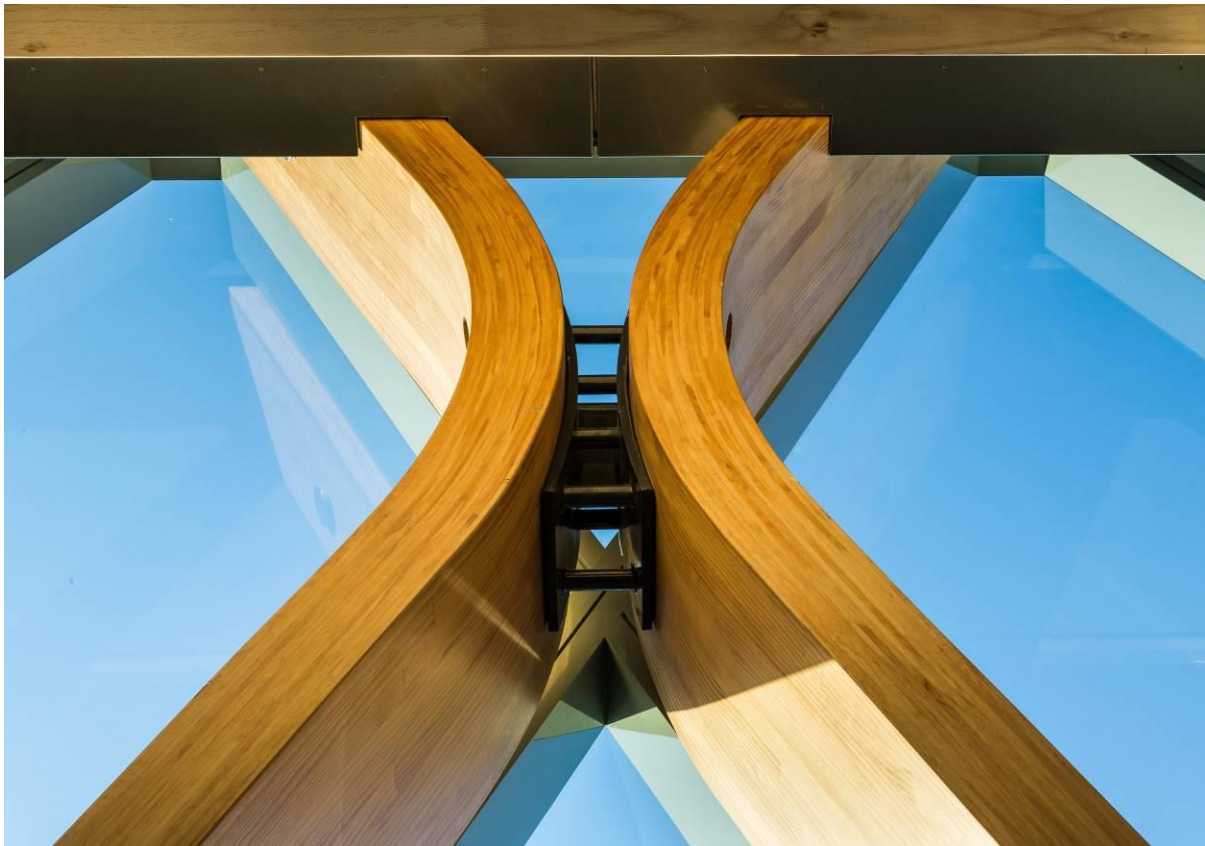


Figure 5. Finished Kiss connection (Paul McCredie Photography)

3.4 X-frame top connection

The top of the X-frames need the ability to gather the large gravity and lateral loads from roof and façade. The initial design was for a square hollow section (SHS) to run along the side of the frames and provide continuous support for the roofing and a clear load path for the longitudinal lateral loads. With incoming steel rafters and the X-frame timber continuing past and above the SHS, there were many clashes.

From the keenness of working towards a solution that complements both structure and architecture in the Kiss details, it was only logical to work on a similar solution for this connection. The architect moved the bulkhead covering up the detail and the engineer proposed a stainless steel pin connection.

Again a prototype for the pin was produced by the steel fabricator to seek acceptance by both engineer and architect. With the simplicity and elegance of the stainless steel and timber it won approval and sits atop the frames visible to those who step into the X-frame façade zone and look up.



Figure 6. Prototype Pin connection

3.5 Ceiling structure and support of non-structural elements

Using the elements of the structural form to provide multiple uses was not restricted to the X-frame facades. The ceiling of the south west pier link provided an opportunity for wayfinding to be incorporated into the building. Large parallel and full length glulam timber beams run the length of the south west pier link and flow in the direction of the jet gates. Hidden from view is a plethora of building services; mechanical ductwork, lighting, power, data, comms, fire sprinklers, PA systems and CCTV cameras. Each component needed gravity support and lateral restraint under seismic loads.

With regular and continuous runs of 1m deep timber glulams, it became clear that these could be used to support the ceiling and the services attached. This avoided individually supporting each pipe or cable tray or duct and an upside down table form was adopted to hang the glulam beams and support the heavily serviced ceiling. With the exception of the fire sprinkler heads, it also meant that building these elements into the ceiling removed the need to separate them with gaps around the ceiling penetrations.

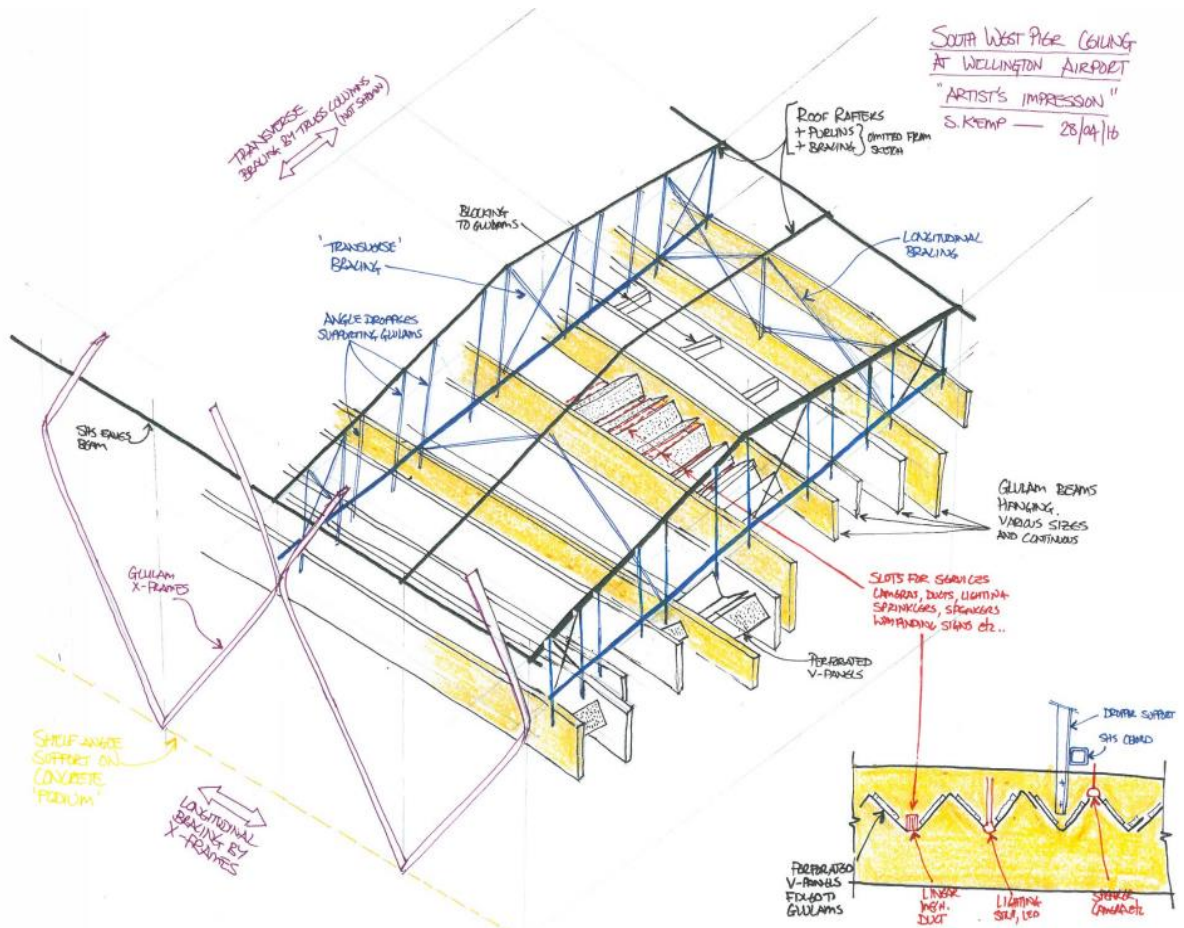


Figure 7. sketch detail of glulam ceiling structure

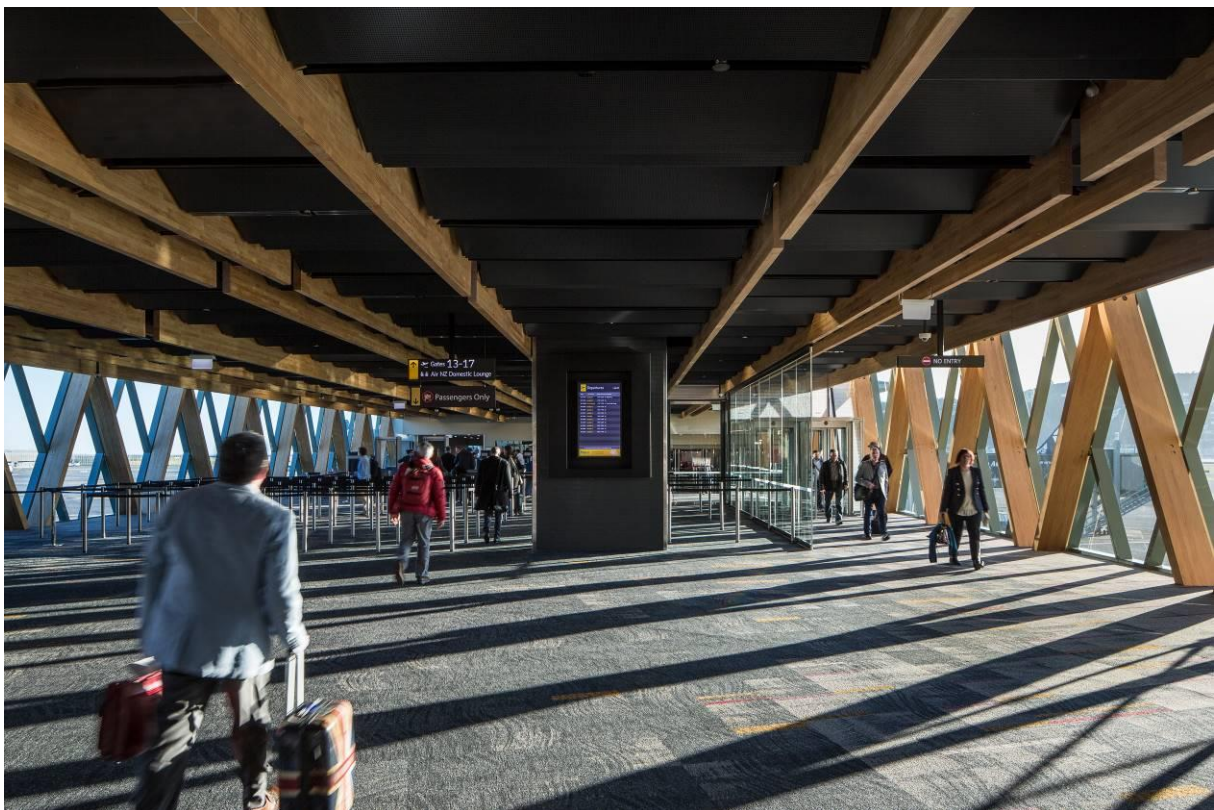


Figure 8. South West pier link in operation (Paul McCredie Photography)

4 CONCLUSIONS

All building projects start with the visions and aspirations of the client. Whilst projects range from the simple to the complex, the key to a successful design outcome is a thorough understanding of the client's needs and aspirations, coupled with a design team prepared to work together in a collaborative yet challenging professional relationship. To fully realise the potential of the design, this collaborative environment filters through main contractor and specialist subcontractors onto the workshop floor. All become embedded in the process and the outcome.

For Wellington International Airport Limited, the Terminal South Extension project provided the opportunity to not only extend the airport to meet increasing passenger numbers but also to further cement Wellington Airport's reputation as an innovative and unique destination in itself. Arriving at Wellington airport, there can be no doubt where you are.

At design stage, deep understanding of the existing building led to the use of exposed structural timber, with refined and deliberate detailing at connections. A wide span structure, utilising opportunities for solid elements where needed operationally to complete the structural system, and utilising ceiling beams as both architectural element and structural system to support services load resulted in a fully connected architectural and structural design, which supports both the functionality required and the aspirations of the client.

In summary, Wellington International Airport's Terminal South Extension Project is a celebration of collaboration - structure and architecture as one system.

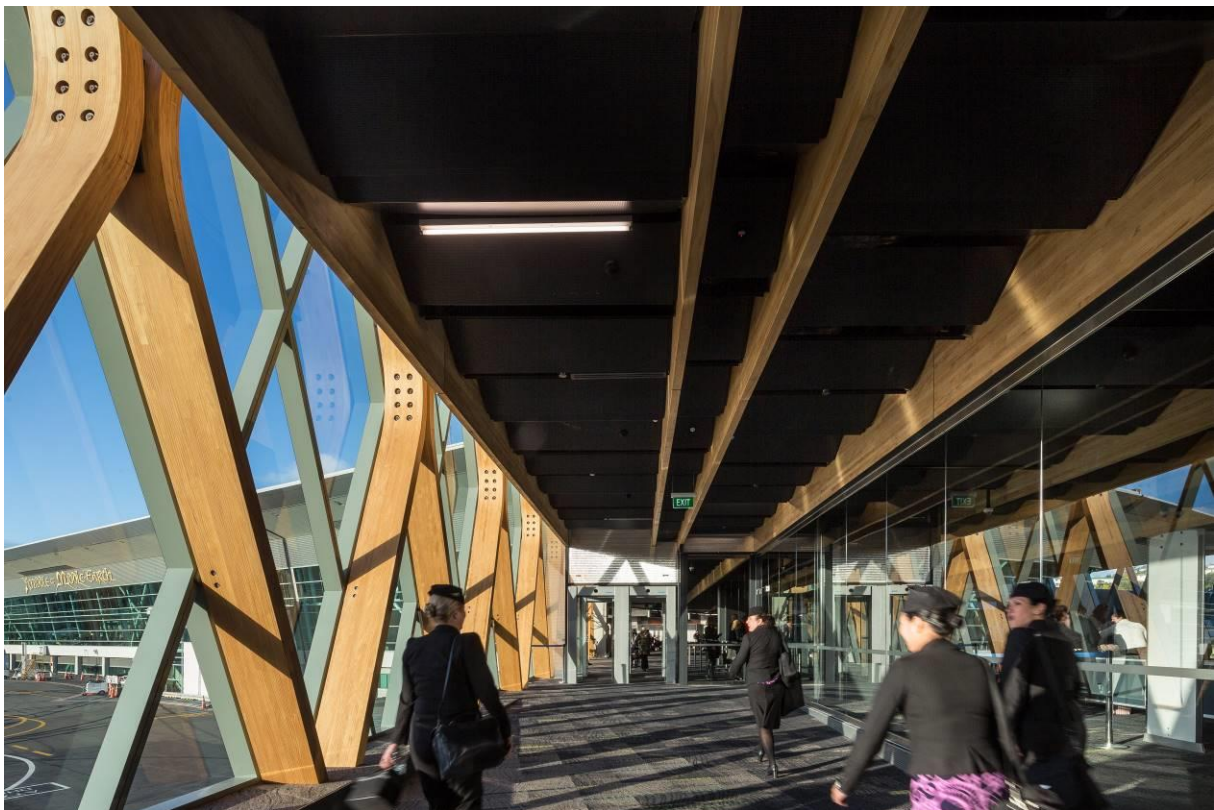


Figure 9. Completed arrivals lane and façade structure (Paul McCredie Photography)



Figure 10. X-frames to the North façade (Paul McCredie Photography)