Collaboration in Transparent Enclosures

Damian Murphy, BEng, CPENG, MIEAUST

Damian.murphy@aurecongroup.com

Technical Director, Aurecon Australia PTY LTD

Abstract

The continued endeavour for more transparent building enclosures push the Architects, Engineers, Contractors and Clients to the limit not only technically but also in their understanding of roles and responsibilities.

The modern enclosure and its endeavour for transparency is an epicentre of lightweight structural design. Maximum transparency comes from the a true collaboration of Architect, Engineer and Contractor;

As materials and methods become more sophisticated it becomes less likely that one party can provide the optimal solution. The greatest outcome is obtained via a truly collaborative effort.

While different projects demand different approaches there are common methodologies that can be employed to maximise the probability of a successful outcome.

This paper discusses these common methodologies with reference to project case studies. The relative significance of collaboration in the context of each project and delivery regimes are also discussed.

Introduction

Collaboration is a word which is probably overused and often misused. The true sense of the word is that it embodies working together to achieve a common goal. It requires that parties have a shared goal rather than an intersection of common goals and it requires that parties work together willingly.

As collaboration evolves there are a plethora of consultants, computer programs, manuals and processes that promise a collaborative experience.

Collaboration is not something that comes from a product.

In the construction industry collaboration is underlying ambition for any work to be completed successfully however more often than not the reality is merely an intersection of goals and the outcome can be a somewhat fractured result of the vision.

When it is a true collaboration the proof is always obvious, the following is a discussion about this process.

"No one can whistle a symphony. It takes a whole orchestra to play it."

- H.E. Luccock

1. Process

In façade or enclosure construction there are three distinct types of delivery methodologies which are commonly undertaken;

1. Design and Construct (co-ordination focus)
2. Performance based Specification (co-operation focus)
3. Prescriptive Design (collaboration focus)

Each method is suitable for projects to varying degrees depending upon availability of expertise and the proposed complexity of the design.

1. Design and Construct projects are suited for commonly undertaken designs such as simple windows and balustrades which are within the product providers skills typically they utilise design tables or limits to the Australian Standards. The Contractor will typically provide solutions based on their own product range. Parties involved could be limited to the Owner, and Contractor.

2. Performance based design requires that a design be described such that it suits the purpose of the client and is considered feasible to construct. The Contractor will complete the design in accordance with the outline provided and undertake the construction. Parties involved include Owner, Architect, specialist Consultants to reflect the complexity of the project.

3. Prescriptive design outlines the solution in its entirety and requires that the Contractor build the design. Parties involved include Owner, Architect, specialist Consultants and Contractor. Whilst this process could be delivered without the collaboration of the builder, it would often not result in a successful outcome without the shared goal of the builder.

Recent changes to the Building Codes, and emergence of more sophisticated design processes and techniques has increased the complexity of the average enclosure to an extent that specialist advice is needed to deliver projects to meet typical design requirements. The following are case studies for each process.

2. Prescriptive Design – Kimmel Performing arts Centre (Architect – Rafael Vinoly Architects, Structural Engineer – Dewhurst Macfarlane and Partners)

The architectural intent was clear from the outset – a performing arts facility covered by a single glass roof, creating circulation space. The levels of collaboration called for all parties to be of working towards the same goal technically but also with construction risks in mind.

The soaring roof, concourse structure and acoustic isolation of foundations included many challenging elements to the design.

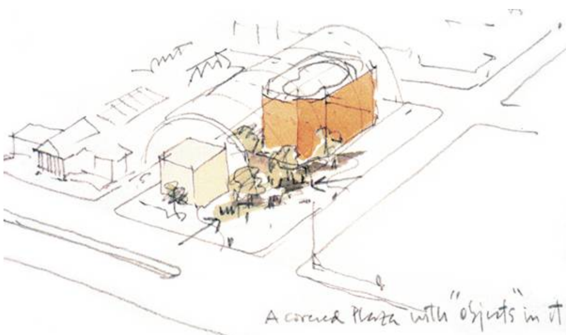

Figure 1- glass roof over theatres

The uniquely challenging element to be resolved on this project was the creation of transparent end walls. Each end wall was constrained by, width, stable support, lack of foundation, cost and constructability.

The selected solution included steel wire cables suspended from arches and weighted to provide tension. The tension cable is then clamped to allow attachment of glass panels, the wall behaves in a flexible fashion to accommodate the wind loads.

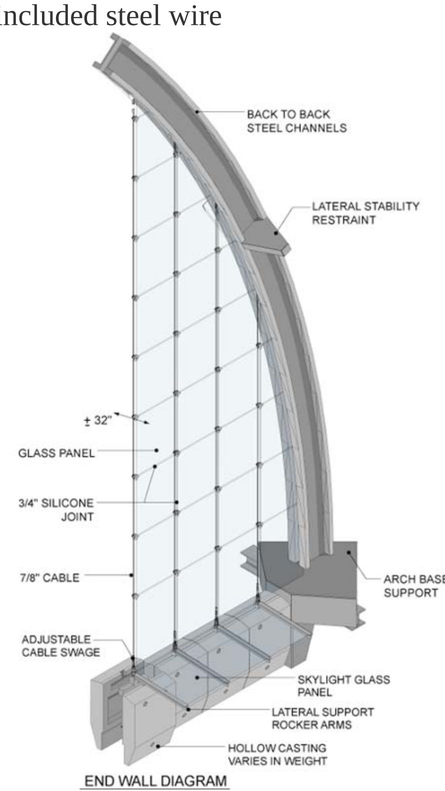

Figure 2 - End Wall solution

The weights provide a constant tension to the cable wall, the arch suspending the cables is laterally restrained by the roof, yet released in plane to isolate the wall from the roof movements. During the design wind event with no stiffening behaviour of the wall the maximum deflection anticipated is 800mm in each direction.

The design underwent significant peer review from several parties throughout the design process. The original solution survived because of its minimalistic use of material and simplistic construction. The end price of the wall construction was approximately $1200/m². The wall remains one of the most flexible and transparent enclosures in the world.

The collaborative process was not possible until all parties were comfortable with their risk profile, especially the propose contractors who were not used to working with such unusal proposals. This Prescriptive design, required the complete collaboration from architect, engineer, material suppliers, casting manufacturers, glaziers, Contractors and Client.

It was not until the Client provided a 'wrap-up' insurance which included all parties that true collaboration could commence and competitive commercial design outcomes result.

Figure 6 - Clamp Detail

Figure 3 - elevation of end wall

Figure 5 - view from below end wall

Figure 4a - view along roof to end wall

3. Performance Design – Shanghai Centre (Architect –Gensler, Structural Engineer – Thornton Tomasetti)

At 632m the Shanghai Centre will be the second tallest building in the world. It is designed as a sustainable eco-tower that sets a new benchmark not only for the region but also the world.
The design intent was developed with the Architects on the façade of what will be China's tallest building, the tender was issued as a performance based design.


Figure 7 - circulation atrium

The building Façade uses double skin façade system; the sky atrium gardens act as an environmental zone around the main form. The height of the building is divided into 9 zones. Each zone features a large glass atrium wall, 58.5m in vertical direction and the curved horizontal span is more than 60m maximum. The atrium is created from the space between the inner concrete floor plate and the outer façade. The outer facade is secured to a self-supporting steel structure.

The integrated design achieves lower energy use in operation and includes a renewables strategy. The challenges included the changing geometries of the envelope which resulted in a continually changing angular alignment and glass panel sizes.

Coordination between structure and façade components was essential in order to avoid construction issues relating to incompatible movement and tolerances between structural frame and cladding elements, especially in tall buildings where methods of construction in service movements – due to creep, column shortening, wind and seismic effects – are a significant issue.

The three different layers are indicated in the adjacent diagram. The internal curtain wall creates the controlled space, the steel frame is adapted to allow a gradual rotation of the geometry up the building. The outer wall is the environmental shield which creates the space for circulation between the various zones of the building.

The rotation of the outer cladding and its shape was developed with the intention of reducing wind pressure concentrations.

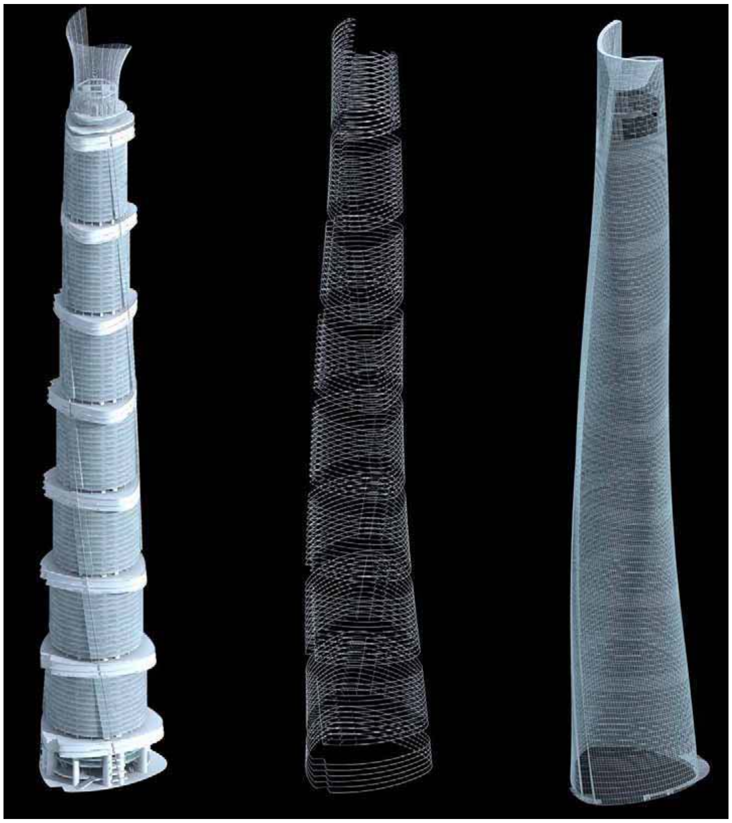

Figure 8 – three layers, internal, skeleton, skin

The external skin design required maximum transparency. To that end the aluminium mullion is stiffened by the use of a glass element. Analysis was undertaken relating to the ability for the glass to provide composite behaviour given it would be glazed into the aluminium extrusion. Due to incompatible material stiffness the mullion requires physical connection to be made at each end.

Figure 9 - glass stiffened mullions

The collaboration on the project included peer reviews between engineers, option studies with multiple architectural alternatives and delivery of a design intent package which includes enough detail to satisfy a Contractor with the right level of experience that the work is viable.

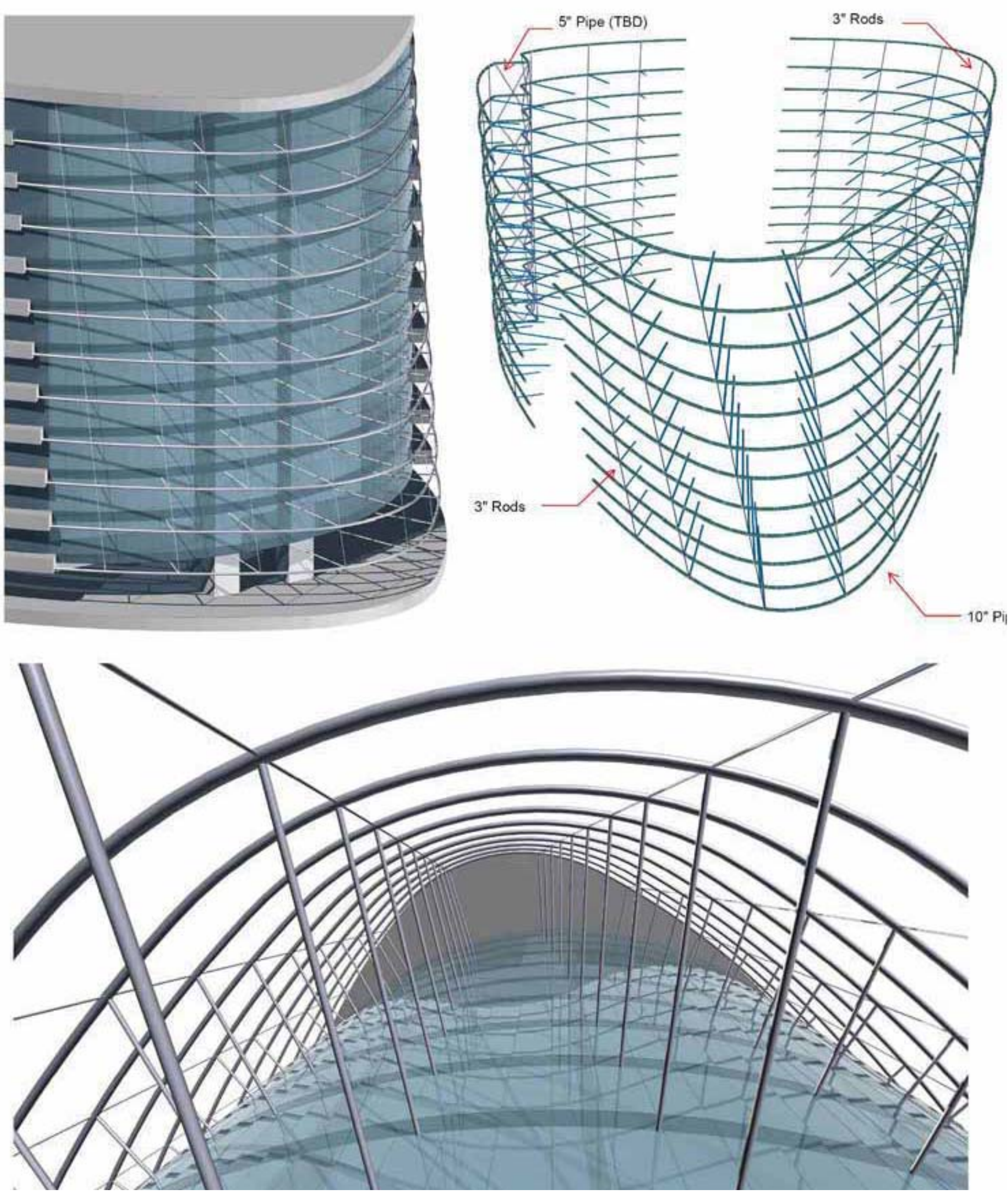

Figure 10 - views of skeletal structure

Figure 11 - Shanghai Centre

The combination of the skeletal frame and the reduce mullion sizesutilising the glass stiffener provides an Iconic Shroud appearance and a practical environmental solution to circulation and amenity for occupants.

4. Design Construct – Jagged Edge (Southern Investments Trust)

This is best described as an atypical ‘Design and Construct’ project.

The design was prepared and presented as a “Design+Construct” package that was sold to the Client. The Builders Team engaged specialist engineers and an architect to develop the concept for a highly transparent dwelling to take advantage of outlook from this striking view. Tender documentation was then provided. The design was then proposed for sale to the market as a complete delivery vehicle.

The project is a residential get-away built on the side of hill with an impressive vantage point. The main goal of the design is to maximise transparency to optimise the view.

The principle design of the structure included that the roof be suspended back to the bedrock and held down by the façade rods which also provide support to the glazing. The roof projects toward the lake and offers expansive views in each direction.

The flexible and dampened nature of the support structure provides a natural structural integrity which assists with design for seismic forces and resistance to wind forces.

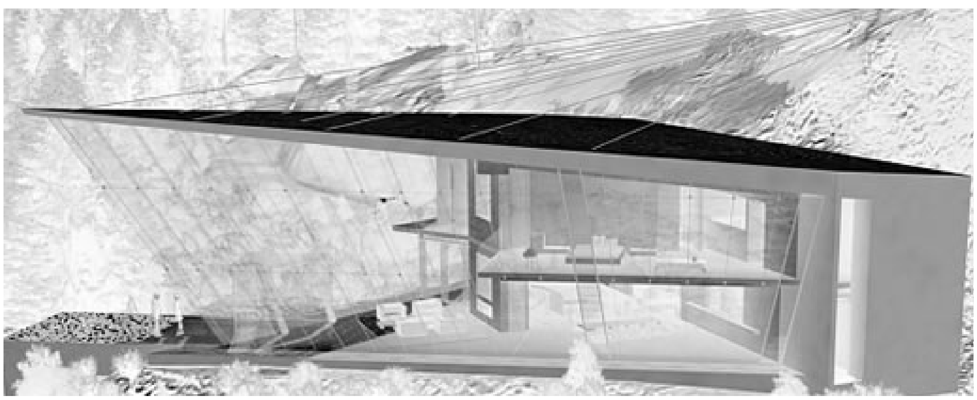

Figure 12 - concept negative

The design intent commenced from simplified sketches which the design team used to form their concepts and provide developed solutions. The first parameter discussed was the angle of the support rods to the roof. Shallow angles become very difficult to control and require significant forces for stability. Small increases in angle provide significant reduction in force with significant increases in stiffness obtained.

The Location of the supporting cables do not align with all of the façade rods, this requires that the roof structure distribute the forces throughout the cable elements.

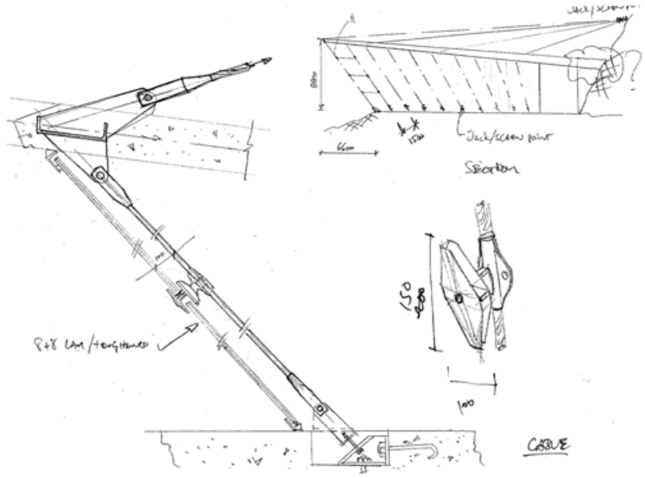

Figure 13 - concept details

Significant modelling was undertaken to determine the distribution of forces throughout concrete roof and cable system for the various stages of the construction sequence. This was required for not just the structural design but also in order to predict the starting point to the construction of the concrete slab. The pre-tensioning of the rods designed to allow for temperature variations, snow load, live load, and concrete creep, in order to maintain the rods in tension.

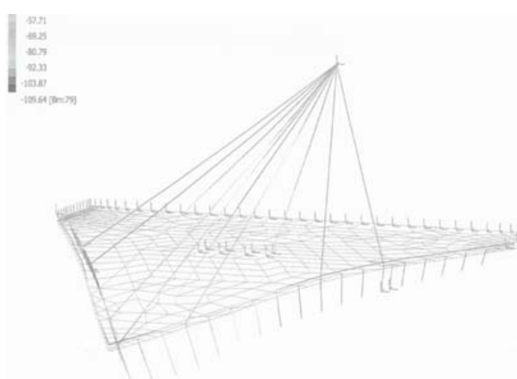

Figure 14 - roof model

The glass panels are laminated toughened panel 20.76mm thick, façade is silicone sealed in place. This particular project has not had a continuity of contractors or designers, the vision has been diluted somewhat in detail. The glass is stacked to allow the geometry to remain planar.

The detailing of the hold down anchors allows the rods to be adjusted for tension should there be any need to do so. Each anchor includes an articulated universal connection at the base to allow for changes in lateral and longitudinal angles of the wall.

This collaboration developed great design ideas. The delivery of the construction required the same level of engagement and shared goal. With the breakdown of the delivery vehicle continuity, the detailed resolution and installation were not the same as the design vision, resulting in a less than anticipated outcome.

D+C delivery should generally be undertaken on projects where the outcome is a conventional product that multiple parties could complete if necessary. For more complicated designs continuity through design and construction is required.

Figure 17 - entry door

Figure 15 - twilight

Figure 18 – external outlook

Figure 16 - internal outlook

5. Conclusions

With the advent of highly demanding structural systems and transparent facades the need for collaboration is now paramount to the successful delivery of modern projects.

Clients, Builders and Designers need to recognise the limits of their expertise and actively engage with professionals who have the relevant expertise.

The delivery method needs to reflect the projects' needs. The delivery methods need to be well understood and their limitation discussed before the process begins.

The entire team must have the same goal in mind when engaging in the collaboration.

One of the parties may have an alternative agenda. This may not become apparent until the end of the process; it will however destroy real collaboration throughout.

The team must consider each relevant objective of the project and its parties to develop a fair platform for collaboration. Whether that be through insurances, fees, risk mitigation, or other issues such as budget expectations, the collaboration needs to occur on an open and fair playing field to allow all the relevant parties to contribute.

When true collaboration occurs in this environment the results will speak for themselves.