Lightweight Glazing Structures

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INTRODUCTION

The desire of architects to produce highly transparent structures of long spans has led to the development of many interesting systems for the support of Glazing. In these structures, the structural engineer often takes a substantial role in developing the form and hence the aesthetics. This is evidenced in case studies of three recent projects presented in this paper. They all demonstrate close collaboration between architect and structural engineer to determine the form and details and with specialist subcontractor to achieve high quality execution.

VRC – FLEMINGTON GROUNDSTAND

Design Brief

The requirement for the glazing of the New VRC Grandstand at Flemington was for unobstructed vision of the racecourse. For this reason mullions were not used (not even glass fins) and consequently, the glass façade, which was in the form of cascading vertical and sloped panels (see figure 1) presented several design challenges as described below.

Figure 1 VRC Flemington, Melbourne

Structure

Each level of the grandstand consists of a vertical glass panel and sloping glazing. The sloping panels are supported by T shaped steel rafters, which are attached to the grandstand structure at one end and to the vertical glass panels at the other end. The uppermost level of the grandstand has 4m long vertical spans of glass. In the other levels, the vertical panels span 3.8m. To accommodate the relatively large structural movements between the levels of the grandstands, a pivoting connection (in the form of a boomerang shaped fitting) was used between the steel rafters and the vertical glass panels (see figure 2). The other features of the design are as follows.

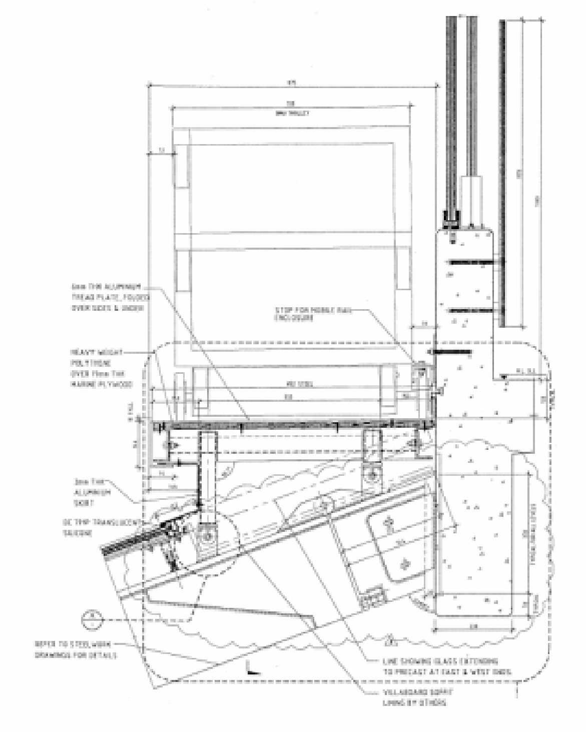

Figure 2

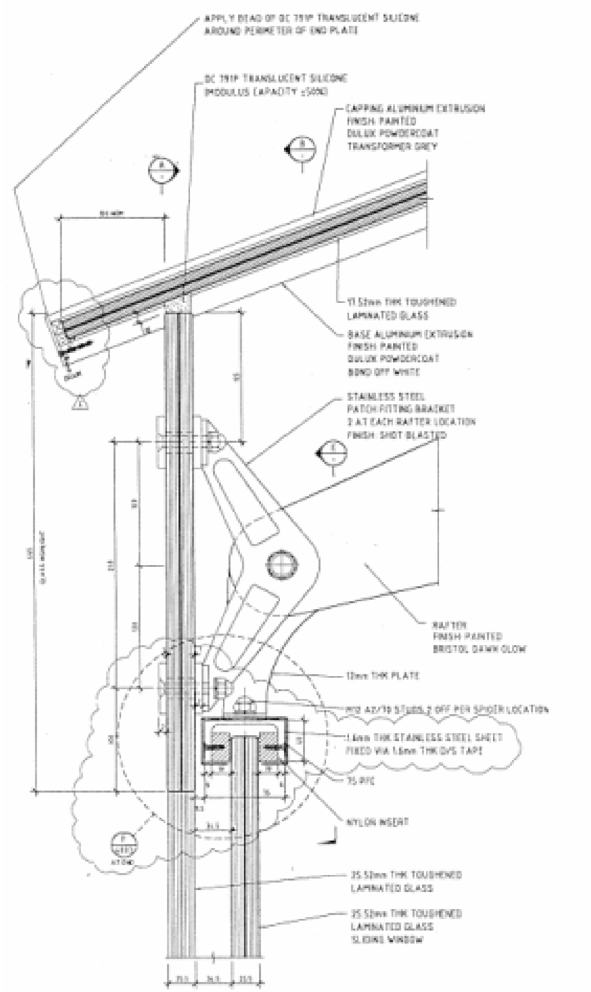

Figure 3

(a) Collapse prevention

The rafters are supported at their upper end by a pinned connection to the grandstand structure. This mechanism allows some rotation to accommodate the expected differential movements, which are of the order of 40 mm. However in the event of collapse of the vertical glazing, an adjustable stop is used (see figure 3) so that the rafters behave as cantilevers after the design downward movement has occurred, thus preventing the slopping glazing from collapsing. For added safety, the vertical panels are constructed from laminated toughened glass, which is less likely to collapse in the event of breakage of any single glass component.

(b) Performance criteria

- Strength – the glazed façade is designed to withstand a permissible stress design wind pressure of 1.05 kPa. This pressure was determined from wind tunnel testing.

- Deflection – the lateral deflection of the glazed facades is designed to be within the maximum limit of span/60, which is recommended by Australian Standard, AS1288. The differential vertical deflection is accommodated by very deep glazing channels (see figure 4)

- Durability – of the toughened laminated glass was assured by the requirements specified in Australian/New Zealand Standard, AS2208 and ASTM C 1048.

- Weatherproofing – of the façade was assured by the testing, which was carried out in accordance with AS/NZS4284.

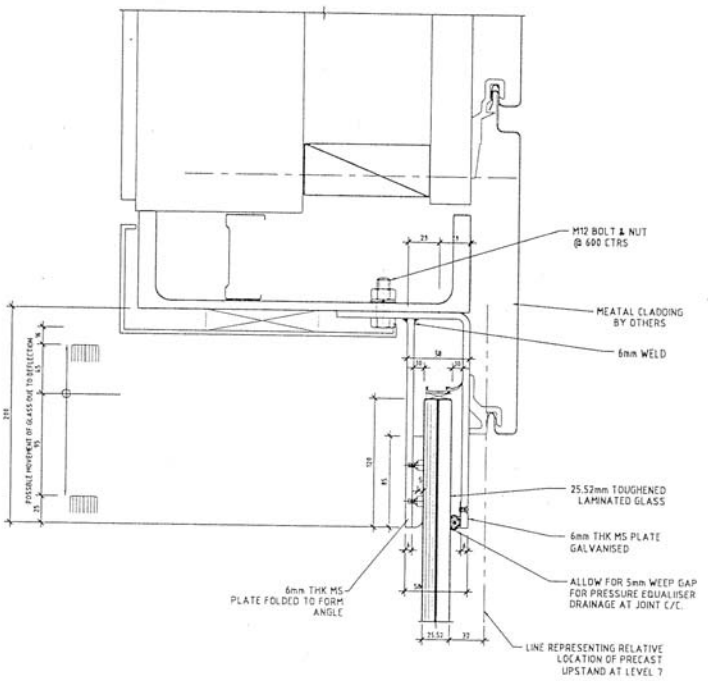

Figure 4

GLASS BOX ENTRY FOYER – 363 GEORGE STREET

363 George St is a prestige 38-storey office development in Sydney completed in 2000. The building is constructed partially above three heritage buildings, and partially above a very constrained basement.

The office tower starts at level 8, some 30 metres above George St, and there is a very large void space below this level. The office tower lobby is formed by an 11m high glass structure, which has a very unusual structural form (Figure 6).

Design Brief

The architect desired a highly rectilinear form for the enclosure. His preference was to have a glass box suspended clear of the structure with strong horizontal rather than vertical lines. The obvious solution would have been to provide a series of steel frames stiffened by opposing catenaries on the wall and by a single sagging catenary on the roof. The walls and roof of the structure could be held on spacers inside the main structural frame.

Figure 6

Structural System

Although the architect was comfortable with the catenary solution described above, the curved catenary shapes departed from his desired rectilinear form. Connell Mott MacDonald devised several alternatives to produce a rectilinear form and minimise the visual weight of the structure. The solution chosen involved a “Vierendeel cable truss”, shown in Figure 7. This form has not been used previously to our knowledge. It gains its strength and stiffness from three different actions:

- Elongation of the rod, due to its composite action with the column and the resulting varying rotations of the arms, which are connected to the column. For inward load, this tends to occur in the central rod elements, and for outward load, in the top and bottom elements as shown in Figure 8.
- Beam action of the column.
- Resistance provided by the taut rod acting as a catenary when deformed in either direction.

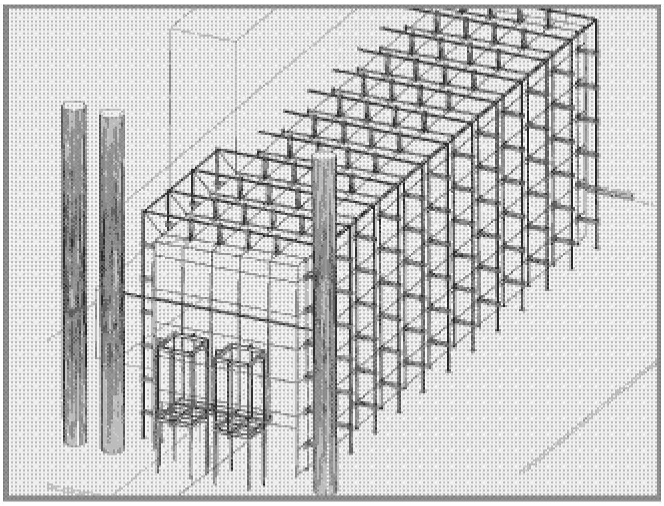

Figure 7

This form achieved the architect’s desires in a way not previously contemplated. It also gave a consistent geometry at each node, reducing the number of different components to be fabricated by the contractor.

This would not be the case with conventional catenary solutions, which have a very different geometry where the draping catenary crosses each support point.

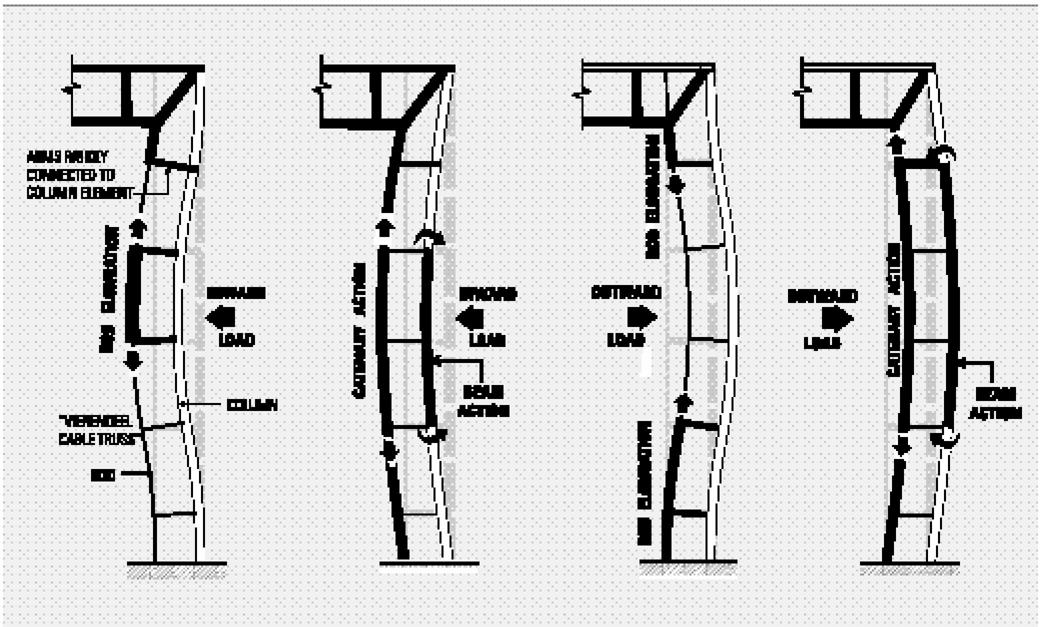

Figure 8

Integration of Sprinklers

Aside from structurally challenging solutions, the design had to be integrated with all of the services.

Sprinkler pipes were integrated within the structure, with the heads fed through a casting connected to a diagonal hollow rod in the corner of the structure. Issues such as how to hide the plumbing for the sprinklers and the cables for lighting took many months of refinement. For example, the rods through which the sprinklers are fed are so small (25mm diameter) that it would be impossible to know that a pipe runs inside them (Refer Figure 9). Electrical services are also integrated inside the structure. These details were developed in a process involving members of the design team pushing the standard use of materials to achieve what the design architect, Richard Johnson, calls a “crafted design”.

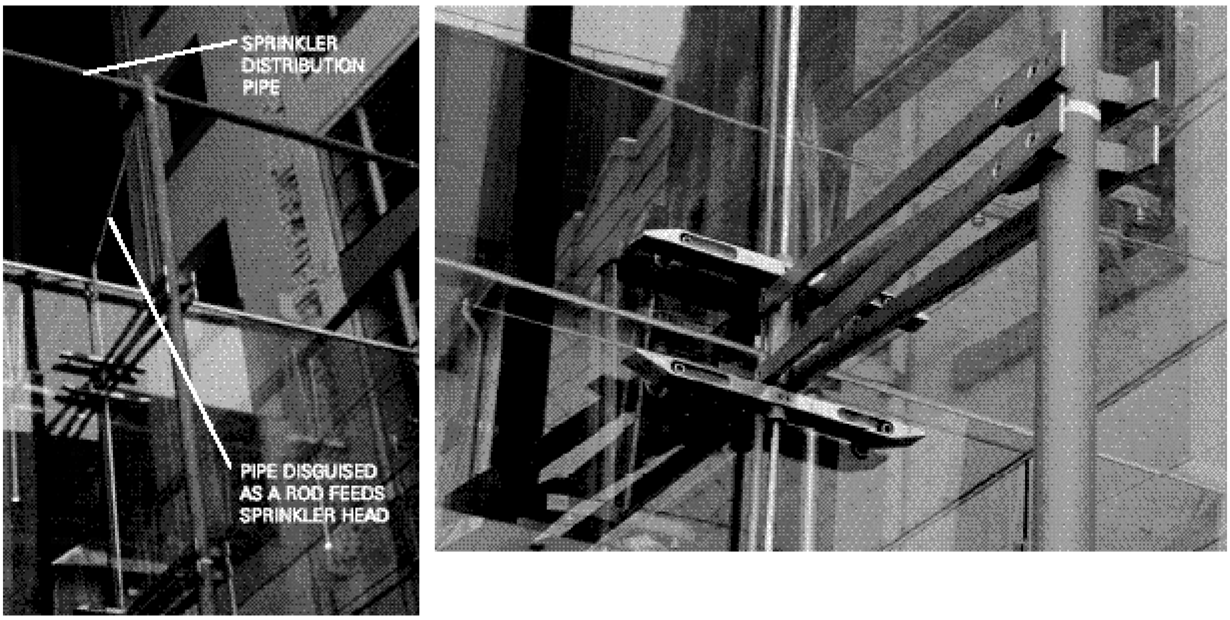

Figure 9

LINK BUILDING – HACKETT HALL PERTH

Hackett Hall is Western Australia's original State Library. In late 1996, architects Cox, Howlett and Balley were commissioned to restore the building to its original condition and also create a modern structure to link Hackett Hall to the nearby Jubilee building.

The new link building features two spectacular 20m long x 12m high cable-stiffened glass walls, as well as elegant light-weight pedestrian bridge.

Figure 10

Design

To contrast with the traditional masonry construction of the existing buildings, the link was to be designed as a light, transparent space 20 metres long and 16 metres wide, with minimal structural support for the 12 metre high glass side walls. The void between the two existing buildings required an elegant suspended pedestrian bridge at 6 metres above the ground.

Structure

The two glass walls have no support framing for the 3.15m high glazing panels other than 6 slender prestressed stainless steel cable trusses spanning floor to ceiling. The panes of glass are supported to each corner by stainless steel 'spiders' connected to the node points of the cable trusses.

The Truss chords are mirror-image arcs that cross over at the first node points above the floor and below the ceiling. They lack the diagonal bracing members of traditional trusses, and derive their stiffness primarily from the tension induced in the chords by prestressing.

Custom designed stainless steel nodes were cast, polished and machined to accept 24mm diameter grade 316 stainless steel chord rods, horizontal spacer bars and glazing spiders. Each truss was pre-assembled off site in a special jig, transported to the site in two halves, re-assembled and erected. Following careful alignment the trusses were simultaneously tensioned to predetermined levels, and the 19mm thick heat soaked toughened glass panels installed.

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The pedestrian bridge was designed to offer minimum visual disturbance to the transparency of the building, and to complement the elegant appearance of the cable stiffened glass walls.

Valued at $6M, the spectacular link building contrasts with and complements the now fully restored Hackett Hall, and showcases a century of engineering and architectural excellence.