Space 207 Glazed Entry Structures

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INTRODUCTION

The entry box and screens to Space 207 at 207 Pacific Highway, St Leonards present a good example of glazed structures that have used recent developments in tensioned rod and glass fixing design to produce an innovative and cost effective lightweight structure.

The glazed screens consist of two 7m wide and 7m high bays of straight tensioned rod supported glazing (Figures 1, 2 and 3).

An offset 3m glass cube that forms the main entry penetrates one glazed screen (Figures 4 and 5). The glass cube is unframed and is held together with local patch fittings. At each end of the cube is a pair of toughened glass sliding doors driven by a Slimdrive door operator supported off the glass box.

The second glass screen has a single leaf pivot door for disabled and after hours access. This door is supported off one of the flexible main glazing tensioned rods and required an integrated analysis to ensure that the door had sufficient clearances and the surrounding glass did not become over stressed.

Aluminium Business Resources Australia (ABRA) was the specialist glazing subcontractor and Connell Mott MacDonald provided the engineering design and certification of the glazed entry structures that were part of the main building façade contract.

The original tender design details were changed significantly by ABRA to include the straight tensioned rod support system and the unframed glass entrance cube. The design team worked well to accommodate these late changes into a main building frame that had already been constructed.

TENSIONED ROD SUPPORT SYSTEMS – BASIC CONCEPTS

Straight tensioned rods support the glazed screens. This system is similar in concept to a tensioned bowstring truss except that the single tensioned rod is active under both positive and negative wind loading whereas with a bowstring truss, each contra-curving cable resists wind load in only one direction.

The straight rod system has two major benefits over a bowstring truss. The first is that whilst the rod size may be slightly larger, there are only a half to a third the number of expensive connection nodes in a straight cable system when compared with a bowstring truss. This results in significant cost savings. The second major benefit is that as there is less structure, there is less visual impact and a more transparent glass wall can be constructed.

One disadvantage of a straight rod system when compared with a bowstring truss is that deflections under wind load will be higher and the cable reactions can also be higher. High deflections being a serviceability consideration are often acceptable for glazing above eye level (about 2m and up) but they can be problematic at doorways.

A straight rod under wind loading behaves exactly like a tightrope and has to deflect before loads can be resisted. There is always a design balance between rod tensioning and deflection under wind loading with a highly tensioned system having lower deflections than a lightly tensioned system.

The structural behaviour of a tensioned straight rod under wind loading is geometrically non-linear and requires a high degree of analysis to be carried out to accurately predict both rod reactions and deflections (Figure 6). In addition to wind and prestress loads, thermal and creep effects need to be considered as they can greatly influence the effective rod prestress. Support stiffness also needs to be carefully considered in the structural modelling as an inflexible support will result in lower deflections but high rod loads and a flexible support will result in increased deflections but a more constant rod load.

TENSIONED ROD DETAILS

The main tension rod material used was a moderate strength mild steel 36mm diameter VSL M600 rod. The benefits of this material are its cost advantage over a stainless steel rod and its ability to withstand the local bending that occurs at patch fittings and column plate connections. The rods are then clad in a seamlessly welded stainless steel tube.

To simplify the stressing process, each rod passes through the central column and both bays are stressed simultaneously. Once the stressing was carried out, the rods were fixed off at either side of the central column to effectively reduce the cable length to one bay wide for the in-service life. If the effective rod lengths were not reduced and the active cable length remained at 16m, deflections would have increased significantly under thermal expansion or any differential wind loading.

The support conditions have a major influence on the behaviour of a tensioned system. For Space 207, the glazing bays are bounded by main reinforced concrete building perimeter frame columns. These columns provided a very rigid support that helped to control wind load deflections in the rods. The final stressing load in the rods was reduced slightly from the structurally optimal load (minimise deflections under maximum stressing load) so that the already constructed columns were not overstressed.

The self weight of the glass is carried by vertical stainless steel flats. These are connected above the ceiling line to a mild steel transfer beam (Figure 7). The transfer beam is connected to the second floor slab above with vertically slotted plates. These resist wind load but prevent any vertical slab deflections from passing into the glass wall.

TENSIONED ROD END CONNECTIONS

The central concrete column was cored to allow the support rods to be passed through but the two end columns could not be similarly cored or have heavy masonry anchors installed due to the presence of cast-in down pipes and heavy perimeter reinforcement. The end connections were achieved by installing heavy steel collars around the columns. These were simply if not economically fabricated from 40mm steel plate in order to fit within the predefined column cladding zones (Figure 8). Additionally, the plates were themselves pre-tensioned by placing a steel block under the mid point of the plates. This eliminated gross connection movements under stressing and loading and helped control overall glazing deflections.

TENSIONED ROD STRESSING

Stressing of the tensioned rods was carried out very simply by using Ajax Smartbolts™ (Figure 9). These load-indicating bolts were able to provide a cost effective and accurately known rod tension. The Smartbolts™ remain in place as part of the whole assembly so rod tensions can be easily checked in the future.

SCREEN GLAZING

The screen glazing is of relatively conventional construction consisting of patch fitting supported laminated toughened glass. The patch fittings used were an off-the shelf proprietary system by AGA which were selected for cost and short delivery time.

The glazing node connection between the glass and patch fitting was via a ‘flexible’ solid connection rather than a more expensive articulated ball joint patch fitting. This type of connection relies on the much lower Young’s Modulus or E value of silicone (1-2 MPa) when compared to the E value of glass and stainless steel (70 000 MPa and 200 000 MPa respectively). The performance of the detail is also dependant upon the thickness of the silicone washer with the thickness of the washer greatly affecting the stiffness of the system. Finite element analysis and testing has verified the validity of this type of patch fitting.

One complication typical of tensioned rod systems is door penetrations, where high support deflections can play havoc with both door operation and glass side panel warping stresses. For the pivoted disabled access door the solution to the warping problem was to set the height of the door so that the deflections of the vertical steel hanger plates supporting the door head were matched to the glass side light deflections (Figure 10).

ENTRY BOX GLAZING

The significant strength and stiffness of glass was utilised within the unframed entry cube. Brittleness or fragility, the major weakness of glass as a primary structural element, was carefully controlled by using laminated glass which can have good post-breakage strength, particularly if only one glass layer within the laminate breaks.

Additionally, multiple load paths were provided so that in the unlikely event of a full breakage of any piece of glass (both layers of glass breaking), there would not be progressive collapse. The glass cube was modelled by finite element analysis and stability was checked for any possible piece of glass breaking (Figures 11 and 12).

The screen-cube interaction was carefully studied to determine the best connection details. A free-standing cube with the glass wall moving independently above was considered but the movements that needed to be accommodated were very high and the required details would have been visibly heavy. A fully connected interface was therefore chosen whereby the stainless steel hanger plates were fixed into the roof of the cube (Figure 13). The stiff glass planes of the cube could easily brace the glass screens once a suitable glass patch fitting connection was found. The added advantage of this connection was that the roof of the cube was then well supported against vertical loads and no visually heavy support beams were required to hold up the glazing and resist any person loading. The one complication with the roof connection was that the cube was supported off the ground level structure and the glass screens were supported at the second floor structure (but independent of second floor structural movements). The differential movements were analysed as imposed displacements on the cube and as the fin connections were well away from the stiff cube walls, the resulting stresses due to warping of the roof glass were small (Figure 14).

The connections of the glass faces of the cube were by means of custom fabricated local nodes so the system was not reliant upon structural silicone. The nodes generally consisted of double patch fittings into the vertical surface that provided a moment resistance and a single patch fitting into the roof glazing (Figures 15 and 16). The patch fittings were rigidly connected to the glass but pinned at the connection to the node.

The Slimdrive automatic doors within the cube were also structurally supported off the glazing with power and control being provided through a custom stainless steel jamb lining.

CONCLUSION

The glazed screens at Space 207 provided a unique entry structure that fully utilised the structural properties of glass and stressed rods. The innovative use of recently developed design concepts such as straight tensioned rods and ‘flexible’ solid patch fittings and off-the-shelf items such as the Smartbolts™ enabled a striking cost-effective lightweight structure to be delivered.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

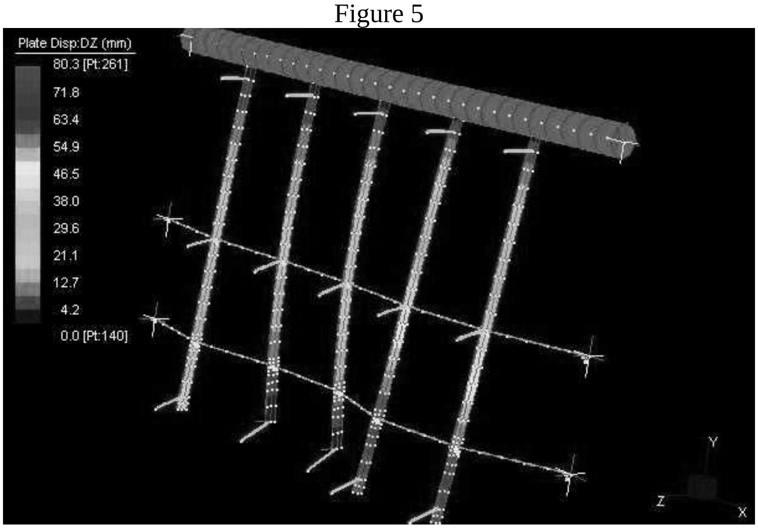

Figure 6

Figure 7

Figure 8

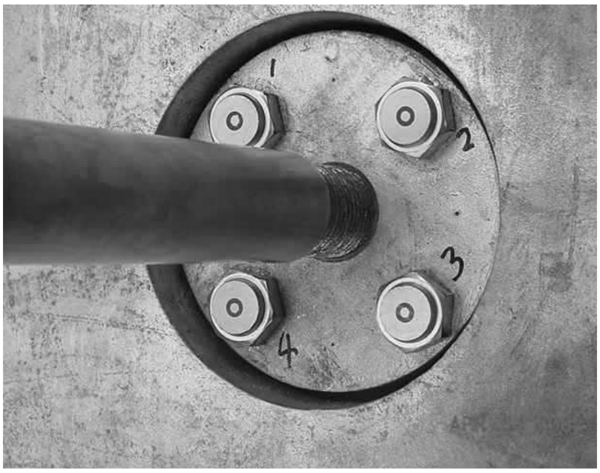

Figure 9

Figure 10

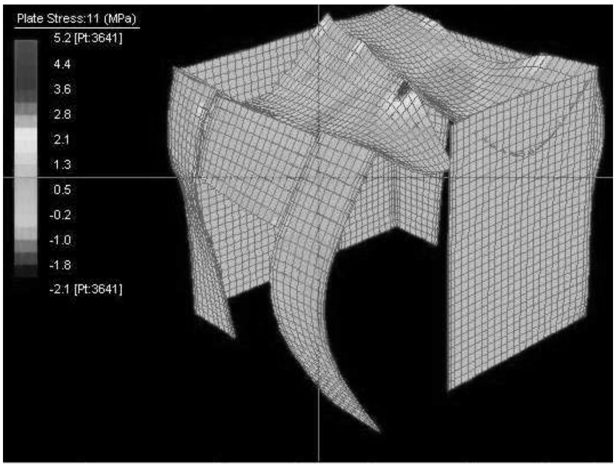

Figure 11

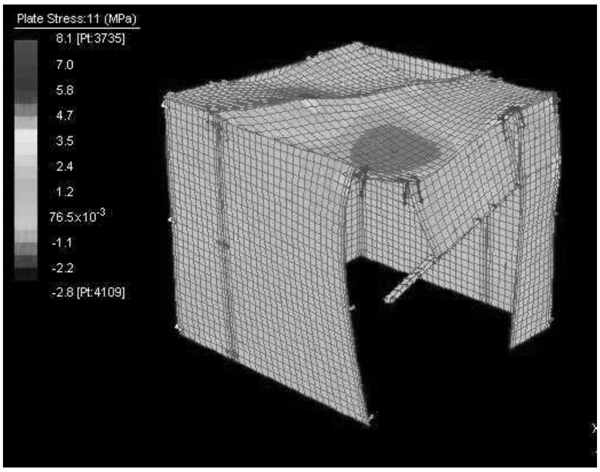

Figure 12

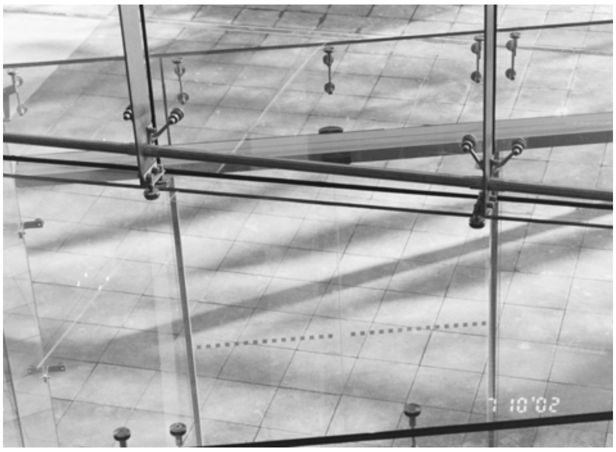

Figure 13

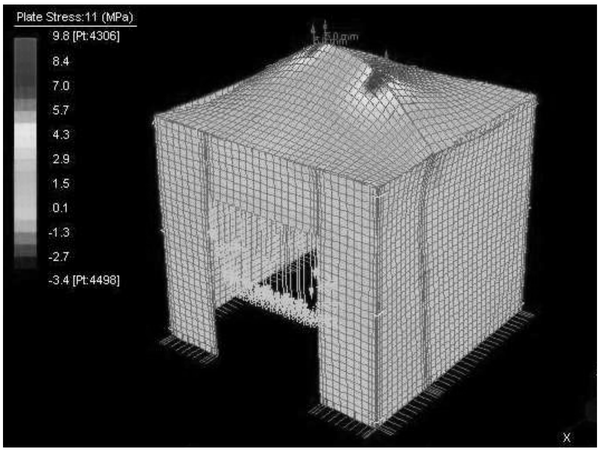

Figure 14

Figure 15

Figure 16

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