TKTS. Once in a lifetime.

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Abstract :

The TKTS Project in Times Square New York includes one of the largest publicly accessible glass structures in the World. Taking a total of nine years to progress from architectural competition to completed structure the project provides 2500 square feet of public seating comprises 25 9m long composite glass beams and incorporates a primary bearing structure constructed entirely from glass.

This paper case studies the development of the project through design engineering and construction culminating in it's public opening in October 2008.

Introduction

The redevelopment of Father Duffy Square, New York, also known as Times Square, incorporating the red glass steps and the TKTS booth was at times a fascinating, challenging and remarkable project to have been involved in. Much can be written about the original competition, the creation of public space and amenity, the innovative combinations of lighting and mechanical systems, or the planning, logistics and management aspects of building a unique structure at the crossroads of the world, but this short paper is focused on the design, development and production of the structural glass elements of this outstanding project.

Following an international design competition in 1999 and several years of delay, the project began to gather momentum in 2001 under the stewardship of Perkins Eastman Architects. The original competition winning scheme contained a set of steps which provided a south facing public arena with approximately 2500 square feet of raised public space, and a volume beneath for a replacement booth for the TKTS organization. This organization sells discounted, same-day theatre tickets and had been operating from a temporary cabin originally installed in the 1970s. In Times Square, where every inch of space seems to flash, glow or pulsate, a constant, yet understated glow was desired and the color chosen was that of the client organization; red.

From an early stage the project was conceived as an all glass structure. Like other structural glass roofs, slender glass beams were required to support the glass surface above – in this case triple ply glass treads and double ply glass riser panels. The glass beams span almost nine metres from the concrete base structure at the bottom of the steps towards a load bearing glass wall mid-way along the structure. Further glass beams span a further nine metres from this mid-wall to the north-wall of the structure. Both the mid-wall and north-wall support the load of the roof in axial compression only. In the case of the north wall these panels rise 5.1m to support the upper beams and are also inclined outwards by seven degrees. (This assembly is shown in figure 1) The structure is enclosed in full height glass side wall panels and these extend to form glass balustrades to all three raised sides. Finally, a canopy cantilevers two metres beyond the line of the north wall to provide protection to the customers queuing below. Further complexity was provided by the site geometry and the decision to align one side with 7th Avenue and one side with Broadway, thus creating an overall tapered form.

Though the project had been developing for several years as an all glass structure, after tender an additional primary focus was introduced; that of systemized prefabrication. Many of the complex all glass structures previously constructed by others had been built inside buildings, onto a steel frame, or as an intervention into an existing, rigid opening or frame. Following the tender process, a decision to manufacture the components in Europe and then simply fix them together on site influenced the design development of the details, placing a greater emphasis on the factory based pre-assembly and ultimately led to a simpler installation and reduced time on site.

Design Detailing – Color

The selection of red as the primary color could be argued as being more influential to the final appearance than the extensive use of glass for the structural frame. The red glass is used to form a 'magic carpet' of treads, riser panels and canopy, but is also used as the core element to the perimeter glass beams to help define a red prism floating above the plaza. At night the red glass prism is lit from within by red LED strip lights to produce a uniform red glow.

Figure 1

Diagram of complete structure.

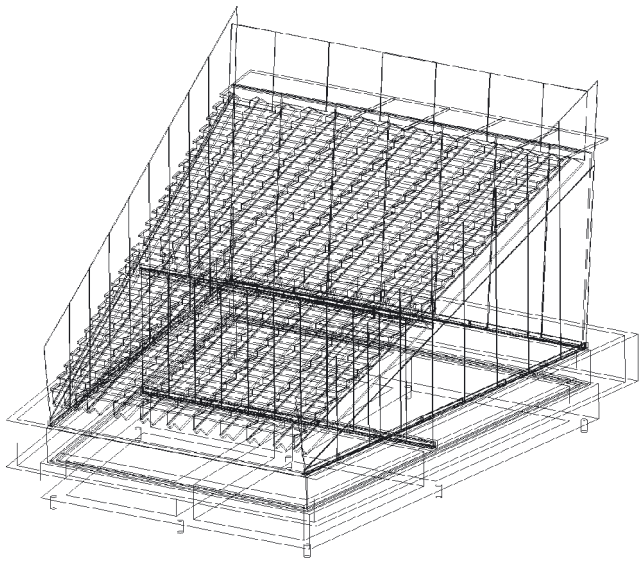


Figure 2

The complete structural chassis, prior to fixing of cladding

The selection of the correct combination of glasses, surface frit, interlayers and edge working involved the preparation of more than twenty five different samples and interlayers from three different manufacturers. The final selection combined a deep red and two regular red layers for the correct color with a single white layer for translucency and light diffusion and a custom pattern for the grey slip resistant frit.

Design Detailing

The glass elements can be subdivided into either chassis or cladding elements. The glass chassis comprises the two load bearing glass walls and the twenty five glass beams and can be seen in figure 2. The beams were detailed with simple, hook-on end connections which mated with simple, cylindrical bar supports fixed to the foundations and middle load bearing walls. (These are shown in figures 3 and 4) These end connectors enabled a quick installation of the beams on site and led to a largely 'dry' installation, with minimal grouting and tolerancing of the primary structure on site.

The only structural connection that required grouting on site was the connection of the upper beams to the taller, load bearing walls. All fourteen upper beams were placed into position on temporary supports, themselves simply hooked over the load bearing glass. Once positioned and checked, the set of 125mm diameter, bespoke rotule connections, weighing over 4 kg each, were fitted and subsequently grouted into the 4 x 12mm load bearing wall panel. (See figure 5) A tolerance on position of less than +/- 3mm was achieved at this connection.

In addition to the obvious dead and imposed load resistance provided by the glass beams and bearing walls, substantial lateral load capacity was also required to satisfy the crown loading requirements. The original design for lateral ties and props were replaced by using the glass treads as a 'stressed skin'. A change to an overlapping 'brick pattern' arrangement of the treads and the use of factory bonded shoes to the underside of the treads enabled a defined and predictable transfer of

Figure 3 :
South Wall Fixing Bracket

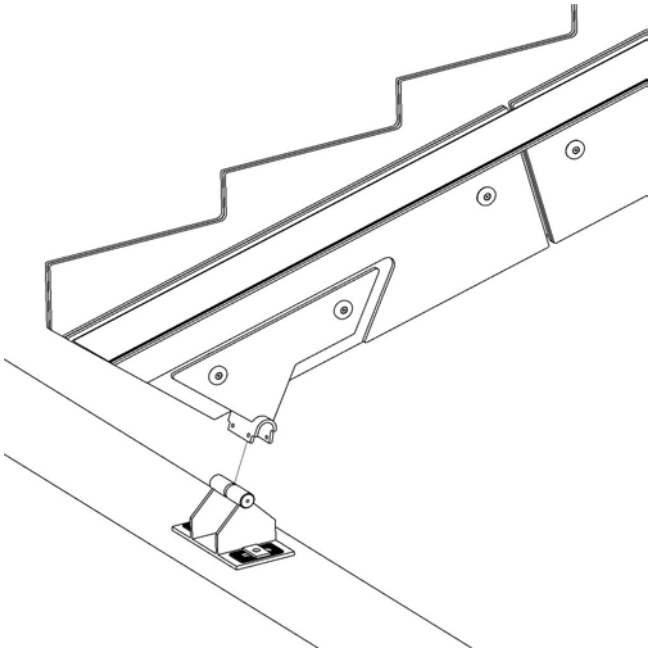


Figure 4 :
Mid Wall Fixing Bracket

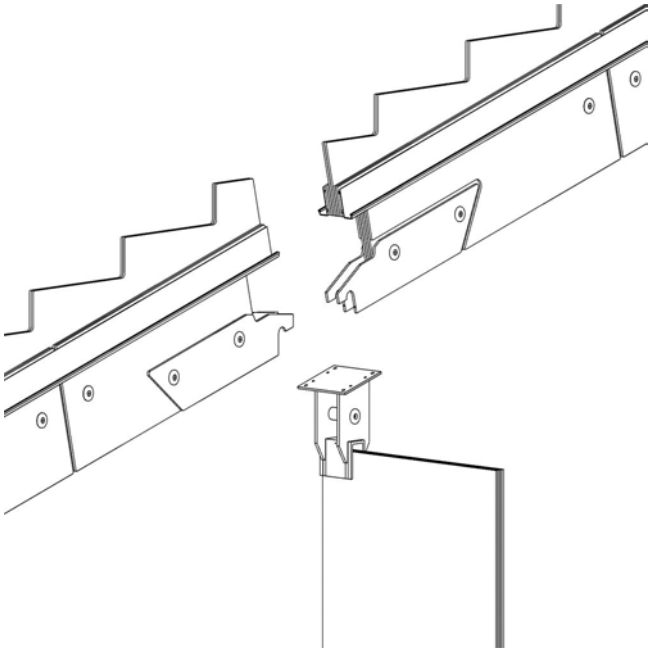
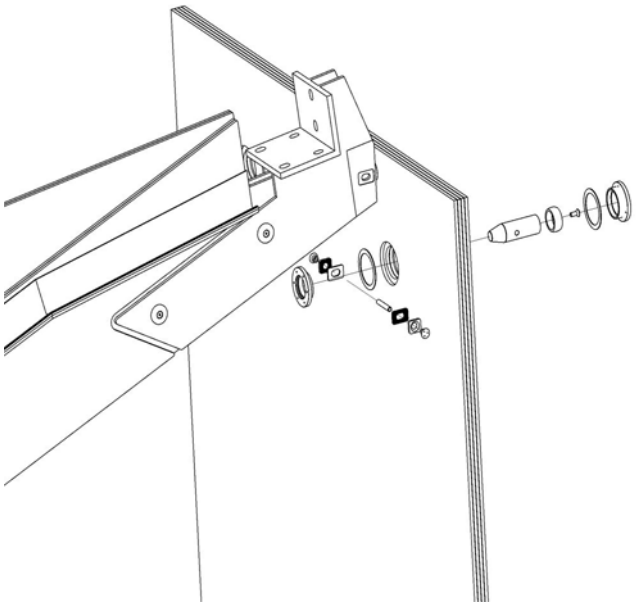


Figure 5 :
North Wall Fixing Bracket



shear loads through the treads and beams to the stiff load bearing walls and foundations.

The canopy panels are fixed to a fabricated stainless steel torsion tube to provide a uniform clamping restraint from which they cantilever almost two meters beyond the line of the North wall. Comprising a structural core of three layers of 15mm toughened glass and two layers of SGP interlayer, they are finished off with a fourth layer (12mm toughened) which sandwiches the combination of red p.v.b. interlayers required to continue the same color and which is finished with the same slip resistant frit. Though inaccessible, the canopy was designed to the same imposed load as the rest of the steps.

The glass treads and risers form a rain-screen supported by the glass beams, but not sealed to them. Rainwater is brought beneath the treads and managed by a series of interconnecting liner trays. The liner trays, formed from folded 3mm aluminum, rest on extruded aluminium gutters that were structurally bonded in the factory to the composite glass beams. They are dry sealed (gasketted) to the glass beams/gutters and not only waterproof the structure but provided a working surface during installation and permanent support to the red LED lighting.

In addition to the weather proofing and structural performance of the liner trays, they also house the radiant panels that have been integrated into the design. The entire soffit area of the glass steps, almost 2200 square feet of surface, has been fitted with radiant panels which are pumped with water at a constant 18 degrees. The radiant system is linked to a set of 5 boreholes which were sunk almost 500 feet into the ground and was designed to reduce ice build-up during the winter and to moderate the internal space during the summer.

Not forgetting that the purpose of the project was to provide the TKTS organization with a place to sell theatre tickets, a total of twelve service desks are located along the north elevation with the ticket sales being conducted through custom service trays fitted into 200 mm diameter openings in the primary load bearing glass wall panels.

Factory Assembly and Installation

The nine meter long glass beams were constructed using eight separate laminated glass panels and spliced together with shear pins and longitudinal lap joints, developing lever arms in the splice joint of approximately two meters and reducing the point loads in the bearing connections. Two laminated central core panels with serrated top profiles were spliced together using laminated outer straps, as shown in figure 6. Each beam was pre-assembled by Eckelt Glas in Austria including the stainless steel end connections and the structurally bonded

Figure 6 :
Beam Assembly showing profile core and uniform flanks

gutter support extrusions, and then all twenty five beams were delivered directly to site in forty foot containers.

The simple elegance of the design belies the extreme complexity of the structural solutions involved. For example, the variation in geometry due to the tapered site, combined with the use of red interlayers in the perimeter beams meant that of the twenty five beams, only two beam arrangements were repeated and there were eleven different beam types, employing bespoke end connections and fixings.

As noted above, the site installation process was quickened by the simple nature of the end connections. These end connections also benefited the factory pre-assembly as they provided clearly defined gauge lengths and enabled tolerances of +/- 2mm to be achieved on beam lengths of up to 9.6 meters.

The installation was carried out by a specialized team of New York glaziers and though this took longer than anticipated the concept of pre-fabrication and pre-assembly of large parts of the structure undoubtedly lead to savings in site operations and helped to control the tolerances of installation on site. For example, after careful setting of the fixing brackets, individual beam installations could be completed in less than an hour. This can be seen in figure 7. The simple structural arrangement, pre-assembly and largely 'dry' site operations have produced a structure where individual panels can be removed for access and maintenance, and replacements may be installed without large scale dismantling of structure.

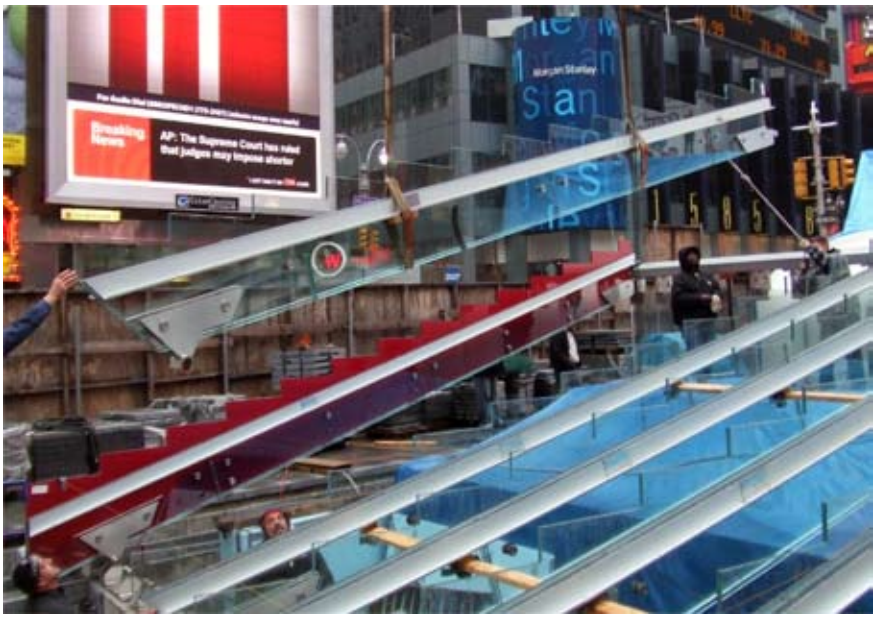


Figure 7 :
Installation of a single composite beam with pre-assembled end fixings.

Summary - Composition

- The glass elements forming the structural glass enclosure to the TKTS booth were formed of the following combinations.
- Glass Beams; 3 x 2 x 12mm laminated (pvb) toughened and heat soaked low iron glass.
- Mid Wall; 4 x 12mm laminated (pvb/ SGP) toughened and heat soaked low iron glass.
- North Wall; 4 x 12mm laminated (SGP) toughened and heat soaked low iron glass.
- Treads; 3 x 12mm laminated (pvb) heat strengthened low iron glass.
- Risers; 2 x 6mm laminated (pvb) heat strengthened low iron glass.
- Balustrade Panels; 3 x 8mm laminated (pvb) heat strengthened low iron glass.
- Canopy; 12+15+15+15mm laminated (pvb/SGP) toughened and heat soaked low iron glass.
- Side Walls; 2 x 12mm laminated (pvb) toughened and heat soaked low iron glass.
- Doors; 2 x 12mm laminated (pvb) heat strengthened low iron glass.
- Fascia; 6mm back painted (white) toughened and heat soaked low iron glass.

Conclusion

The completed project is shown in figure 8. The glass enclosure to the TKTS booth is one of the largest glass structures in the world, comprising over 1000 individual pieces of glass and providing space and capacity for over 1200 people to stand or sit on top of the structure. The design synthesizes structure and architecture, lighting and heating, public and private, into a single, integrated whole. It was achieved using design, engineering, fabrication, pre-assembly and installation expertise from both the US and Europe and now stands as a beacon in the regenerated Father Duffy Square, New York. Since it's opening in October 2008 it has been awarded a number of national and international awards for design and engineering, but it's real success can be determined by it's positive benefit on the cityscape and the number of people using the steps as a place to meet, sit and enjoy the experience of Times Square.

Figure 8 :
Completed Project