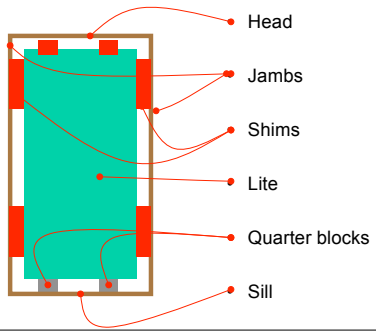
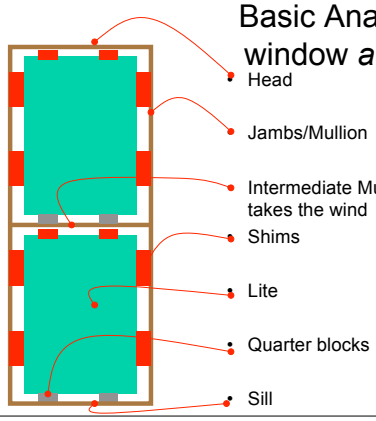
Glass Framing

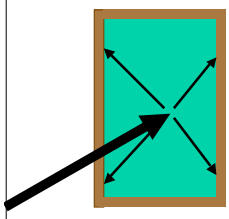
Basic Anatomy...window in a wall



Basic Anatomy… window *as* a wall

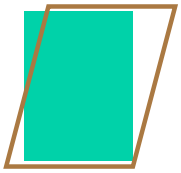


Shed the load



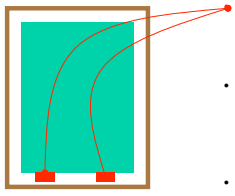
- Glass is usually placed in a frame in order to transfer wind loads from the more brittle glass to the more ductile frame.

Don't Touch!



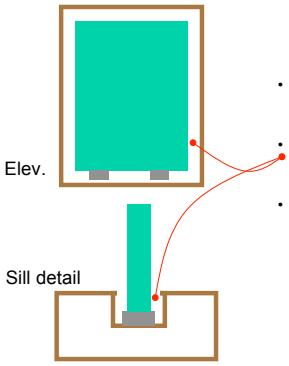
- This load transfer has to happen without the glass contacting a material which is harder than the glass.
- The window frame distorts as the building moves in the wind becoming a parallelogram….but the glass does not!
- Wood is soft, so if the glass hits the wood frame, it dents it, not hurting the glass
- But if the frame is steel, aluminum, or concrete, the glass breaks when it hits the frame.

Untouchable



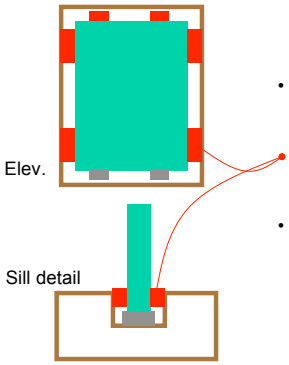
- Setting blocks are placed below the glass to separate the glass from the harder frame.
- Usually the blocks are placed at the 1/4 points along the bottom of the glass to transfer the glass weight to the frame.
- Setting blocks are made from a hard (high durometer) rubber like plastic

Deep pockets



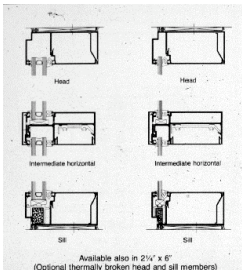
- The setting blocks are placed in glazing pockets in the frame.
- Glazing pockets surround the glass in all sections of the frame.
- They are deep enough to isolate the glass from the frame should the frame wrack into a parallelogram.

Holding the line



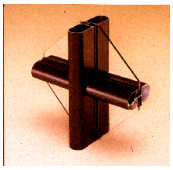
- To keep the glass from hitting the jambs and head, shims made of rubber are inserted between the frame and glass.
- This keeps the glass in the right position within the frame.

Aluminum frames



- Because it is a relatively soft metal, aluminum is a very common material used for commercial window frames
- The aluminum is pushed through a series of dies to shape in complex and intricate forms called extrusions.

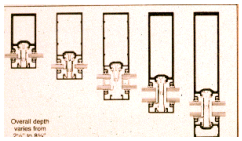
Aluminum finish



As a non-ferrous metal, aluminum does not rust like steel or iron. It does develop a chalky coating as it corrodes.

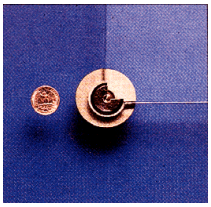
- To prevent this most aluminum frames are dipped in a electrically charged bath of acids and minerals.
- This coating process, called Anodizing gives the aluminum a durable coat.
- Anodized coatings are available in a variety of bronze / brown colors, as well as black, and a silver color

Wind



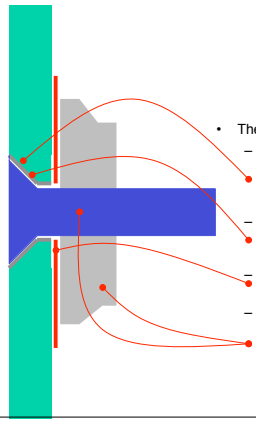
- The taller the window, the more wind load it accumulates, this means the vertical mullions at the edges of the glass panes have to be increased in depth to prevent excessive deflection.
- Most aluminum frames are manufactured in various depths to accommodate this wind load

- For the tall glass side walls at the Dulles airport Eero Saarinen placed steel trusses vertically spanning from roof to floor behind the vertical mullions to transfer the wind load from mullion to truss to structure.

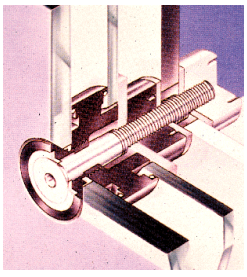


Glass Bolts

- The amazing thing about our time is that as soon as it appears there is a rule, someone figures out an exception.
- The exception to the mullion holding the glass in a clamping fashion is the *Planar* connector from Pilkington Glass ltd.
- The planar connector acts as a bolt, to connect the glass to some form of wind bracing



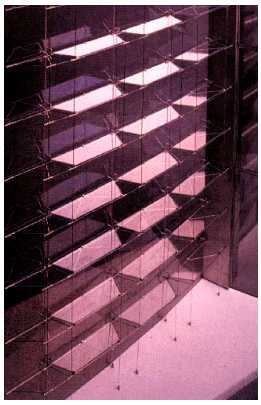
- The keys to the bolt working are:
  - The beveled hole in the glass which gives more surface area to spread out the load.
  - The beveled plastic insert which isolates the steel bolt from the glass
  - The washer, isolating nut from glass
  - The bevel headed steel bolt and nut which spreads its load to the plastic insert, without concentrating forces.



Glass bolts

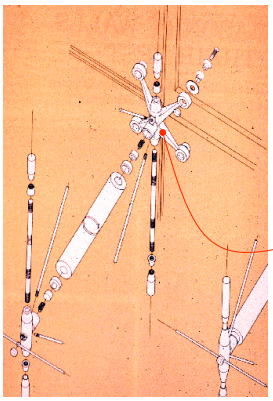
- These fasteners are available for both single and double glazing.
- They pretty much always depend on the glass being Laminated, Fully Tempered, or Heat Strengthened.
- This is because instead of dispersing the wind load along the perimeter of a pane, they concentrate the wind load at 4 points

The Planar connector for double glazing must be installed at the time of fabrication.



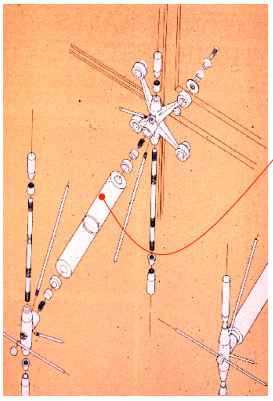
James Carpenter

- The development of the glass bolt freed designers from the mullion.
- Designer James Carpenter took that opportunity to re-think wind bracing, making trusses out of glass compression members and steel rod tension members.



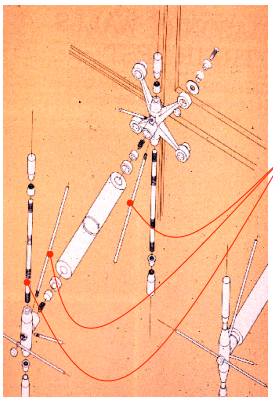
Glass trusses

- The first member of the truss is a alloy casting which receives the glass bolts from the corners of four adjacent panes. Sometimes called a spider.



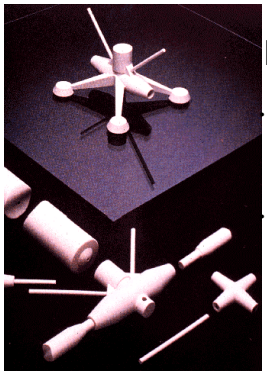
Glass trusses

- Next connected to the spider is a glass compression rod, this develops the depth for the truss essential for developing wind resistance.



Glass trusses

- Finally, a network of diagonal steel tension rods, which give the truss it's stability

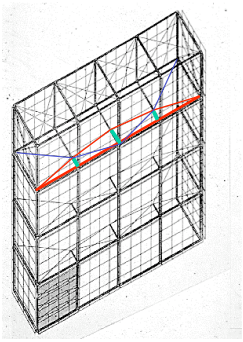


Rapid prototype

- Here the digital solid models have been output to a rapid prototyper which essentially prints the object out of plastic.
- This allows the complex three dimensional characteristics of the wall structure to be studied in mock ups.

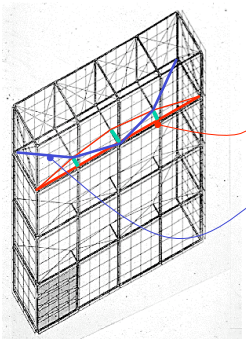
Peter Rice

- One of the leading design engineers of our time, Peter Rice, with Arup Engineering sought to realize the architects goal of glass box gardens and conference rooms on the perimeter of the Museum of Science & Industry at Parc La Villete outside of Paris.



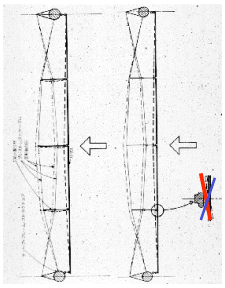
A hierarchy

- Rice & his team developed 16 stacked cubic steel tube structures to make up the glass box.
- To keep the structure from becoming too massive, each horizontal intersection of cubic elements is backed up by a truss, which takes the wind.



A push-pull truss

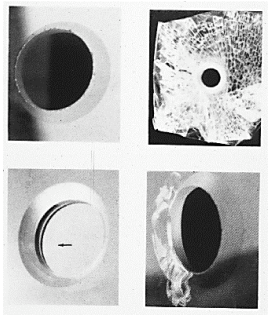
- The red truss transfers the load of the wind pushing on the wall.
- The Blue truss transfers the load of the wind pulling on the glass wall.



A more intelligent glass bolt

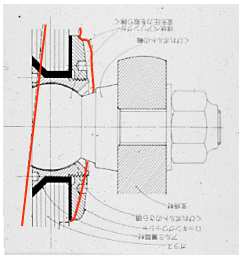
- As the glass wall is pushed in by the wind, or pulled out by the wind, each piece of glass twists slightly as the wall is deflected.
- This means the load on the glass bolt is not always axial, and torque (twisting) should be part of it's design.

Knuckles, not bolts



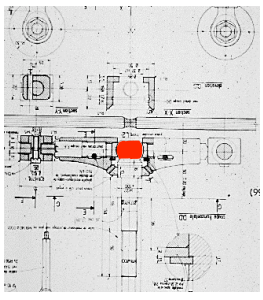
- Testing of the glass bolt showed the twisting forces are the ones that tend to fracture the glass bevel the bolt sits in.
- What was needed was a knuckle type of connector which would accept the movement without overstressing the glass.

Spherical joints



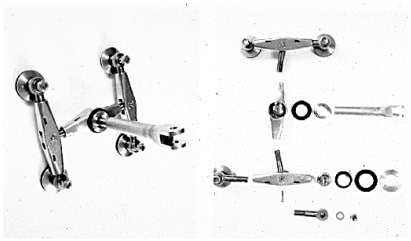
- So Rice and the team designed a custom glass bolt, one with a partial sphere in the bevel insert.
- This spherical insert allows the rotation of the connector without putting excessive forces into the glass.

Twisting spiders

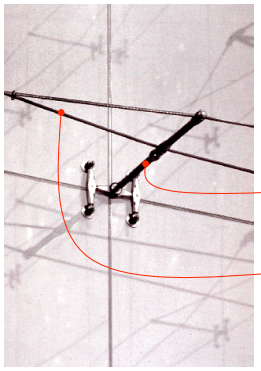


- The connection to the trusses also had to accept torsion without overstressing the glass.
- The knuckle / spherical connector attaches to a spider at the corner of the glass.
- The spider also has a spherical connector to the compression strut of the truss.

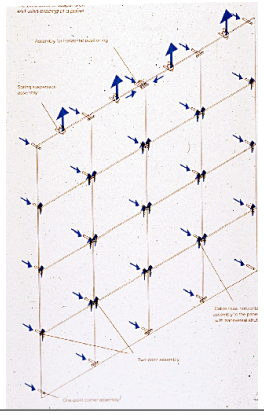
Adjustable Spiders



- Unlike the spider connector from James Carpenter, Rice's connector has many components to allow for twisting and give field adjustability for the installers.

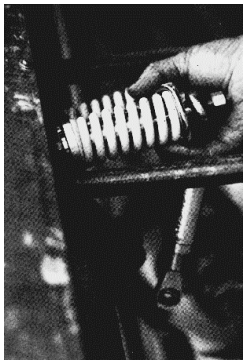


- When installed, the spider carries four corners of the glass, transferring the wind load to a compression strut, which in turn transfers the wind load to the steel cables making up the window truss, which transfers the load to the cubic elements.



Hanging Glass

- All this glass is hung from a set of springs at the top of the glass stack.
- Each spider is hanging the glass below it.
- All this laminated tempered glass is in suspension, the horizontal trusses just tie it back to transfer wind load to the tube frame of each cubic element.



Shock Springs

- The springs are pretty stiff, similar to valve springs in a car engine.
- Their primary role is to absorb the shock of a failure of any one piece of glass.
- The hung glass will redistribute the load as long as it doesn't fail from the shock of losing one pane

- This all goes together to make a series of cable and compression strut trusses which minimize the mass of the structure.
- As the architect, one can always choose between a smaller number of heavy members, or a larger number of smaller members to do a job.