Strengthening the Performance of Laminated Glass

Structural interlayers add protection against hurricane and blast forces

Provided by DuPont Glass Laminating Solutions, E.I. du Pont de Nemours and Company

Technological advances in the polymer "interlayer" in laminated glass panels—the material that bonds sheets of glass together and then is sealed tight in the fabrication process—have enhanced strength, safety and security performance, and allowed design professionals to use laminated glass in many new applications.

Advances have opened up new possibilities for professionals expanding the use of laminated glass in cutting-edge design.

Over the last several decades, the most common interlayer material has been polyvinyl butyral, or PVB, a plasticized film that is sealed under heat and pressure to form a cohesive laminated glass panel. The best-known safety application is the automotive windshield. The chief advantage is that when laminated glass made with PVB interlayer breaks, the glass fragments adhere to the interlayer, greatly reducing the risk of cutting and piercing injuries.

But PVB's limitations include reduced strength under some design conditions and restricted high-temperature structural performance, especially after glass breakage has occurred. So scientists have developed a new, advanced polymer interlayer, that increases strength in laminated glass panels to such a degree that they can be used without conventional supports and in a wide variety of new applications, including glass stairs, floors, canopies, and curtain walls.

CONTINUING EDUCATION

Use the learning objectives below to focus your study as you read **Strengthening the Performance of Laminated Glass.** To earn one AIA/CES Learning Unit, including one hour of health safety welfare credit, answer the questions on page 291, then follow the reporting instructions on page 349 or go to the Continuing Education section on *archrecord.construction.com* and follow the reporting instructions.

LEARNING OBJECTIVES

After reading this article, you should be able to:

- *Understand the development and strength performance of laminated glass*
- *Identify the advantages of advanced polymer interlayers in laminated glass*
- *Gain a perspective on the varied applications where laminated glass with advanced polymer interlayers can be used, for protection against natural and man-made disasters*

Photo credit: Barbara Stoneham, MMC International Architects

Yorkdale Mall skylight closeup

The new, advanced polymer interlayer—also referred to as a structural interlayer, because its properties impact structural performance—is sufficiently strong that the laminated glass panels can be thinner and structurally more efficient, and the glass also maintains transparency and remains clear. The construction is more resistant to moisture penetration and is compatible with most silicone sealants.

The advances have opened up new possibilities for professionals expanding the use of laminated glass in cutting-edge design, while at the same time improving safety performance in this age of monster storms and international terrorism.

A transparent evolution

Ever since a French chemist knocked over a bottle of cellulose acetate from a shelf in 1903 and noticed how the shattered fragments stuck close together, laminated glass has had many applications. It was first used in the lenses of gas masks during World War I, and just before World War II, in the automobile windshield. The interlayer used was a flexible plastic sheet made of polyvinyl butyral (PVB), which could be sandwiched between glass. The PVB adhered well to the glass, was durable in terms of its weather performance, and maintained transparency in the car windshield application. The safety benefits—no shattering on impact—secured the position of laminated glass as an industry standard.

The use of laminated glass in buildings became more common as designers added skylights and built atriums and glass-enclosed walkways with canopies. The glass in these applications needed to be strong and withstand pressure from snow or high winds, and it couldn't shatter into pieces and fall on building occupants in the event of breakage. There were also other advantages to laminated glass in terms of reducing noise, the blocking of harmful ultraviolet rays, glare reduction, and even for protection against break-ins.

A turning point

However, architects and engineers found that to increase strength, making the glass panel thicker was often the only solution. And in some cases, the glass panels also had to be supported continuously on four sides to meet the load requirements.

Meanwhile, two trends were underway. One was that design professionals wanted to use glass in new ways, as stairs, floors, large overhead constructions, and curtain walls. But at the same time, glass had to be stronger than ever, because of evolving standards related to hurricane impact resistance. Rather than make laminated glass thicker, scientists began thinking that what was needed was an improved interlayer. A new, advanced polymer interlayer, or structural interlayer, was developed that was stiffer and stronger than PVB, and laminated glass entered a still-unfolding era of new applications and expanded design performance.

According to Dr. Stephen J. Bennison, Senior Research Scientist at DuPont, "Many structural engineers involved in the design of glass structures have readily embraced the performance benefits of the new structural interlayer." But, he said, "The advances in the laminated safety glass industry are often underestimated. There is a great deal of R&D going on that is related to extending interlayer performance beyond what PVB can do."

The interlayer imparts superior strength and stiffness without increasing overall laminate thickness. This strength benefit is so significant that glass panels may not need to be supported in the conventional four-sided manner anymore, enhancing the use of glass as a structural element. Laminated glass with advanced polymer interlayers is less sensitive to moisture on the edge and appears ultra clear, especially in combination with low iron glasses.

Battering winds

One of the most vivid examples of the use of advanced polymer interlayers in laminated glass applications is meeting strict requirements for hurricane resistance.

The Wilkie D. Ferguson United States Courthouse in Miami [Figure 1], designed by Arquitectonica and the Miami office of Helmut, Obata + Kassabaum (HOK) and completed in 2005, is a leading example of the need for strength in key glass elements. The $163 million, 14-story, 577,000-square-foot facility is adjacent to six courthouse-related buildings constructed between 1910 and 1975 in a downtown area covering two blocks. The new building houses 14 courtrooms, 16 chambers for the U.S. District Court, space for the U.S. Marshals Service, the federal public defender, the U.S. attorney, and the building's owner, the General Service Administration.

The primary architectural feature is comprised of two limestone towers, said to represent the two sides to every argument, connected by a single, curved glass prism that houses the public circulation and waiting spaces. The breezeway marks the entrance to the new courthouse and the entire two-block campus, and it needed to be light and open and transparent. But it also needed to be strong.

The interior atrium prism is about 130 feet tall, starting at the seventh floor and terminating in a skylight at the top of the structure. The design team conducted wind-tunnel studies

Wilkie D. Ferguson, Jr. U.S. Courthouse, Miami, Florida.
The structural glass interlayer provides combined benefits of blast and hurricane protection. Architects: Arquitectonica and HOK, Miami

using a scaled mock-up of the building to establish wind loads and impact that were to be accommodated on each part of the exterior wall system. As a result, the building envelope uses laminated glass with a structural interlayer to provide greater strength and to protect against large storms.

The design challenge was met in the context of evolving building codes and strict standards for withstanding hurricanes in regions of the country most prone to catastrophic weather.

Tests for missile impact and pressure cycling are spelled out in the Florida Building Code, which includes the high velocity wind zone that applies to Miami Dade and Broward counties. ASTM test method E1886, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials* is referenced in both the Florida Building Code and the International Residential and Building Codes.

Laminated glass with an advanced polymer interlayer is becoming a key solution in expanding design innovation with glass.

The large missile impact test, consisting of a 9 lb. 2" x 4" fired from an air cannon at 50 feet per second, is conducted for areas of the building below 30 feet. The small missile impact test consists of a two-gram steel ball fired from an air cannon at 130 feet per second, and is conducted for elevations above 30 feet. Either missile impact test is followed by 9000 cycles of positive and negative pressure; additional tests for air, water, and structural integrity are required for product certification.

According to the 2004 Florida Building Code, all Florida counties within the 110-150 - m.p.h. wind zones as defined by American Society of Civil Engineering ASCE 7-98, have mandatory impact standards. With the adoption of the 2000 International Residential and Building Codes, other states have begun to enforce windborne debris protection requirements in windows.

Following Hurricane Wilma in October 2005, a commission of glass-industry experts surveyed the damage in Miami-Dade and Fort Lauderdale, Fla. They reported that several high-rise buildings had sustained glass-related damage from the hurricane. The buildings with blown out glass used tempered or insulating glass, rather than laminated glass installed in certified window systems. Buildings that were constructed with impact resistant glazing systems withstood Wilma's 120-mile-per-hour winds.

Facing the terror threat

Hurricane resistance was not the only benefit to using laminated glass with enhanced polymer interlayers, at the Miami courthouse and indeed at federal facilities across the country. The other major consideration was protection against the blasts of a terrorist's bomb.

In 1998, terrorists bombed the U.S. embassies in Nairobi, Kenya, and Dar es Salaam, Tanzania. One hundred ninety-seven people were killed and over 5,000 people were injured, many from flying glass shards. To combat a growing wave of terrorist attacks and to protect U.S. embassies abroad, the U.S. State Department began an estimated $21 billion embassy construction program the following year.

The State Department recognized the advantages of the advanced polymer interlayer over PVB interlayer to provide retention and resist tearing under high pressures, impulse loading typically associated with truck bombs. The interlayer was incorporated into structural muntin windows intended for use in embassies. These new blast windows utilize steel elements behind the glazing to give the appearance of true divided lites. A characteristic of this window system is that it exhibits substantial deformation at allowable design loads and effectively absorbs the blast energy.

While PVB interlayers are effective in laminates requiring lower levels of blast resistance, the stiff, advanced polymer interlayer has the ability to increase blast mitigation capacity of laminated glass facades. This benefit is derived from its increased polymer tear energy. In addition, attachments can be integrated into the laminate during or after laminating that adhere well to the interlayer and can allow secure attachment of the laminate to the frame, maximizing the full membrane strength of the glazing element.

From security to design

The focus of the use of laminated glass with advanced polymer interlayers at courthouses and in new embassy construction is on safety and security in the context of natural and man-made disasters. But laminated glass with an advanced polymer interlayer is becoming a key solution in expanding design innovation with glass. Some of these solutions incorporate energy efficiency goals and "green" design strategies such as the greater use of daylighting.

The Shanghai Oriental Arts Center in China, completed in 2004, and designed by Paul Andreu, chief architect of Aeroports de Paris, is Shanghai's new cultural center [Figure 2]. The complex includes three halls: a 2,000-seat symphony hall, a 1,100-seat opera hall, and a 300-seat auditorium. It also features assorted public facilities, including music shops, a restaurant, and an arts library.

For the design concept, the architect wanted the building to glow at night. The design consists of large panels of perforated, galvanized steel metal encapsulated in laminated glass for the façade to create a shimmering effect. The metal featured varying sizes of holes and spacings to reduce solar heat gain and for aesthetics. Laminated safety glass was used for the façade, and the structural interlayer was chosen because it was compatible with the metal and provided all of the desired strength and security features.

Photo credit: Paul Andreu architects

Shanghai Oriental Arts Center, Shanghai, China
Metal mesh screens were laminated between structural interlayers to provide glare reduction and daylighting benefit. Architect: Aeroports de Paris, Paris

The design team cited four reasons for using the material. First, the structural integrity provides high rigidity and strength of the stiff interlayer. Second, the interlayer demonstrated no edge delamination after many years of exposure to very humid conditions. Third, the structural interlayer provided an effective ultraviolet (UV) barrier that prevents the aging and discoloration of fabrics and fibers. Lastly, laminated glass provided the optimum light transmission of any material tested.

Laminated glass can now be stronger, thinner and more transparent than scientists could have imagined only a few decades ago

The structural interlayer provides the necessary additional strength required to accommodate the dominant bending stresses in the construction. The glass construction is 12 mm heat-soaked fully-tempered glass + 1.52 mm structural interlayer + 0.5 mm perforated metal sheet + 1.52 mm structural interlayer + 15 heat-soaked fully tempered glass. The polymer flowed well during laminating, allowing it to completely fill in the holes in the metal mesh. The panel design was minimally supported and attached to one glass ply only, which allowed for a smooth outer glass skin. Most importantly, the structural properties of the interlayer allow the thinnest, strongest design of such a laminate.

According to Andreu, functionally and visually, the space links the auditoriums to the city, which are visible from the surrounding landscape.

Snowy loads

A structural interlayer was essential to bringing light into the Yorkdale Shopping Centre [Figure 3, Figure 4]. Originally built in 1964, the mall was once the largest enclosed shopping center in the world, but after 2000, it needed an upgrade. MMC International Architects Ltd. of Toronto renovated the mall with the addition of a 60-foot-high, barrel-vaulted atrium of laminated glass, running 300 feet in length, and soaring above an 180,000-square-foot portion of the mall. The architect wanted to create an uncluttered sense of being outside.

Yorkdale Mall, Toronto, Canada.
Laminated glass with advanced polymer interlayers enabled a bolted-glass system to meet snow load requirements, resulting in a thinner, lighter skylight system. Architect: MMC International Architects Ltd., Toronto

Without the structural interlayer, a heavier steel truss or membrane support system would have been required, that would have altered the design concept.

"This application required laminated glass due to the fact that the glass is an overhead application," said John Kooymans, a structural engineer at the engineering firm Halcrow Yolles, based in Toronto and London. "The code requires the glazing design incorporate a provision for preventing broken glass from falling. Laminating the glass is the preferred method when transparency is critical in the design application."

The laminated glass used in the mall contains a structural interlayer that is roughly 35 percent thinner and lighter than other laminated glass, including those made with traditional PVB. While thinner and lighter, it still perseveres through Toronto's harsh climate of freezing winter temperatures that often fall below negative 20 degrees centigrade, and continuous months of thick, heavy ice and snow.

The snow load specification was 65 lbs. per square foot. The structural interlayer demonstrated excellent edge stability, which helps the glass construction to bear heavier loads at the sides, where the barrel-vaulted roof meets the walls, and where the glass construction needs to be strongest. In addition, the structural interlayer offers better long-term edge performance. The overall glass construction is thinner, more affordable and more transparent.

A bridge of strength

The three-year, $120 million Chattanooga waterfront redevelopment project was an ambitious one [Figure 5]. The plan called for a joining together of the Hunter Museum of Art, the Tennessee Aquarium and a new spacious riverside park, creating a desirable and functional recreational area. Although the Hunter Museum is only three blocks from the Aquarium, steep steps and narrow streets had made the area inaccessible to many and daunting to most.

What was needed was clearly an elegant pedestrian bridge to link the different areas. The result was Holmberg Pedestrian Bridge, a 200-foot-long glass structure that incorporates the themes of both art and the waterside location, all 50 feet above traffic.

"We were challenged to create a bridge that complemented the existing Walnut Street Bridge—a historic steel truss walkway that led pedestrians to the river—but also one that was a sculpture on its own," said Ray Boaz, partner in the Chattanooga firm Derthick Henley & Wilkerson Architects. "Therefore, we needed to make the bridge as thin and open as possible to maximize views and that's where glass came into play." According to Boaz, the material was eagerly accepted by the client, the City of Chattanooga. The added challenge —a glass bridge—was a first for the firm and the city.

In order to determine the proper structural tolerances, the design team worked closely with interlayer specialists to effectively provide the proper support without over-designing the project. The final product supports more than 300 people and features two distinct finishes that allow pedestrians to chose their path—either a translucent one that obscures the traffic below or a transparent path that provides an experience of walking on air. The walking surface has been treated with a textured traction layer to assure that it is skid-proof and safe.

"It was a lot easier than I thought it would be," said Boaz, who used a new strength calculator (below) to determine the maximum glass stress under load, laminate deflection, effective laminate thickness and time and temperature behavior for the bridge.

Boaz advises other architects to work closely with both their structural engineer and interlayer manufacturers. "Once you understand the tolerances and characteristics, working with the glass isn't a whole lot different than working with any other material. Jump into it—it has a lot of exciting possibilities," he said.

Yorkdale Mall, Toronto, Canada
The structural interlayer promotes good edge stability, enabling the laminated glass to bear heavier loads. Architect: MMC International Architects Ltd., Toronto

Clearly, laminated glass has come a long way since that French chemist knocked over a bottle and saw the cohesive benefits of the substance that would become known as the interlayer—first PVB, and now advanced polymer interlayers that extend and enhance performance. Laminated glass can now be stronger, thinner, and more transparent than, scientists could have imagined only a few decades ago. As more design professionals investigate the uses of laminated glass with advanced polymer interlayers or structural interlayers, innovation and new applications are certain to follow. ■

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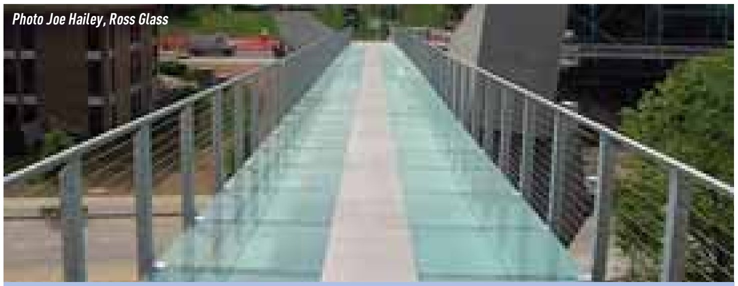
Photo Joe Hailey, Ross Glass



Holmberg Pedestrian Bridge, Chattanooga, Tennessee
The use of laminated glass with advanced polymer interlayers allowed strength and transparency in this key waterfront redevelopment project.
Architect: Derthick Henley & Wilkerson Architects, Chattanooga

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INSTRUCTIONS

Refer to the learning objectives above. Complete the questions below. Go to the self report form on page 349. Follow the reporting instructions, answer the test questions and submit the form. Or use the Continuing Education self report form on *Record's* web site—*archrecord.construction.com*—to receive one AIA/CES Learning Unit including one hour of health safety welfare credit.

QUESTIONS

1. The most common interlayer in laminated glass, polyvinyl butyral (PVB), serves as a:
a. thin sheet of film that bonds window panels together
b. plastic coating on the outside of glass
c. sealant at the edge of panes
d. polish

2. What are the benefits of PVB-based laminated glass?
a. Safety through glass retention
b. UV protection
c. Noise reduction
d. all of the above

3. The use of an advanced polymer or structural interlayer in laminated glass leads to all but which of these outcomes?
a. added strength and resistance to tearing
b. improved post-breakage performance
c. reductions in necessary glass thickness
d. four-sided supports

4. Structural interlayers are less sensitive to moisture intrusion on the edges of the laminate.
a. True
b. False

5. Existing building code requirements in the Florida Building Code require impact resistant protection in wind zones of 110-150 miles per hour.
a. True
b. False

6. Product certification of impact resistant windows may involve:
a. large missile impact test
b. small missile impact test
c. pressure cycling
d. all of the above

7. The use of laminated glass with a structured or advanced polymer interlayer is increasing due to all of which of the following?
a. changing requirements for hurricane resistance
b. new standards for security
c. new uses of glass in design
d. all of the above

8. Why is an advanced polymer interlayer effective in a skylight in a cold climate such as Toronto?
a. It may allow for thinner laminated glass
b. Good glass retention
c. Exceptional cold-temperature performance
d. all of the above

9. Structural interlayers provide an effective ultraviolet (UV) barrier that prevents the aging and discoloration of fabrics and fibers.
a. True
b. False

10. Calculating the effective thickness for laminated glass requires information including:
a. type of load
b. laminate dimensions
c. upper use temperature
d. all of the above.

Assessing strengths

Industry specialists have developed a strength calculator to evaluate laminated glass deflection for one- and two-sided simple support conditions. These types of support conditions might be used in many different applications, such as balustrades, flooring, skylights, and facades. Two different scenarios for loads can be assessed - a line load or uniform load. These scenarios can be applied separately or in combination. The information needed for this calculator includes the following:

- Support type (one- or two-sided)
- Type of load (line or uniform, applied separately or in combination)
- Load magnitude
- Load duration (estimation of how long the load would be applied)
- Laminate dimensions
- Glass type (annealed, heat strengthened, tempered)
- Glass edge finish (clean-cut, seamed, polished)
- Upper use temperature (indoor/outdoor)

When these criteria have been entered in the web-based interactive tool, the values for glass stress, deflection and effective thickness are estimated. A slide-bar at the bottom of the screen can be moved to select different glass thickness values. The calculator is based on glass design principles embodied in standards that address glass strength, including American Society of Testing and Materials Association E1300, Standard Practice for Determining Load Resistance of Glass in Buildings, and prEN 13474, the developing norm published through the European Association of Flat Glass Manufacturers.

The tool compares values between a structural interlayer and PVB interlayer for different scenarios. In some situations, lower deflection and greater glass strength can be achieved with the use of the structural interlayer due to the slightly stiffer nature of the interlayer. The strength calculator helps users consider the relative influence of common laminated glass design variables, but final specifications for laminated glass used in construction projects should always be confirmed by qualified design professionals.

Green benefits

The designers of the new global headquarters for the energy giant Endesa in Madrid used laminated glass with structural or advanced polymer interlayers for a unique glass flat roof, in an example of deriving maximum energy efficiency, sustainability and a striking design.

The 32,300 square-foot roof tops a huge glass atrium that uses a natural ventilation system. The London office of the New York-based architectural firm Kohn Pederson Fox worked with Rafael de La-Hoz Arquitectos on the project, which brought together 1,300 employees previously scattered across several Madrid locations. The client sought climate control for maximum comfort and as much natural daylight as possible.

The design was based on the Spanish tradition of an internal shaded patio or courtyard, but updated for a modern solution and today's business environment, said Cristina Garcia, senior associate partner at KPF. The atrium, which acts as transition and social interaction space and serves as a buffer between the external environment and the thermally controlled office space, had to provide daylight but also energy efficiency in an environmentally responsible manner.

"Glass was the only way to get this big, central space to work aesthetically," said Garcia. "Yet the glass could obviously only be used if it was totally safe. There could be no risk under any circumstances of panes of glass falling out onto the people in the lobby."

Glossary of Terms

Safety glass: Architectural glass, such as tempered or laminated glass, that minimizes cutting or piercing injuries in the event of breakage.

Laminated glass: Architectural glass made with two pieces of glass bonded together by an interlayer material.

Interlayer: The substance that goes between two sheets of glass to form that composite.

PVB: Polyvinyl butyral, the traditional plasticized interlayer used to bond laminated glass.

Advanced polymer or structural interlayer: Stiff, non-plasticized interlayer with 100 times the stiffness and 5 times the tear resistance of PVB.

The construction required exceptional strength and rigidity, in a trapezoidal shape rather than a domed or double-point (triangular) construction. It is believed to be the first time such a large suspended low-slope, single-pitch roof has been built entirely with glass.

A traditional PVB interlayer would have deflected under the accumulated load of such a large roof, Garcia said. The solution was to use the new advanced interlayer to provide enough strength so the suspended laminated glass could be fixed, with a series of drilled points, to a steel grid.

The roof bears stresses including maintenance workers walking on it to clean it, heavy winds and snow loads. If individual panes break, the interlayer keeps the panels intact and adhered to the rest of the structure. The interlayer retains strength even in intense summer heat.

Seismic innovations

A passageway in Seattle's new City Hall was envisioned as a "transposed strip of water" for City Council members to traverse. The idea was well-received although the common response was, "Great idea! But how will you do it?" according to Choon Choi, designer at James Carpenter Design Associates. "It took us three years to figure out how the structural glazing on the floor could act as a safe structural member instead of an infill member in this building in the seismically challenged town of Seattle."

James Carpenter's "Blue Glass Passage," a laminated glass bridge with fully exposed edges and a striking cobalt color that member use to enter the chamber, was made possible by a structural interlayer that allowed aluminum inserts to be incorporated directly into the structure's floor.

The 20-meter passageway links the chambers and offices and floats above the main lobby area of City Hall, which was designed by Bohlin, Cywinski, Jackson in association with Basetti Architects, both of Seattle. The floor of the bridge was always conceived as being in blue glass, as a visual association with Puget Sound.

"This bar of captured light, floating through the lobby, silhouettes and presents the activities and movements of the people within the building to the city passers-by below," said Carpenter. While light penetrates its surface, people or objects on the bridge are seen only as shadows by anyone standing below.

James O'Callaghan, senior associate at structural engineering firm Dewhurst Macfarlane and Partners of London and New York, said that the structural interlayer allowed laminating metallic inserts into glass panels, opening up many possibilities in terms of concealed fixtures. Weaving the interlayer into the blue glass bridge eliminated the need for cumbersome fixtures, he said.

The structure of the bridge owes its integrity entirely to the action of the glass floor and its interaction with the glass guardrail. The glass floor spans seven feet between two stainless steel rails, which in turn are supported by hangers on either side. Visibility from the leaning plate side of the bridge was maximized by the subtle spacing of the hangers at every 10 feet on center. The five-feet-wide glass panels have an intermediate support via the laminated glass guardrail acting as a beam between the hanger rods. The floor panels are interlocked to one another using the continuity of the stainless steel rails and the laminated aluminum channels set in the floor glass.

"The interrelationship between the glass panels is critical for lateral, seismic and gravitational loading cases," O'Callaghan said. "Clearly, with this level of reliance and the very public location of the structure, redundancy in the panels is a vital design feature."

Carpenter also worked with an advanced polymer or structural interlayer in creating dome ceilings over a courtroom and atrium in the new federal courthouse in Phoenix by architect Richard Meier of Richard Meier and Partners. The courtroom won the National Design Award for 1999, and Carpenter won a design excellence award from the General Services Administration as well.

The ceilings act as a lens serving both structural and light purposes. "It gathers and redeems daylight and redistributes it throughout the building," Carpenter said. The laminated glass ceiling also serves an acoustic future. Sound is distributed evenly under the dish-shaped ceiling, whereas traditional dome-shaped atria tend to carry sound away.

The lowest layer of the lens is hanging purely by its adhesion to the structural interlayer, which continues out beyond trapezoidal glass panes to form tabs for drilling. These are used as structural members to support the roof and act as buffers in the case of seismic loading, fulfilling safety requirements for overhead glazing and the sense of openness that Meier sought.

"We wanted to introduce some 'softness' into the system and a corner tab fixing detail allowed us to do just that," said Matt King of the structural engineering firm Ove Arup, part of the courthouse team. "Instead of rigidly joining the pieces of glass together, the tabs will 'give' in the event of an earthquake – they quite literally act as shock absorbers."