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All Transparent Conservation Scheme for the Menokin Ruins

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The challenge of preserving the 18th century ruin at Menokin, Virginia USA, has inspired a radical scheme to authentically conserve the surviving architecture. The ruined building is in a state of decay and Dewhurst Macfarlane & Partners have designed a glass structure to re-establish the protection of the building envelope. The plans presented are not ready for construction. Details for splicing together timber and glass beams are discussed. The conservators plans to recreate the missing elements in glass has led to the development of an all transparent structural system. The paper discusses how the properties of acrylic and glass can be combined to create composite elements that are sufficiently versatile to meet the demands of reconstructing 18th century building elements.

Keywords: Conservation, Menokin, Historic, Glass, Acrylic, Timber, Splice, Connection, Repair.

1. General

The conservation project on the Menokin estate, Virginia USA, attracts a wide range of interests. In this paper I shall discuss the plans for restoring the ruin with a protective glass structure, so that the completed building can be used as a museum for exhibiting 18th Century lifestyle, architecture, crafts and technology. The project is in the early stages of a long process. The engineering work has produced a scheme design and promotional graphics for both the Menokin house and a smaller prototype link passage. The link passage will be used to test and develop the details before they are installed into the main house. At present the design is on hold until the funds are in place for detailed design.

The scope of this paper is limited to topics that involve glass elements and their connections. In order to appreciate the rationale behind the scheme there is a brief history of the events at Menokin and a general description of the glasshouse scheme, explaining the conservation objectives that have lead to such a radical solution. The description of the Menokin scheme is in two parts. The first part discusses the all-transparent structural system and investigates the use of plastic connections. The second part looks at the wider structure, explaining the splices details and the fin connection details.

2. Background

The house was on built the Menokin estate in 1769, a reserved area of natural beauty. It has a significant place in America History, because it was once the home of Francis Lightfoot Lee, a signer of the Declaration of Independence. It was abandoned in 1935 and today it is in a state of ruin. The building envelope was severely damaged in the 1970s, when a tree struck the southeast quadrant and initiated a sequence of decline that has caused the majority of the roof to collapse and many of the walls to crumble.

The estate was taken over by the Menokin foundation in 1995 and work began to interpret the ruin. It was soon realized that a strategy was required to control the decay and assure the stability of the load-bearing walls, which would otherwise have the potential to survive indefinitely. Different studies have proposed a wide range of conflicting recommendations, included further dismantling of unstable sections of the building and the installation of large steel buttresses. Today the house lies beneath a rain shelter, which has been unable to control the forces of decay. Now a more sustainable solution is required that protects the ruin, without damaging or obscuring the architecture.

Figure 1a: Original House (1940).

Figure 1b: Ruined House (2008).

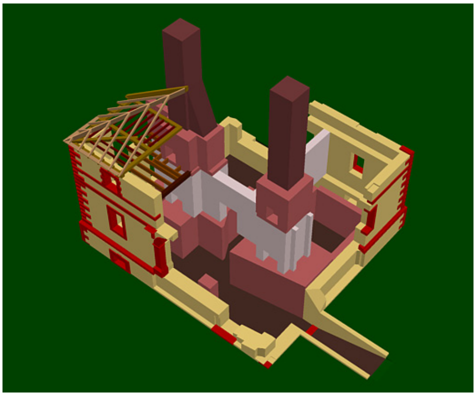

Figure 1c: Geometry Model (DMP).

Figure 1d: Graphical Realization (Future Realities).

3. The Glass House Solution

The glass house solution was conceived by conservation experts from the John Greenwalt Lee Company, who specialize in unobtrusive methods for repairing antique works of both art and architecture. Acting as caretakers for the interests of future generations they try to stabilize artifacts with the minimum of repair and only make replacements when it is entirely necessary. They have identified three important objectives that guide them in determining the most appropriate method of conservation. According to these objectives, articulated by Morgan Phillips and agreed to at the Williamsburg-Philadelphia conference in 1972, an appropriate repair will perform in a predictable way, be physically compatible with the artifact and have the potential to be reversed at a later date. The glasshouse concept provides a good framework for realizing the challenging demands of predictable, compatible and reversible repairs.

Glass is a stable and reliable conservation material that provides an elegant divide between authentic construction elements and modern engineered repairs. The historic value of a deteriorated object is more readily appreciated when it is exhibited in an immaculate setting and further decay cannot be prevented without an environmentally controlled enclosure. Therefore a glass enclosure will provide an excellent prosthetic building envelope and a sophisticated window onto the surviving relics.

The ruin is a controlled archaeological site and all fallen debris has been carefully removed, tagged and recorded during a number of systematic site excavations. Detailed records are made of significant salvages, including photographs and sketches. These artifacts will be investigated in the workshop to determine which part of the building they came from and their remaining capacity to carry load. Today the salvaged members are in storage waiting to be restored into the conserved building. In some cases the timbers will need to be reinforced and designs are being developed to make reliable composite timber repairs, reinforced with carbon fiber and epoxy resin. In many cases only part of a timber has survived intact and the missing part will have to be restored with a prosthetic glass extension.

The debris from the collapsed natural stone walls contains a large proportion of unidentifiable rubble that will not be restored. Any stone salvaged from the architectural features, such as the window dressings, the decorative brick courses and the quoins will be restored to its original place in the building and held in position by glass sub-assemblies.

The glass replacement structure will be more than a protective enclosure. It will be a clear example of the 18th century architecture, where original artifacts can be observed suspended within a transparent replica structure. All the elements will be represented in some form or another. The existing ruin will be spliced into the replacement glass floors bringing stability to the whole unit. Internal walls will be recreated to match the general arrangement and all the new glass elements will be designed to express the geometry of the original structure. As the project progresses, the salvaged elements will be integrated back into the glass structure.

4. Transparent Structural Elements

The Architectural conservators have requested an all-transparent structural system. Many polymers share the chaotic amorphous structure that allows glass to transmit light and therefore replacement elements will be designed to make the best use of the properties of glass and a suitable polymer.

4.1. Beam Arrangement

The original timber elements form simply supported beams that span between two relatively flexible connection points located on supporting elements. Glass cannot tolerate shock loads or stress concentrations, but polymers are too flexible to form a significant part of a loaded element. The bending strain peaks mid-span and therefore the spanning part of the beam will be composed of stiff laminated glass plies.

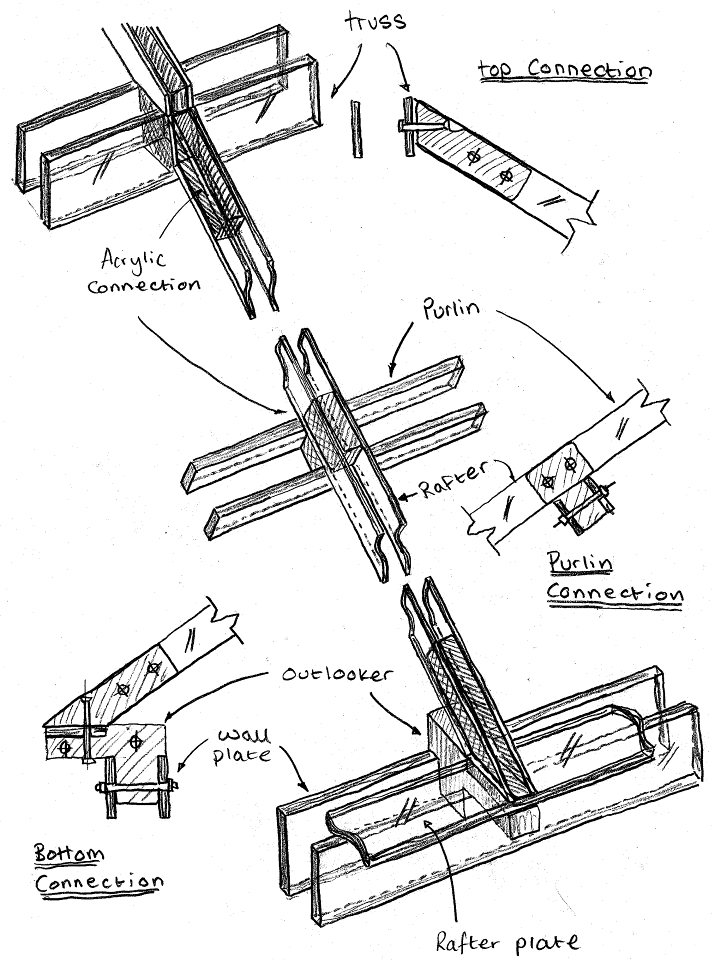

Figure 2: Typical Arrangement of a Replacement Rafter.

The safe design strength for toughened glass beams is roughly five times the strength of undamaged Menokin Timber and time has shown that the specification of original timber was sufficient to carry the applied loads. Therefore, if the bending depth of all elements is equal, then the width of the new glass element need only be one fifth of the width of the original timber. The narrow glass beams will be split into two elements, which are held a constant distance apart, so that the width of the replacement beams matches the originals. This arrangement has good lateral stability and leaves a convenient gap between the two elements that can be used for housing connections.

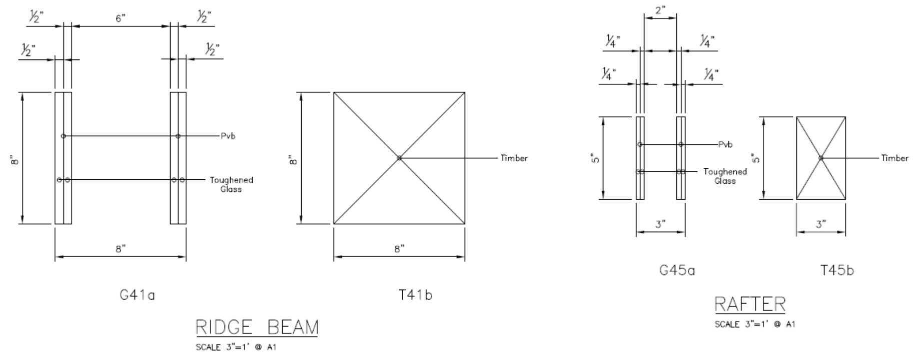

Figure 3: Shop Drawings Showing New Glass and Original Timber Sections Side by Side.

4.2. Plastic Connections

Plastics or polymers can be formed into complex geometries to integrate irregular joint configurations. Glass is too hard and unyielding to make contact with itself, but polymers make a relatively soft and forgiving connection parts that absorb energy by plastic deformation and thereby exhibit significantly better toughness. Therefore plastics make a more forgiving connection part than glass. In the same way that a timber frame can accommodate geometric and loading irregularities, polymers can strain to redistribute or release forces, without passing problems from one element to the next.

All polymers have the unfortunate limitation of loosing their mechanical strength when heated above the glass transition temperature. The elements of the Menokin house will not have to meet stringent fire ratings, but it is not uncommon for the temperature on the inside face of glass to exceed 100°C. Modern coatings and interlayers will be applied to the glazing to control solar gain. Even so, care must be taken to specify the right polymer, because each polymer is suseptible to the migration of different elements into the polymer matrix causing stress cracking and crazing. Therefore, the chemical environment must be clearly understood before the polymer is specified and that may mean analysing the timber for unknown preservatives and treatements.

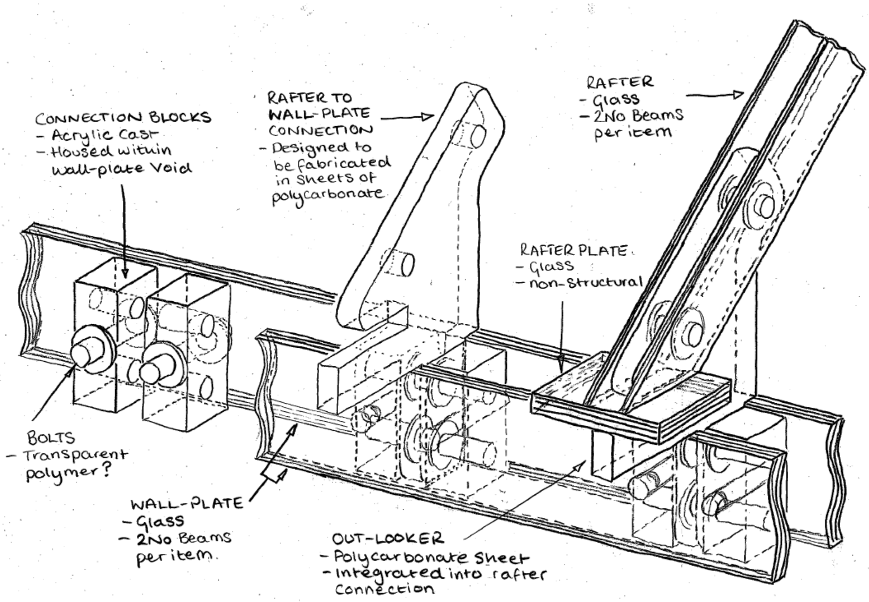

Figure 4: Alternative connection details utilizing polycarbonate sheets.

Three amorphous (transparent) polymers have sufficient mechanical strength to be considered for primary structure; Polymethyl methacrylate (Acrylic), Polycarbonate and Polysulphate. The right polymer for the connections will depend on the service environment and the method of manufacture. Polysulphate is more resistant to chemical attack than polycarbonate and both have superior mechanical and thermal properties when compared to Acrylic. Plastic shell structures with sharp corners will fail early due to fatigue, so the connections must be formed of sheet or cast blocks. The feasibility and cost of casting polycarbonate has not been resolved. Therefore the current plan is to use acrylic for cast items or use polycarbonate where details can be built up from laminated sheets of polycarbonate.

4.3. Acrylic Connections

Acrylic is particularly susceptible to organic solvents. It is UV stable, but direct sunshine and weathering will cause heat cycles that can degrade the structural properties with time. It is relatively soft viscoelastic material that will accumulate surface flaws without protective treatment. Unlike glass, distressed elements show visible signs of deterioration, which can be spotted early in the failure sequence. The deterioration of acrylic can be monitored using polarized filters that could be applied on site to chart the development of internal stress. Whatever the case, the performance of acrylic can be managed by enhanced safety margins and periodic inspection, so that the majority of acrylic parts can be safely relied upon to survive beyond their design life.

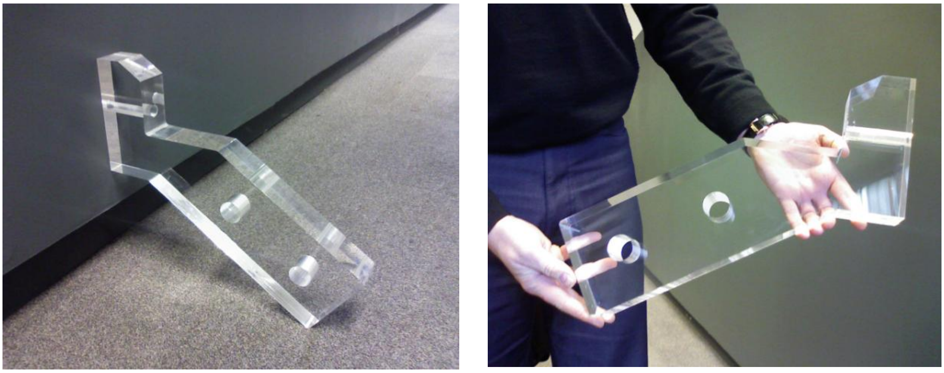

Figure 5: Prototype Acrylic Connection Joint between Rafter and Rafter Plate.

5. The Structural Scheme

The central masonry chimneystacks are largely intact and will provide lateral stability to the whole building and support to the floors. The existing masonry walls and the new glass envelope will be connected to the central chimney core through the rigid floor diaphragms, so that the building elements act together as one stable unit. The structural system must integrate the existing ruin with new transparent structure and restored artifacts. A great deal of the original material has been recovered, but it is unclear how much of that will be restored, either as load bearing structure or as historic decorative cladding. The Menokin challenge is to design a group of versatile details capable of connecting between different materials that could have inconvenient geometries.

5.1. The Splice Detail

Reintegrating the timbers requires a versatile splice detail that can be fabricated by skilled craftsmen and artisans without specialist knowledge or equipment. The conservators have started looking at conforming epoxy resin and carbon fiber repairs to damaged timber and the results are shown. It is likely that some timbers will require both repairing and splicing, but the repair details are beyond the scope of this paper. When the glass envelope is complete, the restored parts will be reintegrated back into the house on a case-by-case basis. As far as is possible, historic elements will be restored so that they play a load-bearing role in final building, even if that means they form small part of the whole element. In severe cases we may employ elaborate structural systems that draw support from trussed walls, cable suspended beams and cantilevered portals.

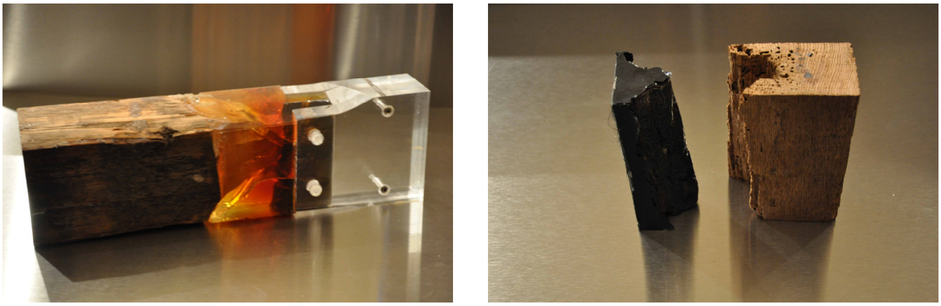

Figure 6: Experimental Repairs.

DMP will advise the conservators on how to make reliable repairs. A series of controlled tests are planned to investigate the as-built strength of the individual parts in each assembly, such as the bonding strength of epoxy and the withdrawal capacity of dowels. This knowledge will be used to design structural sub-assemblies to splice timber elements to glass beams with a predictable bending strength, that can be engineered to meet the specific requirements of the splice detail. The proposed splice detail is designed be disassembled should the timber be required for further interpretation or treatment.

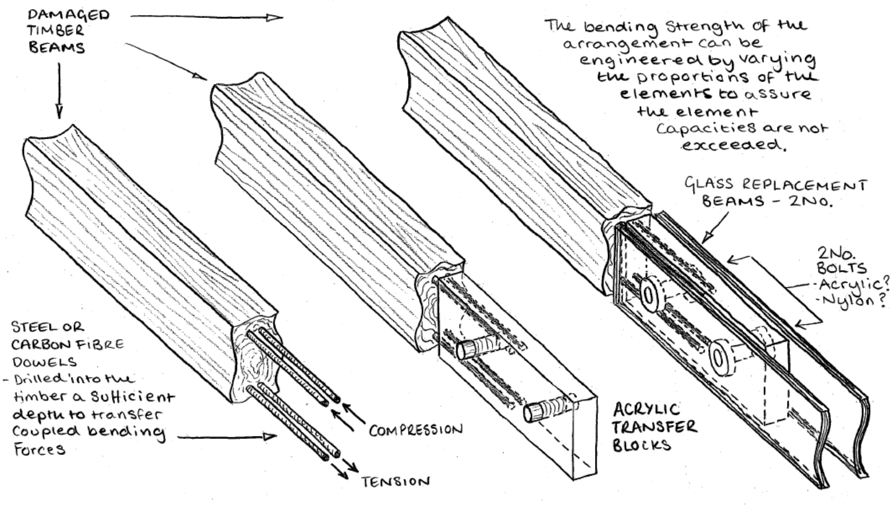

Figure 7: Splice Detail Between Restored Timber and Replacement Glass Beam.

5.2. Replacement Glass Walls

The fallen walls will be constructed from fin-braced glazing. The glazing panels will be annealed so that they can be cut on site to fit the irregular geometry at the masonry interfaces and laminated to enable the use of interlayers. The glass fins step in at each level in order to express the stepped profile of the missing load-bearing wall. The fins support the weight of three suspended floors and the roof. Later on in the project, the fins will support a glass widow substructure designed to house the decorative stone that once framed the windows.

The original architectural brick courses will be restored in bands around the building. These bricks pass straight through the fins at each floor bearing level and shall be supported on a glass shelves. Where the band of bricks meets the fins, a stainless steel connection part is required to avoid supporting the dead load on a notched glass fin.

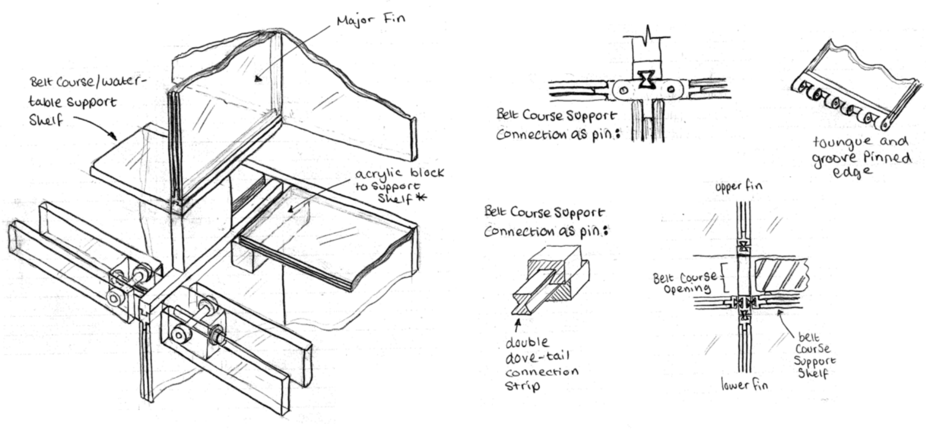

Figure 8: Stainless Steel Connection Junction at Floor Bearing Level.

It is important that glass elements can be easily replaced, therefore we are developing a connection detail that will be applied to all ends of all the fins and shelves. A stainless steel connection strip will be laminated between the glass plies, to make an integrated framing element. A dovetail groove will be machined into both parts to be connected. A double dovetail connection strip slots into these parts, holding them together to make a pinned connection. This connection can be easily released, without having to shift the weight of the element, by sliding out the connection strip.

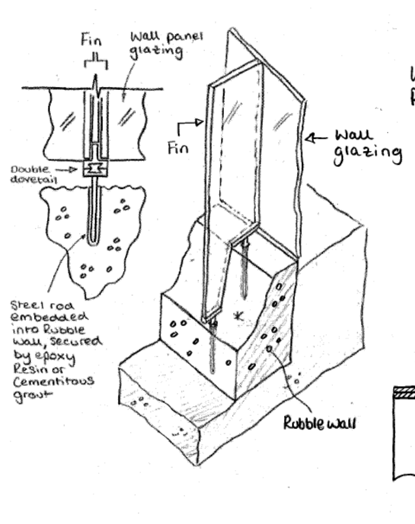

Figure 9a: Fin Connection to Masonry.

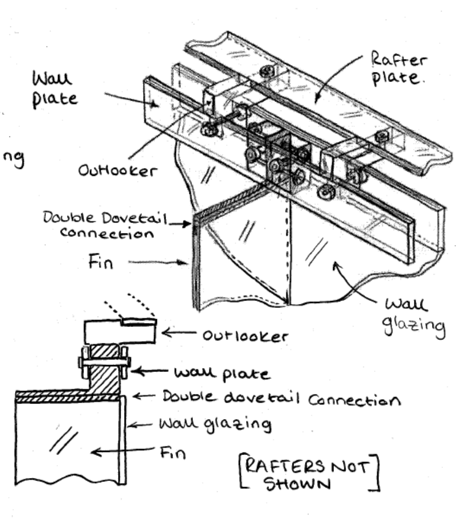

Figure 9b: Fin Connection to Wall Plate.

6. Detailed Design

The construction of glass house will be an ongoing task. The first stage will be to construct the glass enclosure and this must be completed as soon as possible. Once this has been achieved, the conservators can reintegrate the restored elements with less urgency and it is planned that this process will be part of an educational research program, to teach conservation skills to the next generation. Therefore the design of the glass house enclosure must include details to accommodate the reintegration process, so that each glass elements can be removed when its replacement element has been restored.

7. Acknowledgements

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