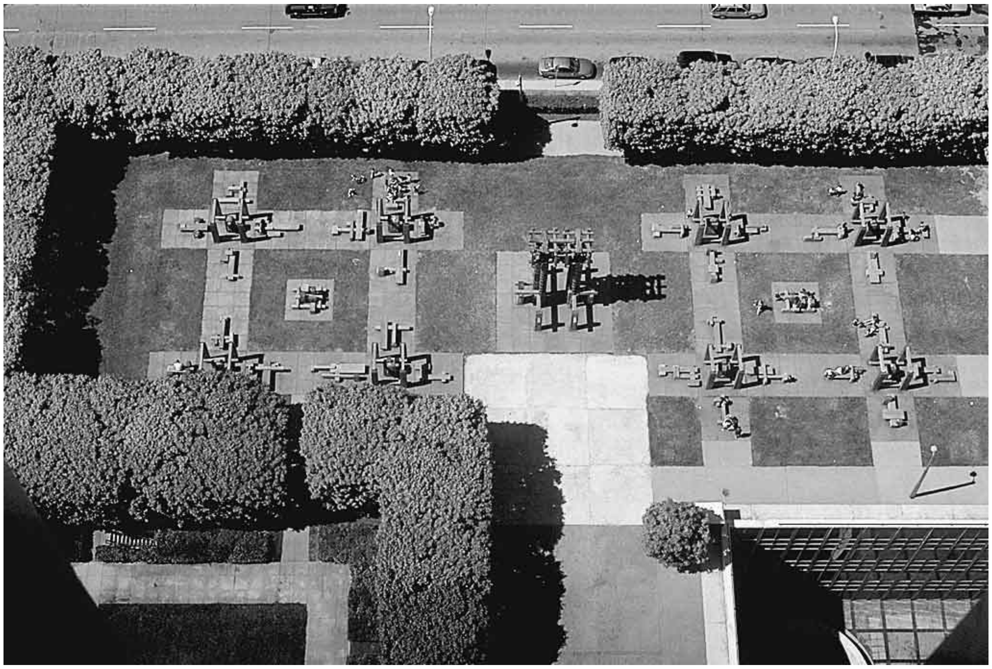

Figure 1: View of Labyrinth *from 30 floors above, in adjacent building.*

Figure 2: South view of Labyrinth.

Treatment of a Labyrinth: Addressing Decay and Losses in a Large Outdoor Wood Sculpture Located in a Public Place

Hugh Glover, Conservator of Furniture and Wooden Objects, Williamstown Art Conservation Center, Williamstown, Massachusetts.

Introduction

THIS PAPER DESCRIBES THE PHASED, four-year, conservation treatment of a large, site specific, outdoor wood sculpture located in Albany, New York. The treatment, which addressed an infestation of decay fungus that has caused significant losses, was completed on-site. It is expected to continue in the future, as deterioration of the object proceeds in the harsh environment.

Ninety-three modern works of art were acquired by Governor Nelson A. Rockefeller and his selection panel to form the Empire State Plaza Art Collection to be displayed in Albany's Capitol complex. The collection represents the work of artists of the New York school of the late 1960's and early 70's, with the exception of *Labyrinth*, which is by the French artist, Francois Stahly. *Labyrinth* is one of several site specific works in the collection, and of the pieces that were located outdoors, only *Labyrinth* was constructed of wood. *Labyrinth* was assembled by the artist and his team of assistants in France during 1970–71 and three years later it was installed at its present site.

The sculpture covers about 1/3 acre, within which there are 43 related structures of large dimension wood, totalling about 30,000 board feet (≈2,500 ft^3), that are secured with simple joints and ferrous fasteners. Visible surfaces are hand tooled with adze and gouge. In plan *(fig.1),* there are two similar squares separated by a forty-foot central tower. There are eight corner structures with large blocks standing between paired arches, four low structures around each of these, and one low structure in the center of the two squares. *(fig.2)* Areas between concrete support pads were originally surfaced with gravel but they are now maintained with grass.

Many visitors find their way to *Labyrinth* for quiet and recreation and younger visitors enjoy the climbing opportunities. Aside from some graffiti, the public has had little impact on the sculpture generally.

In 1973 the wood was described by the artist as "iroko, an African teak" and he had recommended an annual application of linseed oil for protection. In the same year an independent condition survey referred to the wood as teak and assumptions were probably made since then based on the mistaken belief that the wood was teak, which has a noble reputation for decay resistance and stability. That early survey also reported the presence of advanced decay in various members and recommended treatment with preservatives. It would appear that apart from one or two coats of linseed oil applied at the time of installation, no preservatives or coatings have been applied. The inherent properties of wood combined with the location and the absence of a maintenance plan have all served to make the sculpture particularly vulnerable to deterioration.

In 1993 the wood was identified as iroko, coming from a large tropical tree grown in Africa, which is unrelated to teak, but is naturally durable with some resistance to decay. The large size and decay-resistant properties of iroko made it a practical wood choice for the construction at the time.

The Conservation Center began treating the sculpture in 1993, after a heavy block, set between arches, had been pushed over. The block was righted and further conditions were noted. Most of the large blocks between the arches and several smaller elements were heavily infested with a wood destroying fungus *(fig.3)*, identified later as brown rot *(Florian 1996)*. Colonies of carpenter ants were residing in the larger areas of decay and less apparent, incipient decay was also expected elsewhere. Annual precipitation, averaging 36 inches per year (approximately three inches per month), was maintaining favorable conditions for decay within the wood and the fungus was now

Figure 3: Area of decay in the top of one large center block.

spreading at an ever increasing rate and infecting other components. It is possible that the brown rot had been present since the trees were felled or seasoned. Presumably, it has spread from the most affected parts, which are the centers of the large blocks *(fig.3)*, which all include the trees' center or pith.

Conditions for decay fungi

Examples of utilitarian wood use in unprotected conditions include utility poles, railroad ties, and construction lumber for bridges, landscaping and playgrounds. These commercial examples are generally pressure treated with waterborne, creosote and oil-borne preservatives, to resist biopredation. While the life expectancy of treated wood can be several decades, its long term survival usually depends on the extent of protection from water. An outdoor totem pole prepared from a decay-resistant wood serves as an example of an artifact that faces similar threats to survival from its environment (though one end of a totem pole is usually buried in the ground).

The development of decay fungi can be expected to occur in wood that is kept wet through partial burial, ground contact and exposure. For woods with a fiber saturation point of 30%, growth of fungi is retarded at the average moisture content of 25 to 30% and stopped at 20%, based on the ovendry weight of wood *(Pan-chin and de Zeeuw 1980)*.

Controlling decay fungi

The most effective means of controlling the fungus in this example would be to protect the wood from water to reduce its moisture content to a safe level. The installation of a shelter over the site or relocating the sculpture undercover would counter the site specific intentions of the installation and approval for changes of this magnitude has not been forthcoming.

The wood of *Labyrinth* has been allowed to develop gray, weathered surfaces and the original coating of linseed oil is no longer apparent. The artist had recommended annual coatings of drying oil for protection, and the accumulation would have resulted in a dark, cross linked coating that provided a fair degree of protection from water. Applying the missing coatings now would cause irreversible change (color, texture, saturation, permeability for biocides, etc.), while reducing water penetration but without addressing the decay.

The fungus could be destroyed with the moist heat of a kiln *(Panchin and de Zeeuw 1980)*. Even before investigating the implied stresses of kilning or determining whether it would be easier to transport the object or a kiln, this approach was not considered further as the decay would presumably thrive again, as the favorable moisture conditions continued.

Alcohol has been suggested as an effective biocide *(Florian 1996)*. A treatment of soaking the wood with ethanol or isopropanol, combined with wrapping or tenting to slow evaporation, may still be used in the future. At this scale, there are logistical problems to overcome in applying the wraps and the quantity of solvent required would not be without some hazards. Also, the treatment would have to be repeated while the favorable moisture conditions continued.

The interaction of the public with the sculpture determined and limited the selection of a biocide to one that had been approved by the Environmental Protection Agency (EPA).

Diffusible borates

Boron-based preservatives, derived from inorganic borate minerals, have a history of use for wood preservation *(Hamel 1990)*. Borates have a broad spectrum of activity against insects and fungi *(Drysdale 1994)* and being water soluble, they will diffuse to where the hazard is most severe. The probable mechanism of activity is that the borate forms complexes with polyols that interfere with the carbohydrate metabolism and other physiological processes in fungi *(Dickinson and Murphy 1990)*. Borates have low levels of mammalian toxicity, low volatility and they are noncorrosive, colorless and odorless. The essential qualifier for their use in this treatment was the EPA approval for their use as a biocide.

Borates that are currently available for wood preservation have the potential for depletion through leaching, when the wood is exposed to significant water. Borates are therefore recommended for use in protected environments, as in sheltered or coated, and are not intended for use in applications involving ground contact. In the treatment of *Labyrinth*, several measures designed to reduce the level of wood exposure have been carried out, in conjunction with applications of borates.

The American Wood Preservers Association (AWPA) recommends a borate loading of 0.17 lb/ft^3 (0.9% boric acid equivalent (BAE)), when the wood is pretreated in a pressure vessel and remains continuously protected in use *(AWPA 1993)*. The AWPA has no standard for loading of exposed wood or for remedial applications, at present. Measured on a weight per unit weight basis, a level of 0.4% BAE has been specified for preservative treatments for protection of softwoods against wood borers and decay fungi *(BWPDA 1986)*. A BAE of 1.2%, minimum cross-sectional retention has been specified for resistance to subterranean termites *(Lloyd and Manning 1995)*. Several methods exist for analysis of the boron content of wood, including a colormetric test and more quantitative analysis procedures *(Thompson 1991)*. In the present example, core sampling of the sculpture has not been considered necessary or appropriate, so far.

Treatment Plan

The treatment to *Labyrinth* was designed to fulfill three basic criteria. First, an EPA approved biocide would be applied to counter wood destroying microorganisms and insects. Second, measures would be designed to protect the wood to reduce water penetration. Finally, conditions would be monitored to regularly assess developments in the ongoing condition. The treatment would proceed on-site during favorable weather for a short period each year, subject to available funding and curatorial approval.

Application of biocide

Fifty-four gallons of a proprietary borate/glycol concentrate have been applied overall since 1993, with an emphasis on infected and vulnerable surfaces. The product contains 40% of a sodium borate (disodium octaborate tetrahydrate) and is formulated with ethylene glycol to aid its diffusion towards internal moisture. The method of application has involved spraying a 50% solution with hand pumped garden sprayers. In the future, a powered pump that mists the liquid borate will be considered *(Nisus 1997)*. This quantity of borate, or loading, is 1.4 times the minimum application rate recommended by the manufacturer, however, losses occurred due to overspray and runoff. Annual spraying should be continued while the threat of decay persists. Six hundred fused rods of 100% sodium borate, and nine quarts of a gel containing 40% sodium borate, were installed as borate reservoirs within decaying members, using methods outlined below. The reservoirs are expected to slowly diffuse using available moisture in the wood.

The means to monitor efficacy of the borates as a fungicide has been by visual assessment of decay progress and at this early stage complete control has not been achieved. Progress of decay is no longer apparent in the heavily treated areas but applications elsewhere have been uneven and incipient decay is visually undetectable. Practical methods of accurately detecting incipient decay are being investigated. Some methods of detection, such as measurement of weight or respired carbon dioxide, are more appropriately used under controlled

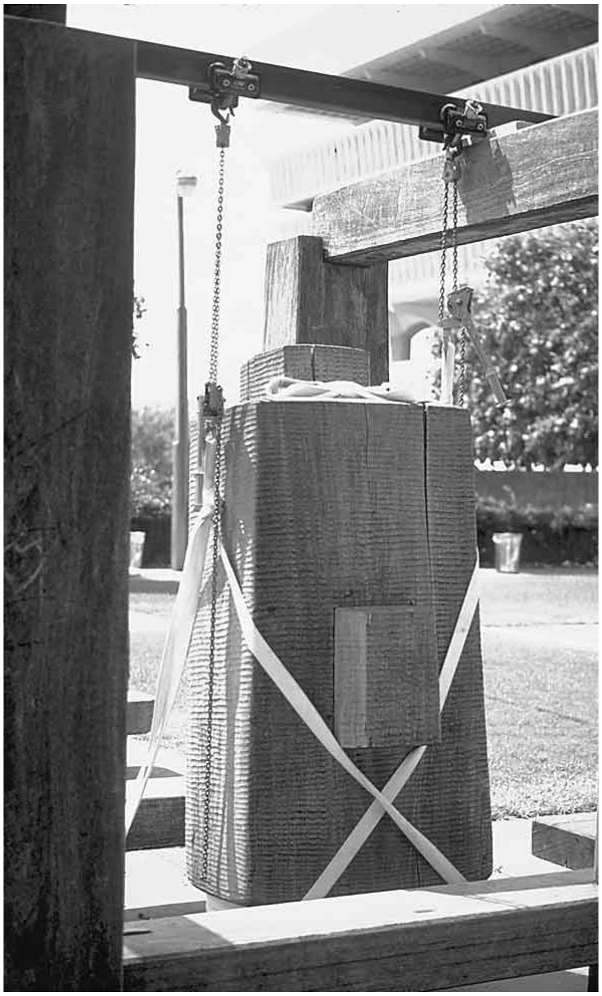

Figure 4: A large center block between arches (1 of 8) showing the lifting equipment.

laboratory conditions. A potential non-destructive technique for field use would be by ultrasonic inspection using a pulse velocity measuring device *(Lee 1970; McCraien and Vann 1983)*. Another method to be considered is fluorescence microscopy *(Krahmer et al. 1982)*, although this would entail sampling. The efficacy of the borates as an insecticide was more easily demonstrated, for the ants departed after two years.

Modifications for ventilation and feet

The eight large blocks set between paired arches had been secured to the ground with short anchored rods and a bedding adhesive, used between the wood, the rods and the concrete. Decay in the top of seven blocks was beginning to meet decay rising from the bottom, and central cavities had formed. With lifting gear suspended from a steel I beam that rested on the convenient overhead lintels *(fig. 4)*, each block was raised and lowered to a horizontal position. *(fig.5)* Most of the soft rotted wood was extracted from the cavities and old bedding adhesive was removed. To help ventilation and drainage of water through the blocks, a hole was drilled through each center, boring from the depth of the decay at each end to meet in the middle.

While the blocks were in the horizontal position, four 3/4″ lead feet were nailed beneath the corners of all eight blocks, to lift the end grain from pooling water. The blocks were then repositioned onto their new feet. It was not necessary to add feet beneath the many low structures as these already stand on neoprene blocks. Only the tall posts of the arches now remain standing on the concrete (the posts of the tower are embedded in the concrete with steel collars).

Filling large vertical cavities

The extensive losses due to decay in seven of the large vertical blocks *(fig. 3)* were addressed. Fills were placed within the decayed openings to restrict rainwater (and trash) and to reinforce the fragile edges. The fill method was designed to be strong, safe and durable, to allow for seasonal movement of the host, to be removable, and to avoid the use of tropical woods (New York State policy now prohibits the use of tropical woods for public works).

A proprietary laminate of a Lexan sheet, approximately 3/4″ thick, (an extremely tough acrylic glazing material) was cut and fitted as a hidden support for the fills. The exposed parts of fills were completed with Trex, a wood polymer composite formed from recycled wood dust and plastic that is designed for outdoor uses like decking. Trex is available in standard construction dimensions from lumber yards. The surface of Trex develops a gray, weathered color on exposure, thus, we suppose, eliminating the need for inpainting.

Describing the fill in more detail, the shape for the Lexan inserts was cut from sheet stock to provide a very loose fit against the walls within the cavities, two to three inches below the top surface.

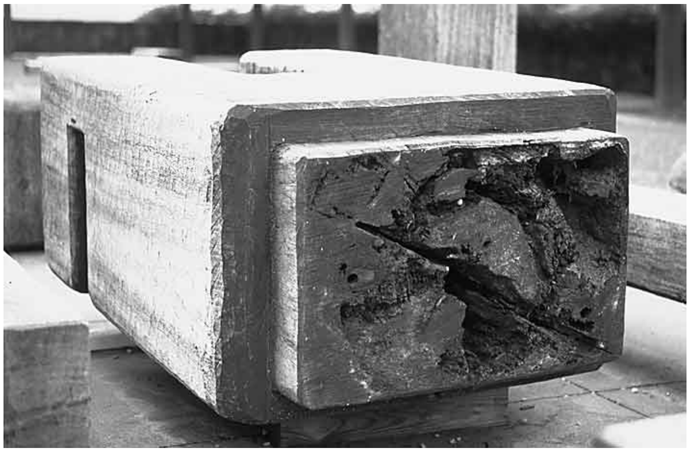

Figure 5: View of the decayed base of one center block.

The Lexan was secured into place with lengths of stainless steel all-thread rod that passed through angled holes tapped in the Lexan *(fig. 6)* and into the walls of the cavities below, to form several variously angled legs. *(fig. 7)* Lower ends of the rods were pointed to penetrate the wood inside the cavity and their upper ends were slotted to enable screwing them flush to the Lexan's surface.

A Mylar tracing of each opening was transferred onto Trex which was cut with a bandsaw to provide an 1/8″ gap around the opening. The larger Trex inserts were formed by adhering smaller pieces with an epoxy resin. The Trex was lowered into place to rest on the Lexan table and secured with latex/silicone caulking around the perimeter. Excess material was leveled with edge tools. *(fig. 8)*

There are limitations to this fill method and the most apparent shortcoming would be the creation of microclimates, where ventilation has been reduced and rainwater and condensation could accumulate within. While interior water has been greatly reduced, the threat of decay continues and will always require a fungicide and protection with coatings. Also, the fill tends to rise and fall slightly in response to the seasonal movement of the host. This fill method was designed to provide a cover over vertical shafts of decay, and more horizontal voids require a different approach.

Borate reservoirs

Diffusible borates were also integrated with the fills. Fused borate rods were fitted into hidden 1/2″ diameter holes bored down into the walls of cavities or bored up into the end grain beneath the large blocks. The rods were also placed onto naturally-occurring ledges within the cavities and integrated with some Lexan and Trex inserts. A more intrusive method was used to install the rods into three decaying members where significant losses had not yet occurred. Visible holes were bored horizontally into the decayed end-grain, packed with the rods, and plugged with Trex. These are the only holes in the treatment that have entered through a visible design surface.

A borate gel was poured into 1″ diameter vertical holes bored into the walls of some cavities. There was only a limited opportunity of boring the reservoirs and there were difficulties as the gel tended to drain through cracks. A valve and pump delivery system is planned for use to apply reservoirs of a borate paste to the bases of vertical posts that still stand directly on concrete, rather than raising these onto feet and risk instability.

Figure 6: Installing stainless steel all-thread rods to locate the Lexan support table.

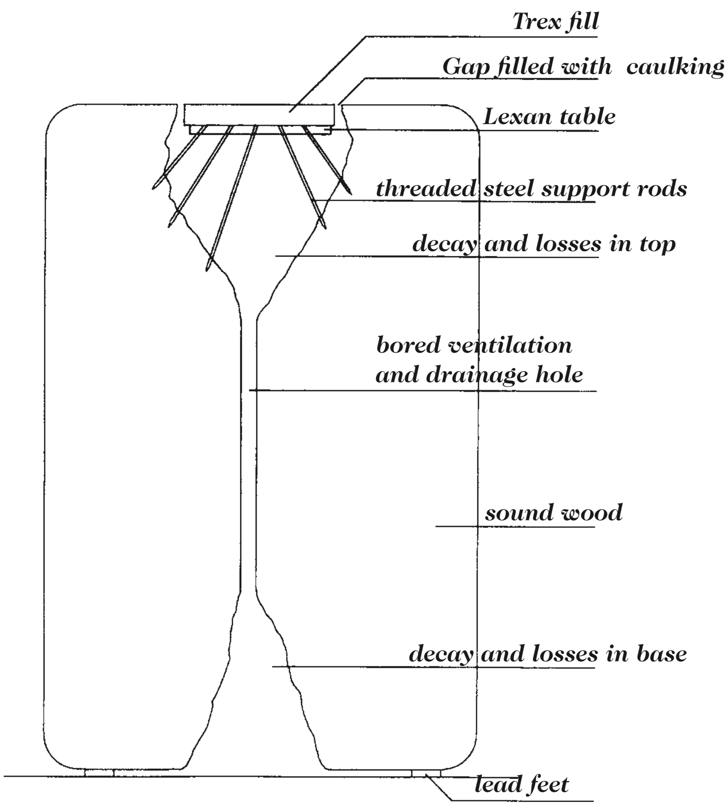

Figure 7: Diagram (not to scale) of cross-section view of a typical center block (≈ 6 ft. h. x 3 ft. w.) showing the decay and the arrangement of the fill and feet.

The method will likely involve drilling a long horizontal hole into each base, fitting a plastic valve and periodically pumping in a 70% solution (paste) of a sodium borate.

Filling small horizontal cavities
Several small horizontal cavities (smaller than a hand) were filled with Trex alone. After routing a firm base and installing borate rods into internal holes, the shaped Trex was dropped in and secured with caulking against the walls. *(fig. 9)* Another fill method had been installed by others several years ago; here, pigmented epoxy resin had been poured directly into one area of decay. All three fill methods are being monitored for durability and any secondary consequences.

Missing and detached pieces
The treatment has also involved refitting some parts. A missing piece was indicated by the shallow mortise in the top of one center block and it was determined to be appropriate to fit a replacement because of its contribution to reducing water entry below. Curatorial photographs had recorded its shape and adjacent surfaces suggested a tooled texture. A locally grown block of decay- resistant locust wood (≈ 9″ x 9″ x 19 1/2″) was prepared and installed in conjunction with a large fill of Lexan and Trex (the mortise area was heavily decayed). An eyelet, hook and vertical rod system, running through the center and tightened up under the base, was used to secure the locust block and two other detached capping blocks, all of which had originally been secured with adhesive. The new method of fixing improved security and reversibility.

Removing debris
Crevices within the joinery and larger checks were cleaned of debris and small pebbles using thin steel bars and a vacuum cleaner. These accumulations were evidently contributing to decay and warping. The pebbles remained from when the site had been spread with gravel and many had become lodged within cracks, and acting like wedges, caused them to continually widen as the stones dropped in response to wet/dry and freeze/thaw cycles. Maintenance plans include the removal of trash and vegetative debris to maximize ventilation around the wood and discourage pests.

Closing gaps
The sealing of crevices to reduce a chief source of water entry has been started. Closed cell polyethylene backing rods have been pushed into cracks and joints measuring 1/4″ wide and more, and pigmented, two-part polyurethane caulking is being applied to gaps over about 1/8″ wide and over the backing rods. Warped and peeling splinters that risk detachment or moisture, ice and debris collection are being relocated with epoxy resin adhesive and pressure from clamps.

Surface coating
A water repellant coating has been selected for vulnerable, upward facing, end-grain surfaces despite the coatings ability to reduce the wood's drying capacity and restrict borate penetration. The clear coating is formulated with paraffin wax and acrylic latex and is intended for application after the borate loading has been increased. The coating would not alter the color of the weathered wood. Performance of any coating will be compromised, however, by the pre-existing weathered

Figure 8: A completed fill showing the Trex insert before its surface color has oxidized.

resist imposed gravity and lateral loads. The engineers used a pulse velocity technique to determine the relative uniformity and quality of wood members.

The distance between two sensors set on each side of a beam, is divided by the transit time of metered pulses sent through the wood, thus providing the propagation velocity. Measurements were taken on a grid format for all structurally important members, with more readings taken on the bottom portion of posts since moisture penetration through the end grain is most likely to cause deterioration at the base connectors.

All of the measurements were reported as consistent, repeatable and within normal variation for wood members. Increased transit times through surface opening splits were recorded, otherwise, the readings did not show large variations and the results indicated no interior deterioration beyond what was visually discernible. The data is expected to be useful for comparison with results obtained in the future and thus ensuring a means of assessment of the structural security of the tower.

Conclusion

We should be prepared to accept that with even all of our intervention, *Labyrinth* is destined to succumb to the forces of nature much sooner than it would in the enclosed environment of a museum

condition of surfaces, and reversibility may not be achievable.

Monitoring

Written and photographic records are used to monitor conditions and the advancement of decay is assessed visually. Two systems have been installed to monitor moisture conditions of the wood and evaluate the efficacy of the planned coatings. A four-channel data logger, with a 7–10 year battery life, was enclosed in the cavity of one large block. It is set to record temperature and relative humidity every two hours, both within the cavity, and externally with a remote sensor located beneath a projection. Data is downloaded with a portable computer connected to a hidden mini-jack.

In the second method, pairs of 4″ long permanent stainless steel probes (1/16″ dia. rods) have been installed in several locations to monitor the wood's moisture content with a moisture meter *(Grattan 1989)*. Probes were placed toward ends most subject to decay, rather than locating them more centrally as for obtaining average readings.

Pulse velocity assessment

A structural assessment of the tower was completed by independent structural engineers. Their evaluation was based upon a visual examination and nondestructive testing, and focused on the primary timber elements that

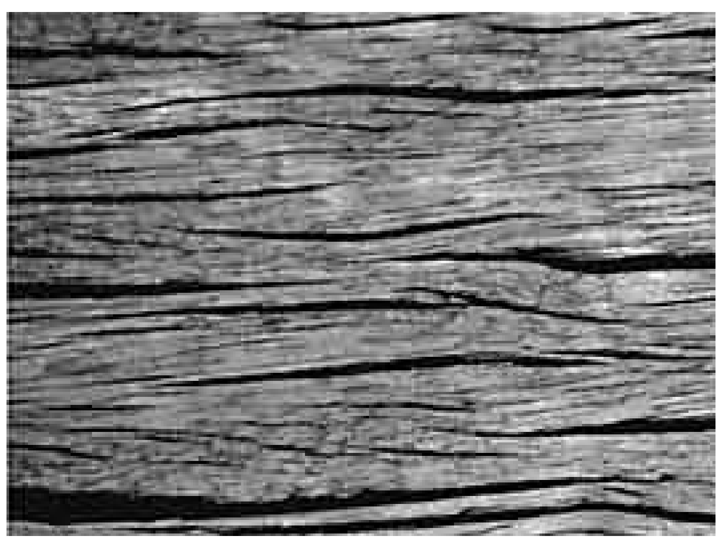

Figure 9: A small Trex fill after its surface has oxidized.

building. It remains to be seen whether continued applications of borates are capable of controlling the advancement of decay in these circumstances. Any future maintenance plans must be carefully designed and prioritized to ensure reasonable economy within the constraints of the state's allocation for preservation. It is possible that the more effective and economic opportunity for prolonging its existence existed many years ago. The scale, the medium and the location of the sculpture, along with the climate and adherence to the interests of public safety and state budgets have required, and will continue to require, an approach that is outside the conservator's normal domain.

Perhaps the unfavorable odds for survival will justify more intrusive preservation measures. The functional playground and park bench aspect of *Labyrinth* could be used to support arguments for replacement of severely deteriorated members. It should be possible to locate a large dimension, decay-resistant substitute wood and devise an appropriate surface tooling. Preserving each of the removed parts would then be more manageable but their active relationship with the site would, of course, have ended.

Acknowledgments

The author would like to particularly thank Alexander Carlisle who participated in this project for two years. Thanks are due to John Ryan and Cor van Horne who also helped in developing and implementing solutions. The author thanks Mary Lou Florian for identifying the fungus and Ryan Biggs Associates of Troy, NY for undertaking the structural assessment of the tower.

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Suppliers List

Backing rods: closed cell polyethylene. Manufactured for Macklanburg-Duncan, Oklahoma City, OK., supplied by local hardware store.

Borate gel: Jecta™. Contains 40% by weight disodium octaborate tetrahydrate in a patented gel carrier system. Manufactured by Nisus Corporation, Knoxville, TN., supplied by PRG Inc., Rockville, MD.

Borate/glycol concentrate: Bora-Care®. Manufactured by Nisus Corporation, Knoxville, TN., supplied by PRG Inc., Rockville, MD.

Borate paste: prepared as a 70% solution of Tim-bor®. Manufactured by US Borax Inc., Valencia, CA., supplied by PRG Inc., Rockville, MD.

Borate rods: Impell Rods®. Manufactured by Chemical Specialties Inc., Charlotte, NC., and supplied by PRG Inc., Rockville, MD.

Caulking, acrylic latex: “35 year” with silicone. Manufactured by Macklanburg-Duncan, Oklahoma City, OK., supplied by local hardware store.

Caulking, pigmented: NP2, a two-component, gun grade polyurethane sealant with Sonneborn multi-component activator and color pack. Manufactured by ChemRex Inc., Shakopee, MN., supplied by Key Waterproofing Co. Inc., Albany, NY.

Data logger: SmartReader™ SR-002, EH-020 remote sensor and TrendReader™ TR-SFW software. Manufactured by ACR Systems Inc. (Canada), supplied by Cascade Group Inc., Oyster Bay, NY.

Lexan®: a 13/16″ laminate of 1/2″ acrylic between two pieces 1/8″ Lexan bonded with LR film, a proprietary adhesive. Manufactured by GE Plastics Corporation, Pittsfield, MA.

Surface coating: Co-Pel™. Manufactured by Nisus Corporation, Knoxville, TN., supplied by PRG Inc., Rockville, MD.

Trex™: a wood polymer composite manufactured by Mobil Corp., Norwalk, CT., supplied by local lumber yard.

Valve and pump delivery system: Valveinjector™. Supplied by PRG Inc., Rockville, MD.