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Condition Assessment of the Timber Frame Supporting USS *Cairo* at Vicksburg National Military Park, Vicksburg, Mississippi

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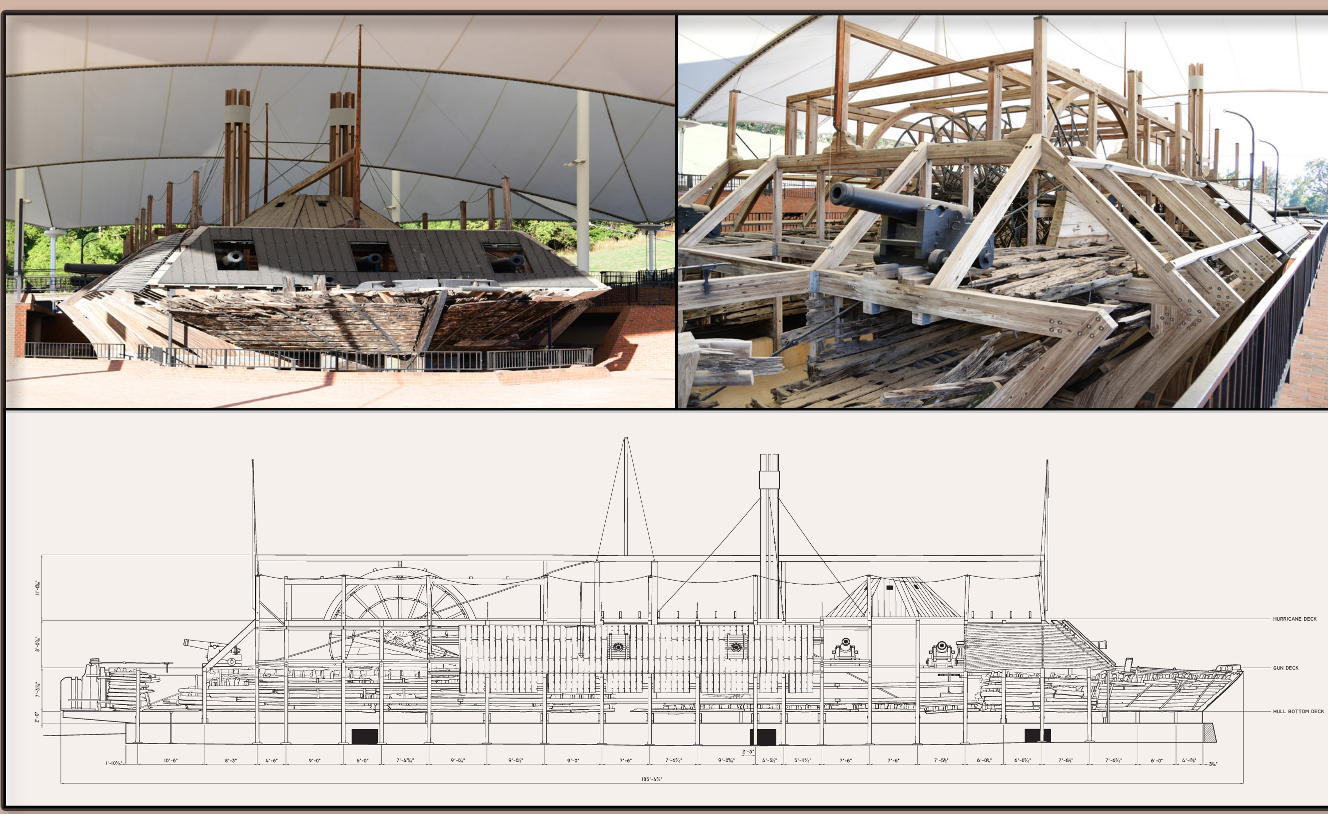

Abstract

The USDA Forest Service, Forest Products Laboratory, was asked to inspect the timber frame that supports the USS *Cairo,* a historic civil war ship at the Vicksburg National Military Park in Vicksburg, Mississippi. Because the display of the historic ship and its support structure are located outdoors and are exposed to the elements, there is concern about deterioration from decay of the support structure. This report summarizes the results obtained from the inspection and assessment. It includes a summary of observations, wood species identification, and recommendations. The timber support frame is constructed from preservative-treated Southern Pine lumber and glued-laminated timbers. Visual- and acoustic-based nondestructive evaluation techniques were used in the condition assessment. Although areas of moderate concern were found, no significant deterioration was observed in the frame. However, many recommendations were provided for the future preservation of the support structure.

Keywords: Condition assessment, visual inspection, decay, moisture, timbers, USS *Cairo*

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Conversion table

English unit	Conversion factor	SI unit
foot (ft)	3.048×10^{-1}	meter (m)
inch (in.)	2.54×10^{1}	millimeter (mm)
knot	5.144×10^{-1}	meter per second ($m\ s^{-1}$)
microsecond per foot ($\mu s\ ft^{-1}$)	3.28	microsecond per meter ($\mu s\ m^{-1}$)
pound per square inch ($lbf\ in^{-2}$)	6.894757	kilopascal (kPa)
ton (2,000 lb)	9.071847×10^{-1}	metric ton (t)

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Introduction

The USDA Forest Service, Forest Products Laboratory (FPL), was contacted in 2023 by Vicksburg National Military Park to assist in assessing the condition of a timber frame designed, built, and used to support a historic civil war ship, USS *Cairo* (Fig. 1). The point of contact at the site was Carrie Mardorf of the U.S. Department of the Interior (DoI), National Park Service (NPS). Researchers from FPL and their colleagues have conducted similar condition assessments of historic structures and artifacts in the past (Clausen and others 2001; Franca and others 2015; Ross and Dundar 2012; Ross and others 1998, 2017, 2018, 2024). The current team of experts conducted an inspection of the USS *Cairo* timber frame support structure on October 24 and 25, 2023. Visual, acoustic, and probing nondestructive testing techniques were used to assess the current condition of the support frame. This report summarizes the findings of the condition assessment.

Brief History of USS *Cairo*

The USS *Cairo* was one of a group of Civil War gunboats of the City Class design. The City Class vessels were designed specifically to perform in the swift and shallow rivers of the Mississippi River basin. Known as the City Series gunboats, *Cairo* and her six sisters were the first ironclads launched in the Western Hemisphere. Built by famed river engineer and salvager James B. Eads at shipyards in Mound City, Illinois, and Carondelet, Missouri, these vessels were uniquely designed for use on inland waters. Each boat had three keels and flat bottoms that enabled them to glide over shallow rivers, and they were propelled by enclosed steam-powered paddle wheels. *Cairo* and her sisters each were 175 ft long and 51 ft wide and had 13 guns mounted on them (Fig. 2). The forward casemate was covered with 2-1/2-in.-thick armor plating, which also covered portions of the starboard and port sides to protect vital machinery in the boats. When fully loaded, they weighed 880 tons, yet only drafted 6 ft of water. Commissioned on January 15, 1862, *Cairo* had a complement of 175 officers and men and was commanded by Lieutenant Commander Thomas O. Selfridge, Jr.

Figure 1—USS *Cairo* in Vicksburg National Military Park on display outdoors under a canopy and supported by a glulam crib structure.

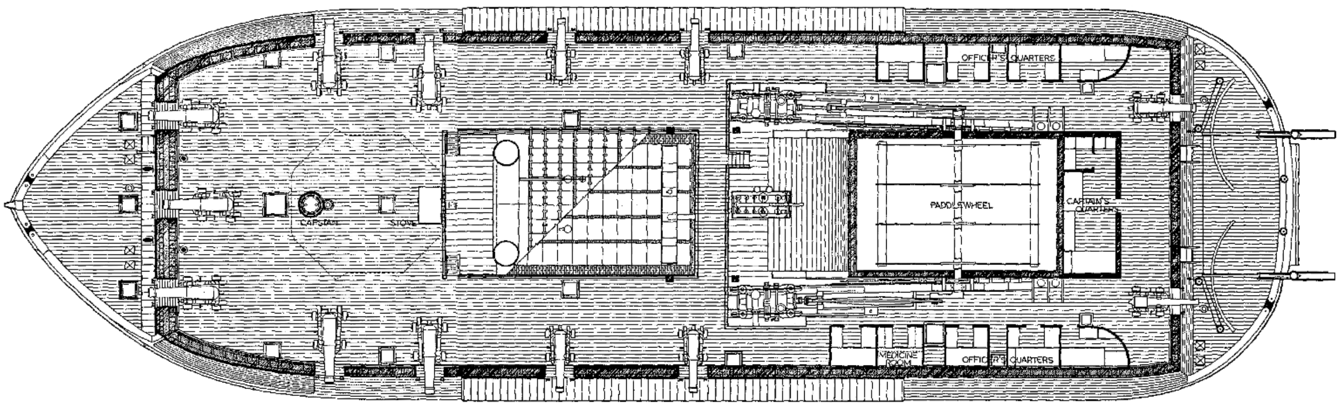

Figure 2—Diagram of USS *Cairo* gun deck showing placement of the 13 guns (courtesy of Denver Service Center, National Park Service, U.S. Department of the Interior).

Because the South could not compete with northern industrial capabilities, it relied on equally revolutionary technology and developed underwater torpedoes (now called mines) to combat Union naval presence on the inland waters. On December 12, 1862, Commander Selfridge was ordered to proceed up the Yazoo River, north of Vicksburg, and clear the channel of torpedoes to pave the way for a landing by Major General William T. Sherman's Union Expeditionary Force. *Cairo* struck two torpedoes, becoming the first victim in history of electronically detonated torpedos, ushering in a new age of naval warfare.

Cairo sank in 12 minutes without loss of life. Remarkably, the vessel remained on the bottom of the Yazoo River undisturbed until her resting place was discovered by Edwin C. Bearss, then historian at Vicksburg National Military Park, and two local historians. Salvage operations were commenced, and on Dec. 12, 1964, exactly 102 years later to the day, she was raised. The remains of *Cairo* were taken to the Ingalls Shipbuilding Yard in Pascagoula, Mississippi, where they remained for some time. In 1977, they were returned to Vicksburg where restoration work began. Today, *Cairo* is on display in a covered dry dock at the Vicksburg National Military Park, attracting close to half a million visitors each year.

The following is a summary of the characteristics of USS *Cairo*. It was compiled by the personnel of the Ingalls Shipbuilding Corporation, Pascagoula, Mississippi, in August 1965, and has been revised and corrected based on NPS research for this report. For further historic description of Cairo's framing, materials, fastenings, etc., the reader should refer to McGrath and Ashley (1981).

General characteristics:

- Type: ironclad river gunboat
- Number of vessels in class: seven
- Class: City Class
- Area of operations: lower Mississippi River

Principal characteristics:

- Overall length: 175 ft
- Breadth: 51 ft
- Full load keel draft: 6 ft
- Displacement, full load, FW: 880 tons
- Tonnage: 512
- Number of hull compartments: 15
- Speed: 6 knots
- Deck planking: white pine
- Hull form: flat bottom, knuckle bilge
- Number of keels: 3
- Paddlewheel arrangement: recessed wheel
- Rudder arrangement: 2 stern-post hung
- Ship's boats: 3 cutter, 1 launch
- Anchors: 2 forward
- Estimated built weight of wood hull and casemate: 350 tons
- Hurricane deck awning arrangement: stanchion mounted
- Frame timbers and hull planking and ceiling: white oak
- Decks: 3 (boiler deck, gun deck, hurricane deck)

The frame timbers, hull planking, and ceiling are white oak, and the deck planking is white pine. White oak is a decay-resistant wood species. Because of this, it was used in marine applications at the time. White pine is a softwood species that has low decay resistance.

Preservative Treatments Previously Applied to USS *Cairo* Pieces

In the mid-1960s, the original parts of the USS *Cairo* were shipped and reassembled in Pascagoula, Mississippi. Larger wood components from the ship were soaked in a solution of 25% polyethylene glycol (PEG) with the addition of 5% pentachlorophenol. Smaller pieces were simply submerged in a solution of 40% to 50% PEG with no added preservative. PEG is a well-documented wood bulking agent (Stamm and Baechler 1960) and has been used for decades to stabilize wood, especially in archaeological settings.

Inspection of USS *Cairo* Support Frame

In 1980, the shelter and the glued-laminated (glulam) crib structure were completed to support and display the remains of the original wood structure of the USS *Cairo*. The glulam components were made up of lamella of loblolly pine (*Pinus taeda* L.) bonded with an exterior-rated adhesive. During construction, these members were pressure-treated with a long-lasting industrial preservative, pentachlorophenol. Pentachlorophenol was commonly used in utility poles and other industrial applications prior to 2022, after which it began to be phased out as a preservative. In the 1990s and early 2000s, Mississippi State University (MSU) faculty administered borate treatments to the existing wood support structure. Borate serves as a diffusible wood preservative intended for wood in aboveground covered construction (AWPA 2023). Most of the observations in this report pertain to the underlying glulam crib and associated connections.

An in-depth, nondestructive inspection of the support frame for the USS *Cairo* was conducted on October 24 and 25, 2023. Photographs taken during the inspection can be found in the Appendix. Figure 3 shows FPL and NPS staff members discussing inspection techniques at the USS *Cairo* display site. Accepted inspection techniques commonly used for wood structures are discussed in detail by White and Ross (2014) and Ross (2015).

Visual Inspection

The simplest method for locating deterioration in wood members is visual inspection. An inspector observes the structure for signs of actual or potential deterioration, noting areas that require further investigation. Visual inspection is useful for detecting intermediate or advanced surface decay, water damage, mechanical damage, or failed members. However, visual inspection cannot detect early-stage decay or deterioration.

Several key indicators are looked for in visual inspections: fruiting bodies (evidence of advanced decay), staining or discoloration of members (indicators of water damage), evidence of insect activity (holes, frass, and powder posting), plant or moss growth in a member, deep checks or splits, and failed or missing members.

Inspectors specifically looked for the items listed below as signs of reduced strength capacity:

- Evidence of water intrusion and subsequent damage, especially where the timbers are in contact with the foundation and other areas where the wood members are compromised
- Evidence of structural failure of the timbers
- Biological signs of fungal decay or insect damage as evidenced by the presence of fruiting bodies, insect frass, or mud tubes produced by subterranean termites
- Locations of moisture catches or other areas of inadequate air flow that would have elevated moisture

Moisture Content Assessment

The estimated equilibrium moisture content (EMC) of lumber and timber stored in an exterior environment but protected from liquid wetting has been reported (Rietz 1978). Temperature, relative humidity, and season of the year are influential factors. For the Mississippi and Louisiana regions, estimated EMC values of 13.6% to 15.2% have been reported throughout the spring, summer, fall, and winter seasons (Rietz 1978).

Based on initial visual inspection, a moisture content (MC) assessment was performed. Logically, if the MC of the support members is at or below 19% (dry basis), then the

Figure 3—On-site team member discussion of inspection techniques used during the USS *Cairo* support structure condition assessment.

likelihood of deterioration, and potential for future deterioration, is relatively small. To this end, the MC of the support members was measured and recorded. Support members under the middle of the hull were preferentially measured because this location receives minimal airflow, is close to the ground, and logically would be the most likely location for MC of the support members to be elevated and stay elevated over time. This area was the most likely to develop strength-reducing conditions and was the focus of examination by inspecting scientists.

Sound Transmission Techniques

A significant volume of research has been devoted to the use of sound waves for locating areas of deterioration in timber structures, and a practical set of guidelines for their use was published by FPL (White and Ross 2014). In summary, the transmission of sound in wood is affected significantly by the presence of deterioration. Consequently, ultrasound and stress-wave-based technologies have been developed and are widely used to inspect wood structures (Allison and others 2008; Brashaw and others 2005; Clausen and others 2001; Emerson and others 2002; França and others 2015; Ross and Wang 2005; Ross and others 1999, 2006) and have been used for the assessment of culturally significant historic ships and artifacts (Ross and Dundar 2012, Ross and others 1998, Wang and others 2008).

A simple, commercially available sound transmission nondestructive testing device was used in the inspection of the support frame for USS *Cairo*. With this device, sensors were placed on opposite sides of a timber. The timber was then impacted, generating a stress wave. The time it took for the wave to travel between the sensors was measured by the device and recorded. Transmission times for wood in good condition from several species are known and were used as a baseline. Transmission times significantly longer than baseline values indicate the likely presence of deteriorated wood.

Establishing the Baseline of Clear Wood Properties

Markwardt and Wilson (1935) summarizes one of the first studies at FPL (dating to 1910). The study was designed to establish the properties of 164 species of wood grown in the United States. The test methodologies developed at FPL as part of this fundamental study serve as the basis for the current standardized methods for establishing baseline properties. Table 1 shows the clear wood properties of white pine and white oak based on data from Markwardt and Wilson (1935).

Significance of Effect of Decay on Mechanical Properties of Wood

The presence of deterioration caused by decay, particularly brown-rot fungi, has a significant effect on many properties of structural timbers. The following sections summarize the effect of decay on various strength properties of wood. Table 2 summarizes early scientific literature on the topic.

Toughness (Impact Bending)

Toughness is the ability of a wood to withstand shock loading. It is generally considered to be the strength property most affected in early stages of decay. Research dating to 1954 indicates that a loss of only 1% in weight corresponds to a toughness loss of up to 50% (Table 2).

Static Bending

Research dating to the 1930s has been conducted on modulus of elasticity, modulus of rupture, and work-to-maximum-load in bending mode. Reported results indicated a significant loss in modulus of rupture (strength) after wood had decayed (Table 2).

Other Strength Properties

Research has shown that compression perpendicular to the grain, compression parallel to the grain, tension parallel to the grain, shear parallel to the grain, and tangential hardness are also impacted by deterioration caused by decay (Table 2).

Results

General Assessment

Condition assessment of the USS *Cairo* glulam crib began with a visual inspection to identify obvious areas of decay within the structure. Overall, the glulam crib supporting the remains of the USS *Cairo* is in good condition. No areas of surface decay were identified during visual inspection. There were bolts missing from some lateral support rods of the structure (Fig. 4). These lateral support rods were located on the USS *Cairo* glulam crib at the access point of the port pedestrian bridge.

One area of particular concern is the white oak bulkhead located below the steam pistons attached to the aft paddle wheel assembly. There was evidence of extensive decay and the beginning of structural failure (Fig. 5). It is recommended that this area be, at a minimum, filled with a two-part wood epoxy or similar material to consolidate the member as well as seal off the damage to prevent further biodegradation.

The second step of condition assessment is determination of MC within the wood. Moisture is necessary for wood decay. As MC increases above wood fiber saturation, the likelihood of wood decay increases. Fiber saturation is species specific, but 20% MC by weight is generally considered below the fiber saturation point. The percentage MC corresponds to the level of concern for the presence or potential of decay. Levels were set at low (below 17%), moderate (17% to 20%), and high (above 20%). At first glance, the underside of the glulam beams appeared damp, but it was determined that this was residual oil used in the original pentachlorophenol treatment. Moisture readings with a pin-

Table 1—Clear wood physical and mechanical properties of white oak and white pine species in green condition and at 12% moisture content (MC)[a]

Species name (common (scientific))	Specific gravity		Modulus of elasticity ($\times 10^6$ lb/in^2)		Bending strength ($\times 10^3$ lb/in^2)		Compression strength perpendicular to grain (lb/in^2)	
	Green	12% MC	Green	12% MC	Green	12% MC	Green	12% MC
Eastern white pine (*Pinus strobus*)	0.34	0.35	0.99	1.24	4.9	8.6	220	440
White oak (*Quercus alba*)	0.60	0.68	1.25	1.78	8.3	15.3	670	1,070
Loblolly pine (*Pinus taeda*)	0.47	0.51	1.40	1.79	7.3	12.4	250	610

[a]Property information from FPL (2021). Data originally reported in Markwardt and Wilson (1935).

Table 2—Estimated softwood and hardwood strength loss at early stages of decay (indicated by weight loss) by brown-rot and white-rot fungi as a percentage of nondecayed samples[a, b]

Approx. weight loss (%)	Strength property loss (%)										
			Static bending								
	Toughness	Impact bending	Bending strength	Work to max. load	MOR[c]	MOE[c]	Compression perpendicular (radial)	Compression parallel	Tension parallel	Shear parallel	Hardness
					Brown-rot softwoods						
1	57	20–38	—	—	—	—	—	—	—	2	—
2	—	20–50	5	27	13–50	4–55	18–24	10	23–40	—	—
4	75	25–55	—	—	—	—	25–35	—	—	6	7
6	—	62–72	16	—	61	66	48	25	60	—	—
8	—	78	—	—	—	—	48–60	—	50	15	21
10	—	85	36	—	70	—	66	45	—	20	—
					Brown-rot hardwoods						
1	—	6–27	—	—	—	—	—	—	—	—	—
2	36	31–50	—	54	32	—	6–10	—	56	—	—
4	—	60–70	—	69	49	—	—	—	—	—	—
6	—	80	—	75	61	—	16–25	—	—	—	—
8	—	9–89	13–34	—	—	—	19	—	82	—	—
10	60	70–92	—	—	—	—	—	—	—	—	—
					White-rot softwoods						
1	55	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	10–20	—	4–38	—	—
4	—	—	—	—	—	—	—	—	8–43	—	—
6	75	—	—	—	—	—	32–61	—	10–49	—	—
8	—	—	—	—	—	—	—	—	14–58	—	—
10	85	—	—	—	—	—	—	—	20–63	—	—
					White-rot hardwoods						
1	—	21	—	—	—	—	4	—	—	—	—
2	—	26	—	28–35	13–14	4	5	—	22–42	—	—
4	70	44	—	38	20	—	—	—	17–44	—	—
6	75	50	—	45–53	20–27	10	12–27	14	12–58	—	18
8	—	—	—	—	—	—	—	—	14–49	—	
10	85	60		58	24	14	35	20	20–50		25

[a]From Wilcox (1978). Values obtained from published experimental results and adjusted to equivalent weight loss levels.
[b]Sources: Brown (1963), Cartwright and others (1931), Gillwald and Michalak (1963), Hartley (1958), Henningsson (1967), Kennedy (1958), Kennedy and Ifju (1962), Kubiak and Kerner (1963), Mizumoto (1966), Mulholland (1954), Pechmann and Schaile (1950), Richards (1954), Scheffer (1936), Toole (1971), Wilcox (1968).
[c]MOR, modulus of rupture; MOE, modulus of elasticity.

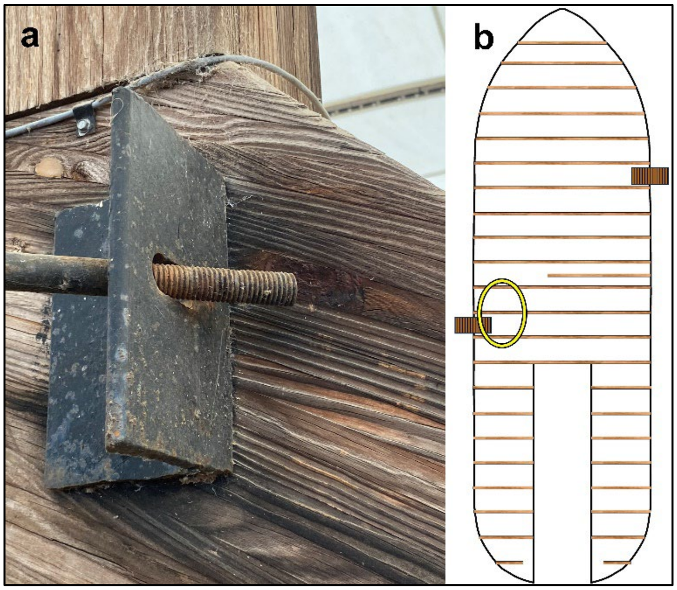

Figure 4—Missing bolt on lateral support rod: (a) rod without bolt; (b) yellow oval shows location of rods without bolts on the USS *Cairo* display.

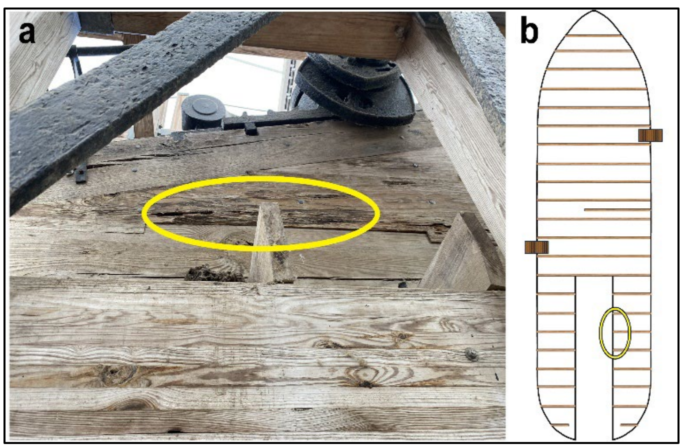

Figure 5—Area recommended for remedial treatment: (a) decayed region (inside yellow oval) of bulkhead of newer white oak supporting the steam-powered piston that originally moved the aft paddlewheel; (b) yellow oval shows location of decay region on the USS *Cairo* display.

type moisture meter ranged between 8% and 15% MC, with most values falling within the 10% to 13% range. These ranges of MC, as shown in Figure 6, are slightly elevated but still below the required 17% to 20% MC range needed for growth of mold and decay fungi. The MC measurements are summarized in Figure 6, and Figure 7 shows how team members performed the moisture measurements.

Average MC and coefficient of variation (COV) for the four sections of the *USS Cair*o were determined and recorded in Table 3. Overall, MC in all four sections was below that required for growth of decay fungi (>25%). No areas of MC above 20% were found.

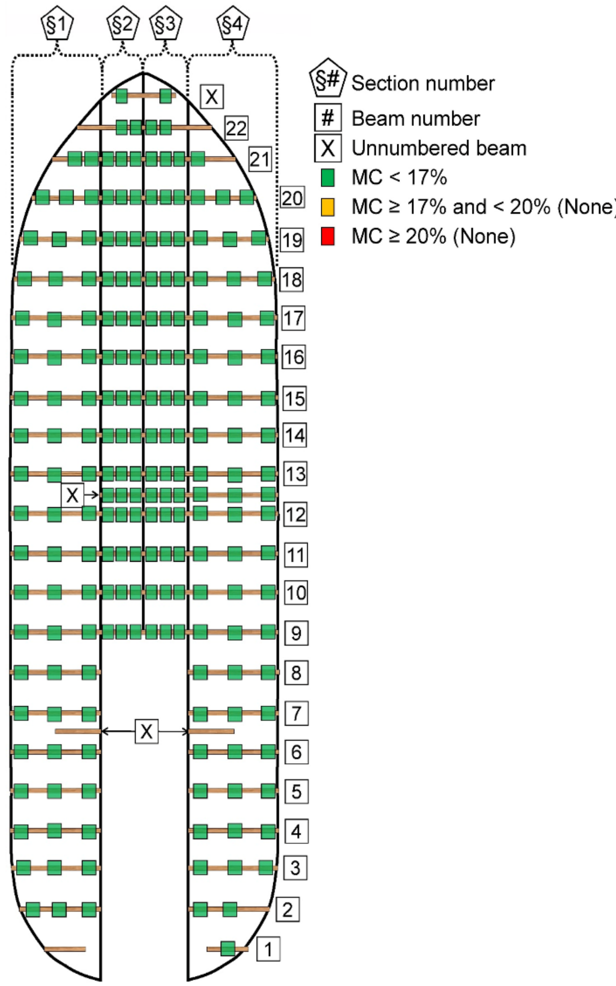

Figure 6—Moisture content of glulam crib underneath the USS *Cairo*. Measurements taken using pin-type moisture meter. All values were below 17%. The four sections, left to right, are port (1), port center (2), starboard center (3), and starboard (4).

Figure 7—Team members performing moisture measurements of USS *Cairo* glulam support structure.

Table 3—Average moisture content (MC) by ship section[a]

Section	Average MC (%)	COV[b] (%)
1 (port)	11.9	10.7
2 (port center)	10.9	9.3
3 (starboard center)	10.8	8.9
4 (starboard)	11.7	9.9

[a]Triplicate readings were measured for each section of the glulam structure housing the USS *Cairo*. Average MC was obtained from the entire length of each section.
[b]COV, coefficient of variation.

Measurements were taken at contact points between the glulam structure and either the concrete substructure or the historic timbers of the USS *Cairo*. Moisture can become trapped at points of contact, which promotes wood decay. Wood–concrete contact is particularly prone to decay because the porous concrete absorbs water, which is then drawn into the wood. Wicking is greatest when the wood end grain is in direct contact with concrete. In the support structure, a thin, barrier layer had been placed at each wood–concrete contact point to prevent direct contact between the two materials (Fig. 8). The barrier layer minimized transfer of moisture from the concrete to the wood. However, there were some instances especially in Section 4 where the moisture barrier between the concrete structure and glulam housing the USS *Cairo* showed elevated moisture readings (15%). This could be a result of the moisture barrier failing, which is allowing elevated moisture readings at these spots. Specific instances of these higher moisture readings occurred in Section 1 (port) and Section 4 (starboard).

A Wagner L610 digital lumber moisture meter (Wagner Meters, Rogue River, Oregon, USA) was used to take moisture measurements. The handheld meter measures moisture up to 1 in. subsurface. Measurement locations are shown in Figure 9. Measurements were taken on both sides of each of the glulam supports along the outer extents of the ship and along the keel. Each black line is labeled with a letter that corresponds to the test location as shown in the diagrams to the right. Green indicates low concern; yellow indicates moderate concern. Most moderate concern locations were midlength where the air flow around the glulam supports is minimal.

Figure 8—Barrier material designed to prevent moisture transfer from concrete to glulam supports.

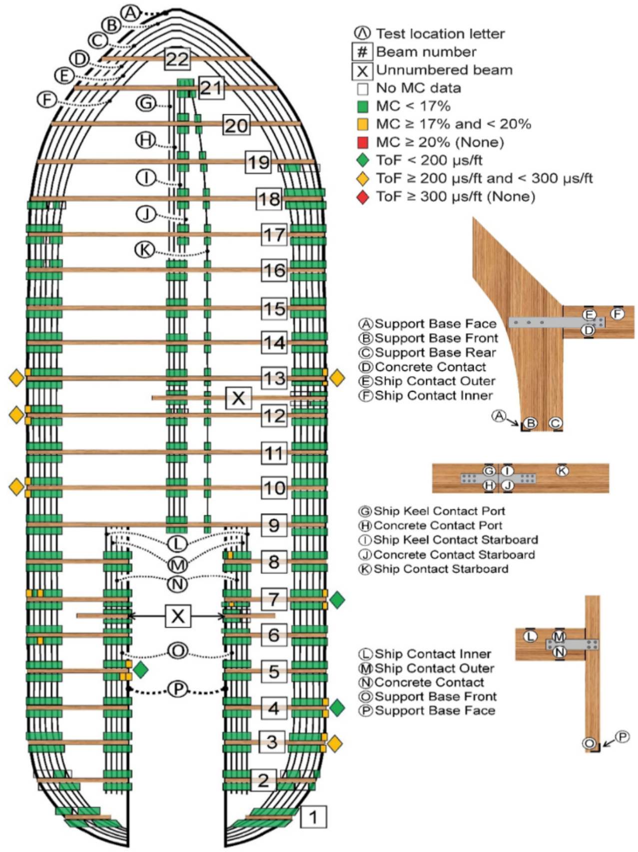

Figure 9—Moisture content (MC) and time of flight (ToF) of glulam timber support structure for USS *Cairo*. Test locations identified by beam number, and location letter provided on diagrams to the right. Locations where MC was at or above 17% were also measured using stress wave ToF. Advanced decay was not found, but stress wave ToF revealed locations that should be monitored going forward.

Moderate concern locations (17% to 20% MC) were further tested using stress wave time of flight (ToF). Stress wave time of travel was measured using a microsecond timer from Fakopp Enterprise Bt (Sopron, Hungary). Mechanical waves (sound or mechanical impact) travel faster in sturdy wood than in decayed wood. ToF less than 200 µs/ft indicates sturdy wood; ToF between 200 and 300 µs/ft should be monitored; ToF greater than 300 µs/ft indicates decay. The Wagner L610 digital lumber moisture meter and Fakopp microsecond timer are shown in Figure 10a and b, respectively. No ToF measurements greater than 300 µs/ft were observed. Several areas where MC was between 17% and 20% had ToF between 200 and 300 µs/ft.

Figure 10—Inspection tools used on USS *Cairo* glulam structure: (a) Wagner L610 digital lumber moisture meter; (b) Fakopp microsecond timer.

Conclusions

The following conclusions are based on our inspection of the support frame for USS *Cairo*:

- Based on visual inspection, moisture measurement, and time of flight tests, it can be concluded that the high humidity and restricted air flow environment have not caused the development of advanced decay.
- Areas of moderate concern were identified and should be regularly monitored for the development of advanced decay.
- Increasing air flow around the contact between the glulam supports and the concrete substructure will reduce absorption from standing water.
- The high humidity environment will continue to be a source of moisture that can potentially lead to the development of advanced decay.

Recommendations

- Supplemental preservative applications at the junction of the wood subframe and the concrete footers would provide additional protection against wood decay fungi and insects, especially in areas of wicking moisture between the two materials.
- Wireless moisture sensors are an invaluable tool in monitoring problem areas and could be installed on the underside of the glulam crib with minimal impact to the form and function of the structure. The building sciences research group at FPL uses these routinely to monitor MC of wood in buildings. These sensors transmit data via cellular signal and can be monitored remotely, which provides real time data without the need for site visits.
- Although no active termite damage was noted during this inspection, it should be a consideration in future planning. Vicksburg is in the introduced range of *Coptotermes formosanus* Shiraki, an invasive termite species that has been present in the United States since the 1940s. These termites swarm at several times of the year, and the flying reproductive alates typically swarm at night. Excessive outdoor lighting can attract these swarming pests, leading to subsequent infestations if left unchecked. *C. formosanus* can infect exposed wooden elements. Periodic inspections should be conducted to minimize this risk.
- A series of fans had previously been installed beneath the glulam cribbing, but these fans did not appear to be functioning at the time of inspection. Ensuring that these fans are operational and moving the appropriate cubic footage of air will help maintain these materials below the MC threshold (17% to 20%) needed for development of mold and decay fungi.
- All moisture barriers between the concrete structure and the glulam that houses the USS *Cairo* should be assessed, and barriers that are worn or showing signs of failure indicated by an increased moisture reading (Sections 1 and 4) should be replaced.
- An enclosed climate-controlled environment would be the best option for long-term preservation of the USS *Cairo*. The canopy currently is shedding precipitation from the actual frame, but the entire assembly is subject to substantial swings in relative humidity and temperature that could exacerbate issues with mold and decay fungi. The structure is also currently exposed to the risk of swarming insects such as termites, powder post beetles, and carpenter bees. The Swedish warship, Vasa, is an excellent example of cultural restoration and preservation (Vasa Museet 2024). The Vasa originally sank in 1647.

Ongoing Monitoring

An inspection of the glulam crib and USS *Cairo* should be performed both annually and at times when the structure is exposed to greater than normal levels of moisture. Greater than normal levels may include particularly heavy rains causing water to flow under the ship, standing water, persistent high humidity combined with high temperatures, rainfall lasting several days, and long-term contact with water dripping from the canopy. Conditions that may cause deterioration of the glulam crib also pose a threat to the USS *Cairo* itself. The ship has greater susceptibility to insect and fungal decay than does the preservative-treated glulam crib. It is almost certain that fungal intrusion has occurred within the original ship structure. Fungi can lay dormant for years and then revive when moisture becomes available. Fungi spores are ubiquitous in outdoor environments; therefore, new spores are contacting the USS *Cairo* daily. Maintaining a low MC within the wood is the most effective option to preserve the current condition of the USS *Cairo* and prevent further deterioration.

The inspection process should follow the steps described in this report as well as the *Wood and Timber Condition Assessment Manual: Second Edition* (White and Ross 2014) and *Nondestructive Evaluation of Wood: Second Edition* (Ross 2015). The inspections should include but are not limited to the following steps:

1. Visual inspection
    a. Fruiting fungal bodies
    b. Evidence of insect activity
    c. Surface decay
    d. Wet wood
    e. Identify new areas of wood staining and monitor existing areas for growth
2. Moisture measurements
    a. Contact points between the crib and ship
    b. Contact points between the crib and concrete
    c. Underside of the ship
    d. Areas of new or growing wood staining
3. Time of flight measurements
    a. Areas with moisture content above 17% identified in the previous inspection
    b. New areas with moisture content above 17%
4. Corrective actions needed
    a. Standing water on or near the crib and/or ship
    b. Fruiting fungal bodies
    c. Evidence of insect activity
    d. Growing areas of surface decay
    e. Time of flight measurements above 300 µs/ft

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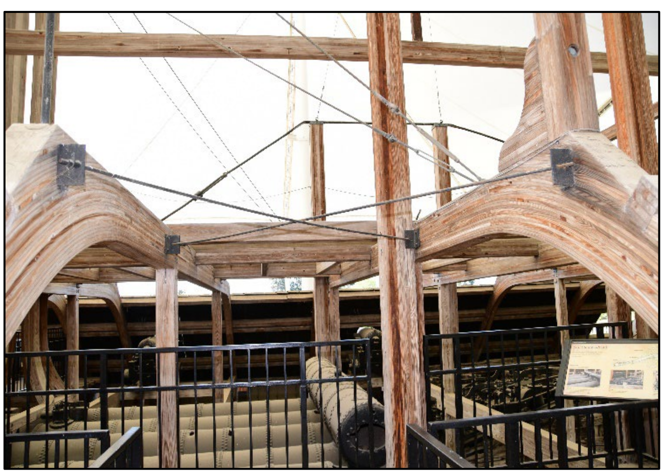
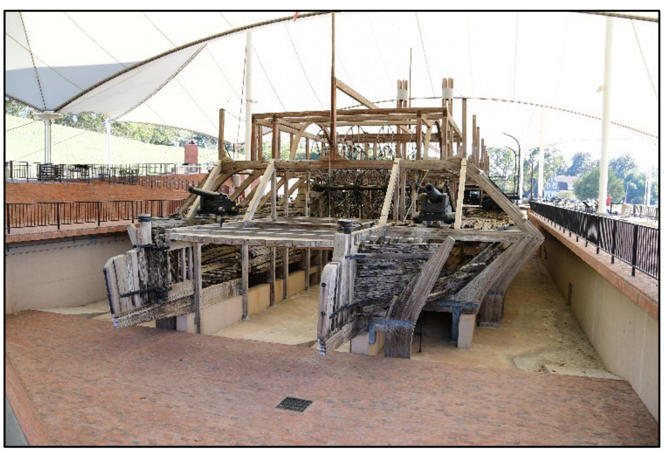
Appendix—Photo Collection from the On-Site Condition Assessment

High resolution photographs available upon request from first author.





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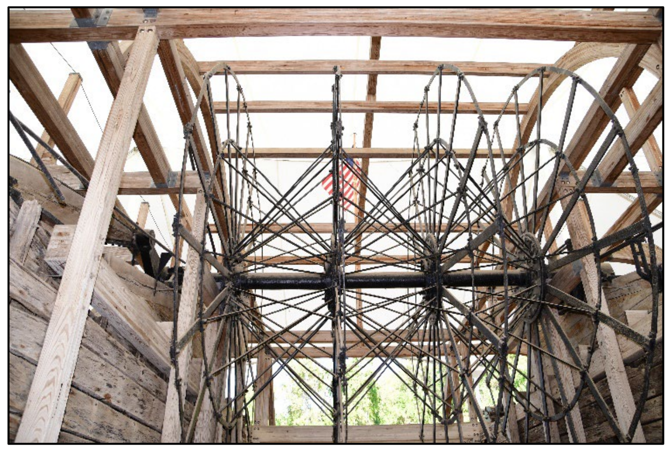

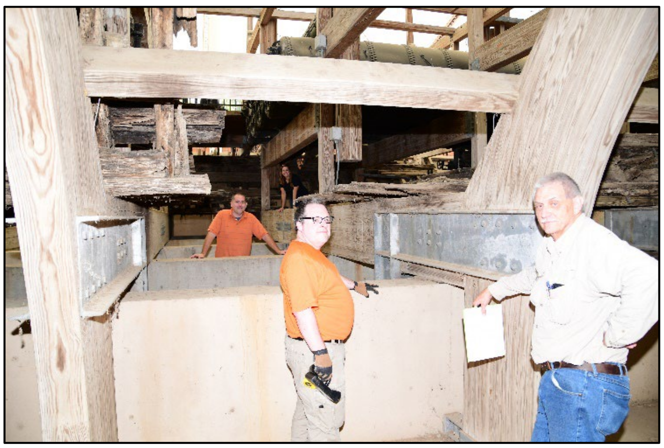









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