

FIELD INVESTIGATION OF A 100-YEAR-OLD TIMBER CRIB FOUNDATION AT A HISTORIC COPPER MINE

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ABSTRACT: In June 2009, the authors conducted a comprehensive on-site evaluation of the timber crib foundation at Alaska's Historic Kennecott Mine Concentration Mill Building. The primary goal of the 6-day inspection was to assess the physical conditions of the existing timber crib foundation and identify timber members and areas that have structural deficiencies. The inspection process included visual assessment, species identification/confirmation, moisture content determination, stress wave scanning test, resistance micro-drilling, and core-drilling. Extensive deterioration was noted in the timber crib foundation members at the lower floors of the mill building. The upper levels of the timber crib foundation exhibited less deterioration, especially in areas where the timber crib cells were not filled with soil. Current efforts are focusing on a comprehensive structural evaluation of the Concentration Mill building with the goal of stabilizing and preserving this historical mining building important to the cultural heritage of early 20th century America.

KEYWORDS: Inspection, historic mine, Douglas fir, timber, substructure, crib foundation

1 INTRODUCTION

An abandoned copper mine located in the village of Kennecott, Alaska (Figure 1), and within the Wrangell-St. Elias National Park & Preserve, is in the process of being fully restored and/or stabilized by the National Park Service (NPS). The mining complex includes 45 buildings with three separate mines located on the mountainsides above the village. It is located approximately 5 miles beyond the east terminus of the McCarthy Road at coordinates 61° 29' 10" North, 142° 53' 19" West.

The mining town was constructed during 1910-12, and its remote site was unique for containing one of the largest concentrations of copper in the world. The copper ore initially contained over 70 percent copper along with trace amounts of silver and gold. The mine was in-service for nearly 27 years until production was ceased abruptly in October 1938. The Kennecott Mines produced an estimated 4 million tons of copper ore valued at over \$200 million. For many years after the

mine closed, Kennecott became a ghost town; lack of maintenance led to deterioration of the roof sections at the upper floors and caused significant damage to the building structure. The village includes several historical buildings that are in the process of being restored by the NPS, which acquired the property in 1998.



Figure 1: Kennecott, Alaska, is located nearly 300 miles east of Anchorage within the Wrangell-St. Elias National Park and Preserve.

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The hallmark structure at the historic village is the massive Concentration Mill Building shown in Figure 2. It was constructed in many phases [1], with new additions added as the copper concentration process became more complex. Each of the phases was supported by a timber box crib foundation with higher building levels stepping up the hillside. As part of the overall effort to restore and stabilize the Concentration Mill Building, the initial focus was placed on the general condition of the foundation structural systems. A more up-to-date condition assessment of the building foundation using current NDE inspection tools was needed to support an overall structural analysis of the entire building system.



Figure 2: Northwest view of the Concentration Mill Building (June 2009).

2 OBJECTIVE AND SCOPE

The focus of this field investigation was a condition assessment of the timber crib foundation in the Kennecott Concentration Mill Building. A three-person inspection team from the Forest Products Laboratory (FPL), part of the U.S. Forest Service, performed the inspection over a six-day period (June 8–13, 2009). The inspection included a variety of non-destructive evaluation techniques, including visual assessment, species identification, moisture content determination, stress wave scanning test, resistance micro-drilling, and core-drilling.

3 CONCENTRATION MILL BUILDING

In 1976, an inspection team from the NPS and FPL performed a cursory inspection of all the buildings at the Kennecott Mine site. Some limited inspection work was done in the Concentration Mill Building; however, it was based solely on visual assessments. The resulting inspection report [2] formed the basis, along with required architectural assessments, to establish the historic site as a National Historic Landmark in 1986.

The Concentration Mill foundation walls at level 3 are shown in Figure 3 and are open-cell type consisting of square timbers measuring $25 \times 25\text{cm}$ or $30 \times 30\text{cm}$ interconnected with saddle notching. The “headers” are

notched members (designated as “E” members) that are aligned perpendicular to the face of the wall. The “stretchers” (designated as “S” members) have no notching and are aligned parallel to the face of the wall. Timber planking is attached at the backside of the stretchers at most locations to contain the soil fill material inside the timber crib cells.



Figure 3: Timber crib foundation wall at level 3 of the Concentration Mill Building during 1976 inspection.

4 INSPECTION METHODS

Our field investigation employed a variety of non-destructive testing tools to provide an enhanced view of the internal integrity of the timbers. The NDE inspection included a moisture meter, hammer sounding, stress wave timer, and a Resistograph micro-drilling device. Initially, we established a reference baseline by collecting data with the NDE tools in areas of the building that appeared to be in good condition. Data collected in other portions of the building would then be compared to these “benchmark” values for each NDE tool; the tools are further described in the following sections. We typically followed a five-step process during our field investigation:

Step 1. Identify those areas in the timber crib foundation members that were visibly damaged or show signs of deterioration using visual techniques. This step included mapping of general condition of the members.

Step 2. A stress wave timing device or hammer-sounding was utilized to identify suspected areas of internal deterioration based on sound wave speeds.

Step 3. A micro-drilling tool was utilized at those suspected areas and helped to confirm the presence and magnitude of internal decay and voids.

Step 4. Core samples were removed from target areas for wood species identification, density measurements, and decay detection in the laboratory.

Step 5. Condition assessment of the integrity of the member based upon all inspection data.

4.1 CORE SAMPLING

Several core samples were removed from the timber crib members at level 1 through level 6 in the Concentration Mill Building. Core samples were drilled perpendicular to the longitudinal fiber axis of the member and measured approximately 10mm diameter and 51mm long. The cores were used to determine compressive stress values, to examine for the presence and type of decay organism, and to determine the moisture content and specific gravity of the building material. All core holes were re-plugged with treated timber dowels to prevent an avenue for future deterioration due to moisture intrusion or insect damage.

4.2 MOISTURE CONTENT

An electrical-resistance-type moisture meter (Delmhorst Inc.) was used in conjunction with 77mm long insulated pins and a hammer probe. Corrections for species and wood temperature were performed automatically by the moisture meter.

Table 1. Summary of moisture contents at different penetration depths.

	Depth of Probe Penetration (mm)				
	25	38	51	64	76
No.	31	3	34	2	29
Max.	40	21.2	40	25	40
Min.	11.2	18.8	12.7	17.5	13.5
Mean	19.7	20.4	25.1	21.3	27.3
St. Dev.	7.6	1.4	9.3	5.3	9.3

4.3 STRESS WAVE TIMING

A stress wave timing device (Fakkop Enterprise) was utilized to measure the time it takes for sound waves to travel through the large timbers (Figure 4). For decay detection purposes, spiked-transducers are inserted into opposing faces (perpendicular-to-grain orientation) of the timber member. Then a hammer impact sends a sound wave through the member with the timing device precisely measuring time of flight through the member.



Figure 4: Testing a “header” timber crib member with a stress wave timer device.

4.4 RESISTANCE MICRO-DRILLING

Sample plots of the resistance micro-drilling data are provided in Figure 5 with a complete set of drill-resistance plots provided in [3]. The sample resistance micro-drilling plots show the internal relative drilling resistance of the member versus the depth of penetration in inches. Short distances of zero resistance are usually indicative of splits or checks in the member. Zero resistance lasting approximately 1-inch and longer is usually indicative of internal decay pockets.

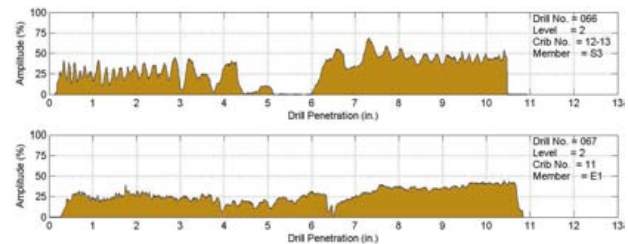


Figure 5: Typical plots showing relative density profile from the resistance micro-drilling tool (1in. = 25.4mm).

4.5 CONDITION ASSESSMENT MAPPING

The overall condition of the timber crib foundation is detailed in [3]. Examples of the physical conditions of the timber crib foundation walls in the Concentration Mill Building are provided in Figure 6 (Level 2) and Figure 7 (Level 6). Many areas of the timber crib foundation walls contained timbers with advanced to severe deterioration.

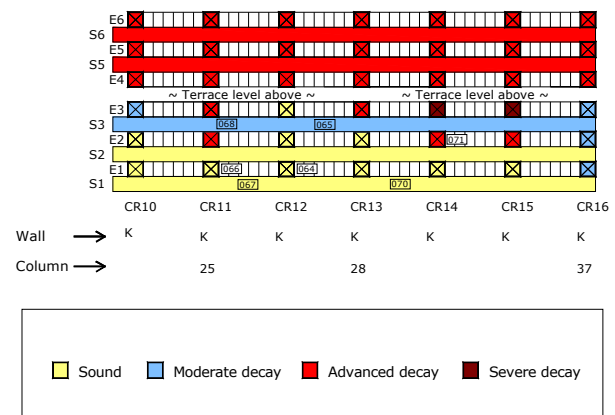


Figure 6: Mapping of the physical conditions of the timber crib foundation wall at level two.

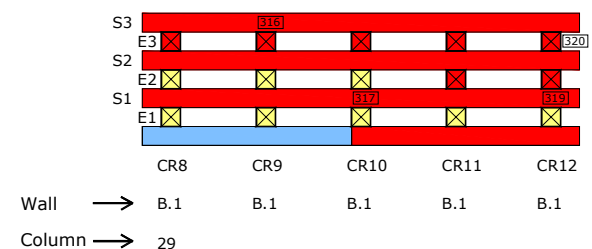


Figure 7: Mapping of the physical conditions of the timber crib foundation wall at level six.

5 SUMMARY & CONCLUSIONS

Our investigation of the Concentration Mill Building was focused on the condition of the timber crib foundation structure from ground level to level 6B. Access for inspection of the Concentration Mill Building was limited by machinery, wall partitions, and other debris. The majority of the work was conducted on the exposed faces of the heavy timber cribbing members (headers and stretchers) at each level. The following conclusions are provided:

- The timber crib foundation walls in the poorest condition, characterized by widespread severe deterioration and multiple failed members and wall sections, were found at level 2 (crib 10-16 terrace level), level 2A (crib 1-6), level 3 (crib 12-22), level 3B (all exposed sections), level 6 (crib 8-12), and level 6B (crib 8-12). The timber crib foundation walls in the best condition, characterized by many sound members with sporadic moderately decayed members, were found at level 1 (crib 2-15) and level 4 (all exposed sections).

- Moisture intrusion into the building is the leading cause of the decay and deterioration in the timber crib foundation walls within the building. Many areas of the timber crib members at several levels in the building are saturated or show signs of past wetness. In addition, much of the construction debris and rock/gravel in the cribbing cells are trapping moisture adjacent to the timber crib members. It appears that much of the water may be coming from surface runoff down the hillside as the wet areas on several levels are in general vertical alignment.

- Microscopic analysis of core samples revealed the presence of decay fungi on most levels of the building. Most decay fungi were soft rot, which is an early form of decay.

- Mechanical testing of core samples indicated compression perpendicular-to-grain values that were similar to those published in ASTM Standard D 2555.

6 RECOMMENDATIONS

The following recommendations are provided for stabilizing and preserving the timber crib foundation walls in the Concentration Mill Building:

- Eliminate water intrusion from roof leaks and hillside drainage that keep the timber crib members at moisture contents conducive for decay activity. One possible solution for the hillside drainage is the installation of a berm structure on the uphill side of the building to divert drainage around the foundation members.

- Improve the stability of the tall timber crib foundation walls located on levels 3 and 4. There are several possible solutions that could help achieve more stability. One option involves anchoring the wall into the hillside via drilled rock anchors and whaler-blocking. Instead of whaler-blocking, the construction of an architecturally

authentic heavy timber crib wall façade could serve as anchorages while minimizing the stress on the original timber crib members. Another option involves excavating the debris and gravel inside the timber cribbing cells to install interior frame bracing systems.

- Utilize diffusible preservatives that can aid in preventing further decay and deterioration. Diffusible preservatives have distinct advantages in historic structures as they are odorless, invisible, and environmentally friendly. As many of the timber crib members are wet, it will aid the diffusion of preservative via the free water in the cell wall.

- Investigate the use of cooling technologies to keep the lower timber crib foundation members from thawing out. It appears that several of the foundation members are frozen due to ice formations and this may have helped to stabilize the foundation system as it has progressively deteriorated over the decades.

- Investigate the feasibility of using other nondestructive evaluation techniques to reliably predict the general condition of the timber crib members that are buried behind the face of the foundation walls.

- Explore the possibility of testing full-size timber-crib members with various degrees of deterioration with specially developed on-site testing equipment. This would aid in learning more about the residual compression and bending strength of deteriorated timber crib foundation members.

7 ACKNOWLEDGMENTS

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