Wood Building Research Center

ANALYSIS OF BIODETERIORATION IN TIMBERS IN 50 YEAR OLD BARN AT JACKSON STATE FOREST

by

John R. Shelly

Report No. 35.04.183

In Cooperation With

Brian Barrette
California Department of Forestry

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FOREST PRODUCTS LABORATORY
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INTRODUCTION

The Wood Building Research Center was contacted by the California Department of Forestry and Fire Protection to evaluate the extent of deterioration in the wood structural members of the "Cat Barn" at Camp 20 in the Jackson Demonstration State Forest in Mendocino County, California. The barn was part of a logging camp established in 1939. The barn was apparently used to repair the logging vehicles (caterpillars) and other equipment used in the logging operation.

The historical significance of the Camp 20 barn was reported by Randolph Langenbach (Assistant Professor of Architecture, University of California at Berkeley) in his letter, dated October 21, 1989, addressed to Forest Tilley, Forest Manager of Jackson State Forest. Langenbach indicated that the barn was built by the logging crew to house the gantry and crane that came from Camp 19. The barn was likely constructed from the redwood trees in the immediate location, whereas the gantry supporting the overhead crane was constructed of different material. Of special historical importance to Langenbach is the small structure attached to the rear of the barn that must have been brought to the site from another camp and is likely older than the barn.

The general design of the barn is similar to California agricultural barns of the period with a high center bay (gantry bay) and two side wings (Langenbach letter) (*Figure 1*). Most of the main structural members are round redwood timbers. It appears that trees of the desired diameter were selected for these members and the only "manufacturing" was to remove the bark and size to length.

The barn is built along the bank of Chamberlain Creek, so that the floor at the front of the barn is at ground level but the rear of the barn is elevated because of the slope of the creek bank *(Figure 2)*. The barn is constructed on a wood foundation of round redwood piers or columns supporting large redwood girders. The columns

Figure 1. - Historic "Cat" Barn at Camp 20 in Jackson State Demonstration Forest, Mendocino County, CA

Figure 2. - Rear of the Barn, showing the elevation of the Main Floor at the Creek Bank

(poles) supporting the superstructure of the gantry bay, bear directly on the large floor girders running east to west *(Figure 3)*. These columns support the roof beams (also round timbers) and are adjacent to the columns which support the gantry. Diagonal bracing provides lateral support to the structure *(Figure 4)*. The wood framed walls are clad with redwood siding boards and the roof is covered with wood shingles.

PROCEDURE

The main structural members were visually examined, sounded with a geologist's hammer and probed with a sharpened implement to determine the extent of deterioration. Zones of obvious wood decay were recorded and zones of probable or potential decay were evaluated by removing a 1-inch diameter core from the member in question.

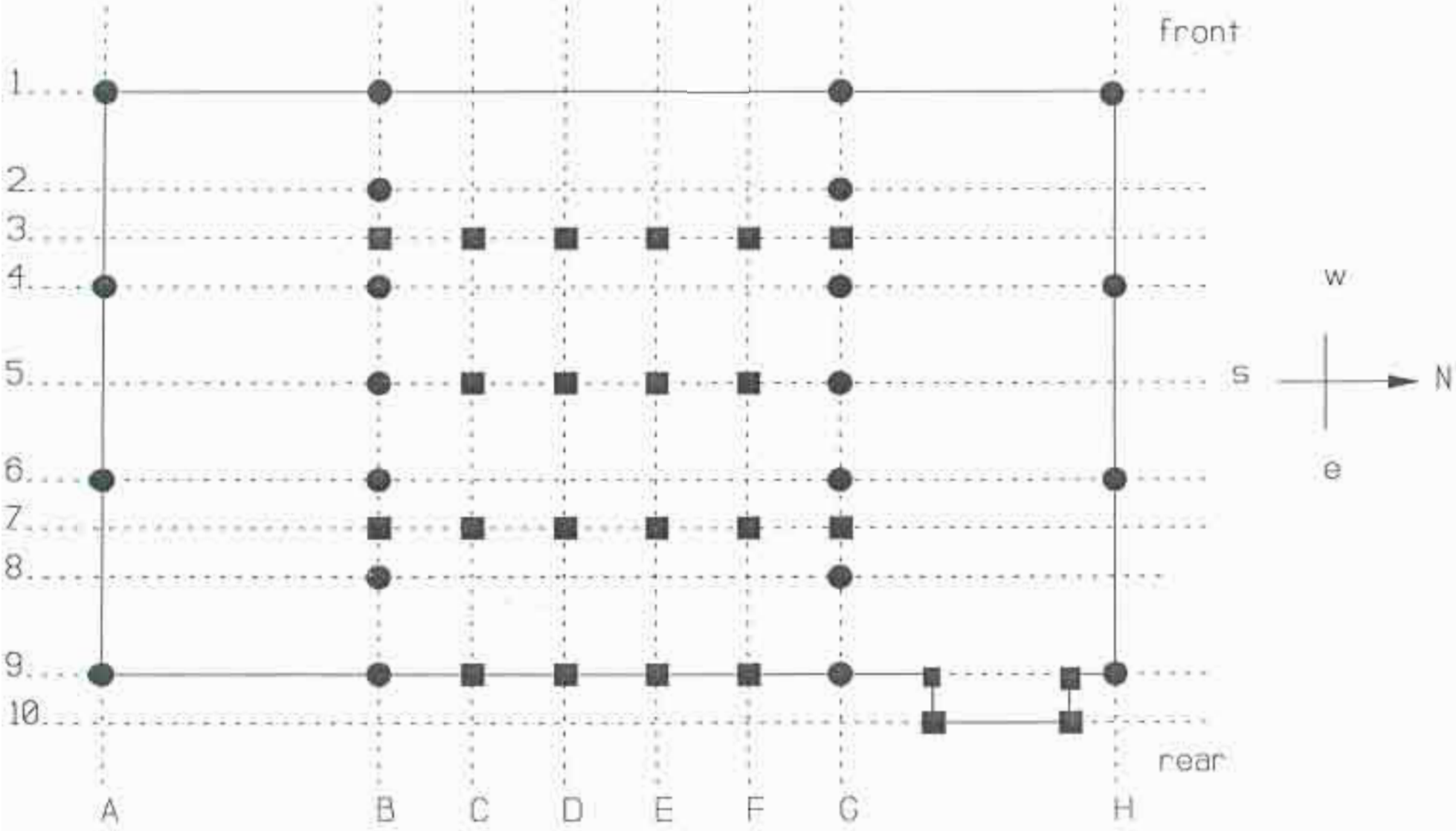
RESULTS AND DISCUSSION

The exterior wall framing and horizontal siding appeared to be in serviceable condition, however, the condition of these materials was not confirmed. Many of the deck boards placed between the main girders of the gantry bay are so completely decayed that they were not safe to walk on (many were removed by a Conservation Camp work crew on the day of our inspection). The main structural members, both horizontal and vertical, exhibited varying degrees of deterioration and will be discussed below. The location of each structural member is identified by using a letter and number which refer to *(Figure 5)*. The letter refers to the grid lines running east to west and the number refers to the north-south grid line. Horizontal or spanning members (e.g. girders) are identified by the grid points at each end of the member (or group of members).

Figure 3. - A Girder (lower left corner) supports the vertical columns.

Figure 4. - Diagonal bracing between main columns of the gantry bay.

Figure 5. Sketch of Camp 20 Barn Showing the location of the main support columns (circles) and Foundation piers (squares)



Substructure of Gantry Bay

The floor of the gantry bay is supported by a system of wood piers (along lines B, C, D, E, F, and G in Figure 5) and girders *(Figure 6)*. This area is at a lower elevation than the two wings; it was apparently dug out to provide access beneath the floor. All of the piers are in direct contact with the ground and were found to be severely decayed at the ground line when sounded with the geologist's hammer.

Seven of the 30 piers were cored to a depth of 10 inches at the ground line. Three of these seven (piers G5, F5, and E9) had approximately 1 to 2 inches of "semi-sound" wood (section of the core which held together, but the wood was punky) in a shell near the outer circumference of the pier, but the remainder of the core was completely decayed *(Figures 7 and 8)*. The remaining 4 cored piers (D9, F7, G7, and G9) were completely decayed at the ground line *(Figures 9, 10 and 11)*.

The piers supporting girders B5-G5 and G1-G9 and pier B3 are at least in partial ground contact along their entire length and as a result are decayed along the entire length *(Figure 12)*. The remainder of the piers in the substructure have a decay zone extending approximately 12 to 20 inches above the ground with the rest of the above-grade length of the pier being relatively sound. For example, a 10 inch core removed 12 inches above the ground line in pier B9 was sound along its entire length.

Girders B1-B9, B9-G9 and G1-G9 support most of the barn superstructure. Girder B1-B9 has zones of advanced decay along its entire length and is in danger of failing completely *(Figure 13)*. Girder G1-G9 has some pockets of decay but is remarkably sound along most of its length. Girder B9-G9 is decayed and infested with drywood termites and is in danger of failing; approximately 80% of the top half of the girder is completely deteriorated *(Figures 14 and 15)*. There did not appear to be a girder along B1-G1; the main columns B1 and G1 are in direct ground contact.

Figure 6. - Substructure of gantry bay showing pier B7 supporting girder B1-B9 and floor boards.

Figure 7. - Pier G5 supporting girder B5-G5.

Figure 8. - Pier F5 supporting girder B5-G5.

Figure 9. - Pier F7 supporting girder B7-G7.

Figure 10. - Pier G7 supporting girder B7-G7.

Figure 11. - Pier G9 supporting girders G1-G9 and B9-G9.

Figure 12. - Pier D5 supporting girder B5-G5, note advanced decay along entire length of pier.

Figure 13. - Section of girder B1-B9 at pier B3, showing advanced decay in both girder and pier.

Figure 14. - Section of girder B9-G9 at pier G9 in the substructure area, showing the location of advanced decay.

Figure 15. - Area of drywood termite infestation in the exterior portion of girder B9-G9.

The wood members in the southeast corner of the gantry bay substructure are wet (moisture contents above 30%) and supporting an active colony of decay fungi. Mycelia were readily apparent on the underside of the girders, joists and floor boards *(Figures 16 and 17)*.

Elevated Section at Southeast Corner

The southeast corner of the south wing is elevated because of the sloping creek bank *(Figure 18)*. This corner is supported by columns A6, B6, B9, and A9 and beams A6-B6, B6-B9, B9-A9, A9-A6. Columns B6 and B9 were examined from the gantry bay substructure and their condition as piers was discussed above. Both are decayed at the ground line but the remainder of the above ground section is sound. Column A6 *(Figure 19)* had a semi-sound shell of 3 inches with the remainder of the 10 inch core completely decayed. Column A9 was cored from the down-slope side starting approximately 6" above ground and cored horizontally so that the end of the core was below ground level at the up-slope side. The core removed from this column was sound for the first 8 inches with the remainder being completely decayed. This core indicated that the above ground section is sound whereas the wood at and below the ground line is decayed; an observation consistent with results of the other ground contact vertical members in the barn.

Except for floor beam B6-B9, which was reported as severely decayed in the gantry bay substructure, the floor beams supporting this southeast corner of the barn appeared to be free of decay, however beams A6-B6 and A9-B9 had evidence of wood-boring beetle deterioration. There was no evidence that this was an active infestation.

Attached Shed

The shed attached to the rear of the barn was apparently built on two beams *(Figure 20)* which are supported by girder G.3/9-G.3/10 and column G.3/10 and by beam G.7/9-G.7/10 and column G.7/10 (decimal notation indicates position between grid

Figure 16. - Fungal mycelia on floor joists and floor boards in the southeast corner of substructure area.

Figure 17. - Fungal mycelia on floor joists and floor boards in southeast corner of substructure area.

Figure 18 - Elevated southeast corner of the south wing at column (pole) A9.

Figure 19. - Column A6 of south wing supporting beam A6-A9.

Figure 20. - Shed attached to the rear of north wing of the barn supported by a pier and girder frame.

points in Figure 5). The columns are severely decayed along their entire length with near complete decay at the ground line *(Figure 21)*. The girders are badly decayed and currently infested with wood-boring beetles *(Figure 22)*.

Perimeter Columns of Wings

The north and south exterior walls of the side wings of the barn are a pole type construction. A series of vertical columns (poles), which are embedded into the ground, provide the foundation and main structural support for these walls. Columns A1, A4, A6 and A9 support the south exterior wall. The condition of columns A6 and A9 were discussed above, as part of the support of the elevated southeast corner. Column A1 was completely decayed at the ground line *(Figure 23)*, but the core removed from the ground line zone of A4 did not reveal any evidence of advanced decay in the heartwood zone (the outer shell of sapwood is totally deteriorated) *(Figure 24)*.

The columns along the north wall have varying degrees of decay at the ground line *(Figure 25)*. Column H1 is completely decayed at the ground line. The 10 inch core removed from the ground line of H4 did not reveal any evidence of advanced decay, although incipient decay was likely. In column H6, the outer 3 inches were completely decayed but the inner core was semi-sound. In column H9, incipient decay was evident in the outer 9 inches and the center of the pole was completely decayed. As with the other vertical members inspected, the advanced decay does not extend very far above the ground line.

Main Columns of Gantry Bay

The main columns of the gantry bay provide the support for the superstructure of this bay and also the inside walls and roof beams of the north and south wings *(Figure 26)*. The columns along the north side (line G of Figure 1) of the gantry bay are in remarkably good condition. No evidence of decay was found in these columns. The columns along the south side of the gantry bay have varying degrees of decay.

Figure 21. - Advanced decay in pier G.7/10 supporting the northeast corner of the shed.

Figure 22. - Pier and girder frame supporting the northeast corner of the shed.

Figure 23. - Advanced decay in column A1 at the southwest corner of the south wing.

Figure 24. - Column A4 of the south wall of the south wing.

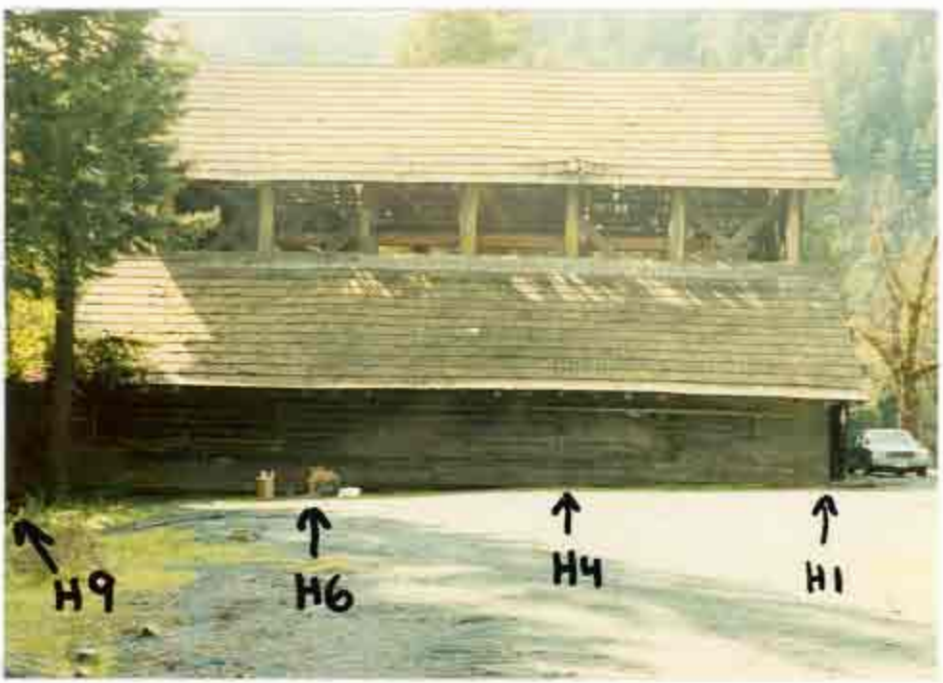


Figure 25. - North side of the barn showing the location of the columns supporting the north wall of the north wing.

Figure 26. - Interior view of the northeast corner of gantry bay.

Column B1 has advanced decay in the bottom 2 feet of the pole *(Figure 27)*. Columns B2, B4 and B5 have a sound outer shell (outer 2 inches) but the inner core is completely decayed at a location 6 inches above the bottom end. Columns B6 and B8 and B9 *(Figure 28)* did not exhibit any evidence of decay along the entire length of the poles.

Superstructure of Gantry Bay

The roof assembly is supported by a system of notched round timbers forming girders and roof beams *(Figure 29)*. The seven main support columns on each side of the gantry bay support a girder running east to west along line B and G. Into these two girders are notched seven roof beams (also round timbers). Trussed framing, bearing on the roof beams, supports roof joists (small diameter poles). The roof is clad with wood shingles on spaced sheathing.

Nearly all of the shingles on the south side of the roof are missing *(Figure 30)*, however the north side is relatively intact. As a result, deterioration is greater on the south side of the barn. The roof beams all show major deterioration in the southern half of the gantry bay.

All of the roof beams are considered to be in danger of failing. Beam B2-G2 *(Figure 31)* was only observed from a distance, however the moss and mildew growing on the surface of the beam indicate that favorable conditions exist for decay. This beam also had a horizontal split at the bearing notch which extended approximately 4 feet towards the center. Beam B4-G4 is missing *(Figure 32)*; evidence indicated it had failed at an earlier date and had been removed. Beam B5-G5 has advanced decay in the top 5 inches, extending from the bearing notch inward for 3 feet *(Figure 33)* and a split extending from the bearing notch toward mid span. Beam B6-G6 has advanced decay in the top half starting approximately 10 feet from the bearing notch and extending for 4 feet towards the middle of the beam *(Figure 34)*. Beam B8-G8 *(Figure 35)* is severely decayed in nearly all of the southern half of the beam and is in **danger of immediate failure.** Roof beams B1-G1 and B9-G9 could not be safely evaluated.

Figure 27. - Southwest corner of the gantry bay showing column B1 bearing on girder B1-B9, note the advanced decay in the bottom of the column and the girder.

Figure 28. - Interior view of the southeast corner of the gantry bay.

Figure 29. - Interior view of the northeast corner of the superstructure in the gantry bay.

Figure 30. - View of the south roof of the gantry bay as seen through the open north side wall (roof in foreground is the north wing).

Figure 31. - South end of roof beam
B2-G2 in the gantry bay.

Figure 32. - The north roof of the superstructure
of the gantry bay at the location of
the missing roof beam B5-G4.

Figure 33. - South end of roof beam B5-G5 in the gantry bay.

Figure 34. - Section of suspected decay in roof beam B6-G6 of the gantry bay.

Figure 35. - Zone of advanced decay in roof beam B8-G8 of the gantry bay.

The roof joists and superstructure framing could not be examined closely but no obvious signs of decay were observed from a distance. These members are of a small enough diameter that they may have avoided decay because they can readily dry after being wetted.

Gantry

The overhead crane is supported by a frame of large redwood timbers. This gantry frame consists of 5 vertical columns along each side, each side supporting a girder *(Figure 36)*. Each side of the gantry frame is connected together by end beams. The gantry beam at the west end failed and was removed at an earlier date *(Figure 37)*. The crane was mounted onto a movable carriage that could traverse the gantry along rails on the top girders *(Figure 29)*.

Gantry columns B2 and B4 have evidence of decay in the bottom 6 inches, however no evidence of decay was found in the remainder of the gantry columns. Also the gantry beam at the east end of the gantry does not exhibit any evidence of decay. Of the two main beams that formed the movable carriage for the crane, the easternmost one appeared to be sound but the westernmost one has numerous deep checks and sounding with a hammer indicated possible decay *(Figure 38)*.

DISCUSSION AND SUMMARY

The barn has extensive wood deterioration caused by both decay fungi and insects. The decay component is either a direct result of ground contact or above-ground exposure to rain. The most severe decay damage was found in the southern half of the gantry bay, because of the failure of the southern roof shingles. Ground contact decay was extensive and distributed throughout the barn. The insect-caused deterioration is apparently limited to three locations at the rear of the barn.

Figure 36. - Northwest corner of the crane gantry.

Figure 37. - Broken gantry end beam at the northwest corner.

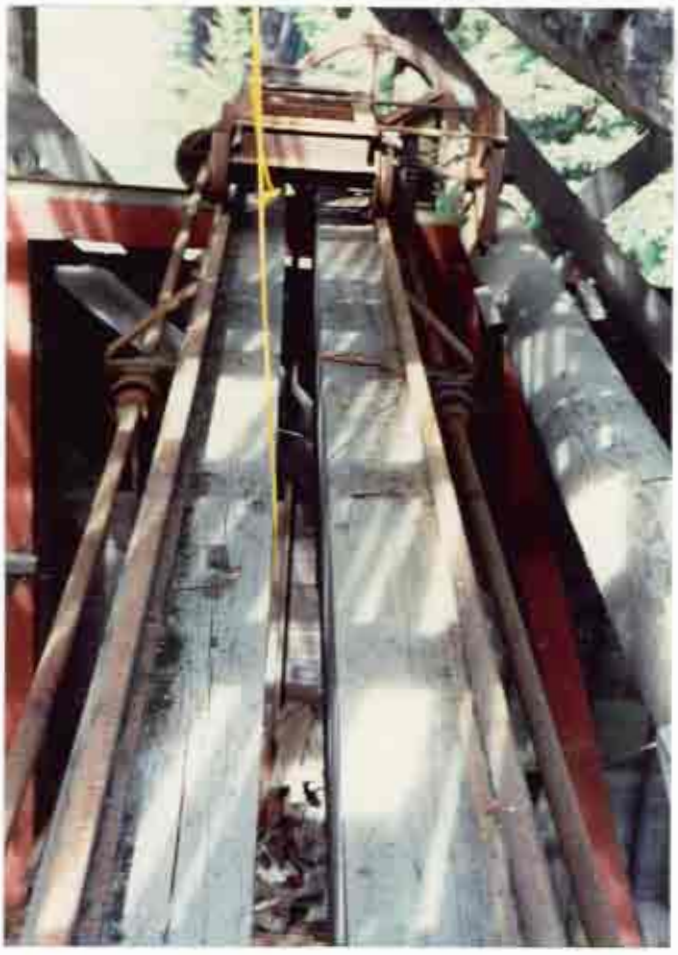


Figure 38. - Double beams of the overhead crane carriage.

Ground Contact Decay

All of the wood members that are in contact with the ground are decayed at or near the ground line. Even though these timbers are redwood heartwood, many are almost completely decayed in this zone. In some, there exists a shell of semi-sound wood near the sapwood/heartwood boundary, which is where the natural resistance to decay is expected to be the greatest in redwood. Even this remaining zone will eventually be consumed by the decay fungi.

The most serious deterioration was found in the substructure of the gantry bay. All of the piers are severely decayed at the ground line and in danger of failing completely. The piers along lines C, D, E, and F and along lines 3 and 7, in Figure 5, support the floor only and not the superstructure. The piers supporting girders B1-B9, B9-G9 and G1-G9, however, are the main foundation for the barn superstructure. If these piers fail the barn will collapse. While these piers presently support the limited loads they are subjected to, they will continue to deteriorate as long as they are in ground contact. Future failure is certain.

The western end of girder B1-B9 is in direct ground contact and as a result is severely decayed and in danger of immediate failure.

The columns at the exterior walls of the north and south wings as well as the piers supporting the shed attached to the rear of the barn, are also severely decayed at the ground line. Considering the small load these columns carry, they will probably survive longer than the foundation piles in the gantry bay substructure.

Above Ground Decay

Decay above the ground is limited to areas where large wood members are readily wetted by rain. This water easily penetrated the end-grain or the checks common in the horizontal surfaces of the large timbers. Re-drying of these large members is minimal because of the large size of the members and poor drying conditions.

Above ground decay was found in the girders of the southern half of the gantry bay, the base of the main roof and gantry support columns along the southern side of the gantry bay (line B in Figure 5), in the southern half of the roof beams and in the southern half of the crane carriage beams.

The most serious deterioration from a structural point of view is the decay of floor girder B1-B9 and the decay in the roof beams. These members are crucial to the structural integrity of the barn. If the roof is repaired before the next rainy season, then some of the floor girders may be salvageable. However it may take 1 to 2 years for the larger members to dry enough to arrest the decay. The roof beams are considered decayed to a degree that makes them unsalvageable. Roof beam B8-G8 is in danger of immediate failure and the remaining roof beams are also considered unsafe.

The decay at the base of roof and gantry columns B1, B2, B4 and B5 is of concern. However these columns may be repairable by using an epoxy consolidation technique or designing a structural connection from the floor girder to the sound wood in the columns.

The decayed crane carriage beams will probably survive in their present condition. However, if any additional load is applied to the crane or if it is not protected from future rain, then its condition will need to be reevaluated.

Insect Damage

The damage caused by wood-boring beetles, in the beams supporting the southeast corner of the south wing and the beams supporting the attached shed, did not appear to be active. The damage caused by these insects was not sufficient to warrant replacement.

The damage caused by the drywood termites in girder B9-G9 is extensive. This girder also has extensive decay damage and is not considered salvageable.

RECOMMENDATIONS

The barn has suffered serious biological deterioration in many major structural members. It is imperative that the south roof of the gantry bay be repaired to minimize water infiltration into the barn and thus minimize future decay. Unfortunately the roof cannot be repaired until the roof beams are replaced, or at the least thoroughly shored and braced. The condition of the roof joists and spaced sheathing boards could not be assessed, therefore any work on the roof must proceed with caution.

Girder B1-B9 and the gantry and roof columns it supports must be adequately shored before work is done on the roof. Shoring of the gantry floor and lateral bracing of the west end is also needed. These shoring and repair recommendations are not to be taken as comprehensive; additional evaluation of the building shoring needs should be done by qualified design and construction professionals.

The following critical areas of decay were identified as requiring repair or replacement, listed in order of structural importance.

- Girder B1-B9
- Roof Beams B2-G2, B4-G4, B5-G5, B6-G6 and B8-G8
- Piers supporting girders B1-B9 and G1-G9
- Girder B9-G9
- Piers and girders supporting attached shed
- Columns supporting exterior walls of both wings
- Substructure of gantry bay floor

All replacement wood members in ground contact should be replaced with members pressure-treated with a wood preservative and rated for ground contact use. Acceptable standards (set by the American Wood Preservers Bureau, AWPB) and treatments are listed below. Note that LP denotes lumber and plywood, specify CP for round building poles and CFP for foundation poles.

- LP-22 Waterborne preservatives (CCA or ACZA)
- LP-33 Pentachlorophenol (Penta) in light solvent
- LP-44 Penta in LPG (cellon treatment)
- LP-55 Creosote
- LP-77 Penta in heavy oil

Any of the above treatments could be used effectively in an uninhabited barn, but penta and creosote should not be used in inhabited structures.

Long term control of the wood-destroying insects is difficult if not impossible in a forest setting. Replacement of infested wood or periodic spot treatment with an approved insecticide will probably be as effective as a more intensive method such as whole structure fumigation.