WESTERN WOOD
STRUCTURES, INC.

20675 S.W. 105th Ave.
Post Office Box 130
Tualatin, OR 97062-0130

Telephone: (503) 692-6900
Fax: (503) 692-6434

wwsi@westernwoodstructures.com
www.westernwoodstructures.com

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Port of Moses Lake
Attn: Patrick Jones
7810 Andrews St. N.E., Suite 200
Moses Lake, Washington 98837-3204

Patrick,

Brentley A Matthias, P.E. of Western Wood Structures, Inc. (WWSI) inspected the timber roof truss systems for hangar buildings 401 and 408 on November 7th and 8th, 2012. Hangar buildings 401 and 408 are located at the address listed above. Each building is approximately 160'x120' with seven trusses in each building. Building 401 is still used as a hangar where as building 408's floor space has been converted to office space and warehouse type storage. The inspection was performed from an aerial man-lift with an operator, both supplied by the owner, or from catwalks where the lift could not reach. Previous building inspections prompted this inspection.

In both buildings, all the trusses have similar construction. These trusses are double chord, single web bowstring style trusses. Typical construction of the top chords consists of glue laminated timbers with the desired curvature built into them. The bottom chords are a double run of solid sawn members spliced at intervals along its length. Bottom chord splices typically consist of a solid sawn wood block between the two bottom chords and solid sawn wood plates on the exterior sides of the chords. Webs are solid sawn wood members that are sandwiched between the chords at the top and bottom of the trusses. Connections typically consist of machine bolts and split rings at wood to wood connections and machine bolts where metal side plates are attached to the wood members.

In this particular case, the trusses span 160'-0" from center of bearing to center of bearing and are spaced 20'-0" on center. The 160' trusses have curved double top chord members that are glue-laminated. The top chord (TC) consists of multiple layers of 2x6's glued together with lapped joints. There are no splices in the top chord members. The bottom chord (BC) is a double run of 6x12 sawn members. There are six splices along its length. The webs (W) are either 6x6 or 6x8 sawn timbers. The attached drawings were generated from original construction documents to illustrate the truss connections and details. Field verification is recommended for all dimensions and configurations as actual construction of building can deviate from the original drawings.

Observations

The limitations of this inspection were due to access. For both buildings the trusses marked T1 and T7 have the exterior walls framed tight to the side of these two trusses. This did not allow the exterior side of trusses T1 and T7 to be inspected in either building. In building 401, two planes remained inside the hangar and access by man-lift was not granted above one of the planes. The other plane restricted access for the man-lift by occupying floor space. In building 408, office space and storage racks occupy approximately 80% of the floor space. This severely restricted access by man-lift. Where the man-lift was not able to get into, the catwalks were used to visually inspect truss members from a distance in both buildings. Portions of either buildings that had limited or no access at the time of inspection will have to be addressed during the repair and upgrade work.

In both buildings, the roof trusses appear in satisfactory condition given the age of the structure. The trusses have deflected downward over time, but that is expected. The top chords of some of the trusses are out of alignment side to side. This appears that it may have occurred at the time of construction. There is no sign that the connection between the roof joists and the top chord have shifted or failed to create this condition. It also appears that the top chords may have been glued onsite since there is no splice along the entire 167' length. This process of gluing and installing this top chord onsite would have presented many obstacles such as keeping a perfect alignment in the top chord. Throughout the inspection some members were found to be broken in place. Below is a summary:

Building 401:

Top Chords –	Appear OK
Bottom Chords –	Mark # BC2-1 is broken at truss T2
	Mark # BC3-2 is broken at truss T6
	Mark # BC1-1 is broken at truss T7
Webs –	Appear OK
BC Splice Plate –	10-15% Split or Broken
2x12 Roof Joists –	1-2% Split or Broken

Building 408:

Top Chords –	Appear OK
Bottom Chords –	Mark # BC6-1 is broken at truss T3
Webs –	Appear OK
BC Splice Plate –	10-15% Split or Broken
2x12 Roof Joists –	1-2% Split or Broken

During this inspection the condition of the horizontal wind trusses was observed as well. The horizontal wind trusses reside between the first and second roof trusses at each end of each building, four in all. Please see the details on the attached drawings. These wind trusses are held up in place by double 3x14 sawn beams at 10'-0" on center (15 double beams per wind truss, 60 total in both buildings).

According to the original drawings provided by the Port of Moses Lake these 3x14 beams would have to be notched to install the system as drawn. The notches are on the bottom of the beams (tension side) one notch at each end. The drawings do not detail how the beams were to be notched and so the notches appear oversized for easier installation.

Notching beams in general reduces the section thus reducing the capacity. It is highly recommended that beams not be notched on the tension side of beams. This condition results in a stress concentration at the corners of the notches which creates a tendency to split. It was found during the inspection referenced above that approximately 25% of the total notched beams, both buildings combined, have split with six double beams being split at the one wind truss between trusses T1 and T7 opposite the door side of 408 building. This side of 408 currently holds occupied office space below the affected truss.

Truss Analysis

The trusses were analyzed with a finite element computer analysis, using the general structural analysis program, SAP2000, written by Computers and Structures, Inc. The required loads cases and load combinations used are given in the 2009 International Building Code (IBC). Three load combinations were considered for the truss; Dead Load only and Dead Load + Uniform Roof Snow Load and Dead Load + Unbalanced Roof Snow Load. The local design roof snow load is 25.2 psf which was used for the balanced load case. For the unbalanced load case, the roof snow load is half of the uniform roof snow load at the peak and two times at the eave. Results from the SAP2000 analysis was then used by the Western Wood Structures, Inc. in-house program SAPSTRESS to check the adequacy of the individual elements.

SAP2000

A two-dimensional truss analysis was performed for defined element forces (axial, shear and moments). The self-weight for each member was included in the dead loads.

SAPSTRESS

The adequacy of each member was checked for shear, tension, compression, and for combined stresses based on current allowable timber design values.

Connections

The connections have been checked using current timber and bolt capacities. The connection design check conforms to the requirements of the National Design Standard for Wood Construction, 2005 Edition. (NDS)

Findings from Truss Analysis

The trusses are significantly overstressed. The double top chord members are stressed up to 1.05 times the allowable value for combined compression and bending at the exterior trusses and 1.00 times at interior trusses. The double bottom chord members are stressed up to 1.88 times the allowable values for combined tension and bending at the exterior trusses and 1.92 times at the interior trusses. Web members with mark numbers W9, W13, W17, W21 and conversely W23, W19, W15, W11 have excessive l/d ratios for the unbalanced load cases.

Some web-to-chord connections are also inadequate. Based on the current split ring design values obtained from the 2005 NDS, the web to chord connections are overstressed up to 1.49 times the allowable values.

The bottom chord splice is stressed up to 1.03 times under full loading.

The heel connection to the bottom chord utilizes 1-1/4" diameter bolt. Under current code this large size bolt does not have a design value, so no allowable load can be attributed to this connection.

A lateral load analysis for the roof trusses has not been performed in this report. In addition the roof purlins and roof deck have not been evaluated.

Discussion of Truss Analysis Results

The timber trusses analyzed are significantly overstressed in the bottom chord. This is largely due to the differences in allowable sawn timber stresses between the time the truss was designed and current values. For example, the value for bending stress has been reduced from 1450 psi to 1000 psi and the value for the tensile stress has been reduced from 1450 psi to 675 psi.

Increases to the snow loading and the addition of unbalanced snow load are two other factors that effectively reduce the capacity of the trusses.

In the 1991 NDS, bolt design values were limited to fasteners with one inch diameter and less. This change came after several field problems with connections involving large diameter bolts and the results of new research. The research showed that in service drying, variables in workmanship and perpendicular to grain load components can interact and adversely affect the capacity of connections made up of multiple large diameter relatively stiff bolts. The connections in this particular inspection appear to have performed satisfactorily over the years. However, current code does not have any allowance for this size bolt, so the use of the previous procedures in design specifications is the sole responsibility of the designer.

Repair and Upgrade Recommendations

These trusses should be repaired and upgraded to bring their capacity up to current building code requirements. The required repairs include the following.

1. Replacing broken bottom chord members as well as installing a post-tensioning system along the full length of the bottom chord.
2. Strengthening the top chord.
3. Provide additional lateral stability for the truss webs that have excessive L/d ratios.
4. Upgrade heel connection and web to chord connections that are structurally deficient.
5. Repair or replace all notched beams that support the horizontal wind trusses. Since so many of the notched beams have already failed, particularly above the office space in building 408, it is strongly recommended that repairs on theses beams occur immediately. It is recommended that a repair be installed on all beams whether they are split or not. This will prevent further splits from occurring and the existing split beams from completely fracturing and the horizontal wind trusses collapsing.
6. Lateral analysis of the roof system should be performed.

All this work should be done by a qualified company with at least five years of experience in timber rehabilitation and repair under the direct supervision of a Professional Engineer.

Respectfully Submitted,
Western Wood Structures, Inc.

Brentley A Matthias, P.E.
Project Engineer