Bowdoinham Recycling Center ~ Rehabilitation Summary

On August 21st 2013, Calderwood Engineering inspected the Bowdoinham Recycling center. The building is a converted (3) story chicken barn that has been modified several times throughout its service life. At first glance the 36' wide by 290' long building appears to be in relatively serviceable condition but upon further inspection there are many structural members that are visibly overstressed.

Recently the building has had a structural failure of the roof which since has been repaired. In 2011 Calderwood Engineering performed a structural analysis of the roof system and concluded that the existing members were undersized and needed to be reinforced. Two different rehabilitation options were designed and detailed for the rehabilitation of the roof. During the 2013 inspection only a fraction of roof members were found to be reinforced, and those that were reinforced were not strengthened to the level that was shown in Calderwood Engineering's details. These modifications, although better than leaving the roof as it was originally, are not enough to bring the roof structure up to code. The existing repairs should be added to in order to bring the roof up to code to prevent future structural failure.

Calderwood Engineering has calculated an unbalanced snow loading of 60psf (pound per square foot) on the roof using the 2012 International Building Code (IBC) and the Minimum Design Loads for Buildings 2010 (ASCE 7). This snow load is much larger than the capacity of the roof members. Calderwood Engineering has designed various options to strengthen the roof.

The following roof members were found to be undersized:

- 2x6 Rafter @ 3'-0" Upper Section Spanning 7'-0" +/-
- 2x6 Rafter @ 3'-0" Lower Section Spanning 11'-0" +/-
- (2) 2x8 Spanning 12'-0"

The recommended rehabilitation for the Upper section of the 2x6 rafter is to sister an additional 8'-0" +/- long 2x6 to the existing rafter.

There are (2) recommended rehabilitation options for the lower section of the 2x6 rafter. The first option is to add (1) 2x6 web member and (1) 2x4 web member to the lower section, converting this portion into a truss structure. These members would be fastened to the existing members with plywood or OSB gusset plates and nails. This option would also require (1) 2x4 to be sistered to the existing rafter. (Option 1)

The second option for the lower section of the rafters is to sister (2) additional 2x10 to the lower half of the existing 2x6 rafter. (Option 2)

There are also (2) rehab options for the double 2x8 "Roof Girders" that support the rafters and span 12'. The first option is to add (2) 2x4 kickers off of the supporting posts @ a 45° angle to reduce the 12' span to (3) 4' spans. These smaller spans reduce the stress in the existing members to an allowable level. (Option A)

The second option is to add (1) 11 7/8" x 1 3/4" Boise Cascade Versa-Lam Beam to the existing (2) 2x8. The existing posts carrying the 2x8's will need to be notched to allow the additional of the Versa-Lam Beam. (Option B)

Calderwood Engineering also analyzed the rest of the existing structure under dead, live and snow loads. The use of the building was determined to be a light storage warehouse on the account that the majority of the structure is housing various materials. According to ASCE 7 and the IBC for a light storage warehouse the design live load is 125 psf. The existing allowable live loads were calculated for the structural members, below are the results:

- Floor Joists (2x8 12' Span @ 2' Spacing) ~ 27.4psf
- Triple (2x8 Beams Supporting (1) Span (Center Bay Undecked) ~ 20.6psf
- Triple (2x8 Beams Supporting (2) Span (Center Bay decked) ~ 10.3 psf
- 6x6 Built-up Column (2nd Floor Center) ~ 61.1 psf
- 6x6 Built-up Column (1st Floor Center) ~ 56.1psf

From the above results it is evident that the existing structure is not adequate to support a design live load of 125psf. In order to provide the best solution for the strengthening of these members a number of rehabilitation options have been designed.

The option designed for the strengthening of the existing floor joists is to sister each floor joist with a 5 1/2" x 3 1/2" Boise Cascade Versa-Lam Beam. A secondary option was explored but when looking into the cost for this option is was removed because the cost was extremely high.

There are (2) rehab options for the triple 2x8 beams. The first option is to add (2) 5x5 kickers @ 45° angle to each existing posts to reduce the existing 12' span to (3) 4' spans. This would reduce the stresses in the members to an allowable level. This option is relatively low in cost but it would reduce the available area to move and store materials, which is not ideal. (Option 1)

The second option is the addition of (2) C6x8.2 channels (1) on either side of the existing members. The channels would be connected by 1/2" diameter A325 bolts spaced at 2' centers. The bolts would be through bolted in holes drilled through the channels and the existing 2x8's. This option is more expensive but does not reduce the usable area in the building.(Option 2) Triple 2x8 shall be jacked up 1/4" at center span or until visibly level prior to the addition of the 5x5 kickers or C6x8.2 channels.

The existing columns were found to be built up columns made up of (3) 2x6 or to be solid sawn 6x6. The column rehab was designed separately for the 1st and 2nd floors. The columns on the 3rd floor supporting the roof were found to be adequate and no further modifications are required.

There are no modifications required for the 2nd floor columns if the rehab option using the 5x5 kickers is used. If the kicker option is not included, an additional 2x6 is required to be added to the existing post. The first floor columns are undersized with or without the addition of the kickers and need (2) 2x6 added to the existing column to carry the design loads. These 2x6's should be added (1) on each side of the existing column such that the final section would be (5) 2x6 lined up face to face.

The exterior walls were found to be made up of 2x4 @ 2' centers. For the design loads, these were found to be adequate to resist the vertical loads as long as they are braced laterally by sheathing. During inspection one entire wall did not have any sheathing connecting the 2x4's together. There were few lateral bracing members installed but these members do not brace the 2x4's enough to develop the capacity needed. In order for the existing walls to be able to carry the design loads 1/2" plywood/OSB should be added to all exterior walls that are not covered by plywood or planking.

During inspection it was found that in the rear of the building there was a portion where the first floor is extended up to the floor joists of the 3rd floor. This sections is approximately 16' high and has (2) large trusses that span 24' each. The trusses have been modified with the addition of 1" diameter bolts to the connection of the tension diagonal web members. Calderwood Engineering performed an analysis of the existing truss and found that not all the existing members were adequate to carry the design loads. The following truss members were found to be undersized:

- Bottom Chord - (3) 2x10
- Top Chord - (3) 2x10
- Tension Diagonal - (2) 2x8
- Compression Diagonal - (2) 2x8

The recommended option for the rehabilitation of the bottom chord is to add (2) 1/4" thick plates to the middle 14' +/- of the bottom chord. It was determined that the tension force in the bottom chord in the middle portion could be carried by adding (3) 2x10 to the existing (3) 2x10, but this did not seem feasible so the addition of a steel plate was inspected. The new steel plate should be connected with the existing 1" diameter through bolts located in the bottom chord. The minimum required width of the plate was found to be 4 5/8", but it is very likely that the location of the existing bolt holes will control the width.

The recommendation for the top chord is to add (2) 2x4 lateral braces at 6' centers. Each brace should be connected to the top chord and extend at a 45° +/- angle to the existing floor joists. There would be (1) brace required on each side of the top chord every 6'. This option is recommended because it requires the least amount of work and material added to the top chord.

The recommendation for the tension diagonals is to replace the (2) 2x8 members with (2) 1/4" thick steel plates. Wood was not an option for the tension diagonal because

it would require (5) additional 2x8 which did not seem feasible. The 1/4" would be connected to the bottom chord with the same bolts as the bottom chord steel plates and would be connected to the top chord with the existing through bolts. Since the capacity of the bolts in the wood in the top chord is not adequate to develop the tension in the diagonal members, the installation of (2) C6x8.2 channels as described in the repair of the triple 2x8's above would be required. These channels should extend (1) span on each side of the truss and would be enough to strengthen those spans. With the addition of the channels the bolt capacity is large enough to develop the tension required for the diagonal members.

The recommended solution for the compression diagonals is to add (2) 2x10 or (1) 6x6 solid sawn post to the diagonals. These members would be cut to be wedged tight between the existing vertical and horizontal members. Also (2) 1" diameter A325 bolts should also be installed through the existing 2x8 compression members and bottom/top chord in order to develop the compression members. Both the bolts and the direct compression of the additional members would be required to develop the compression force required.

For the rehabilitation of the truss, the web diagonal members will be required to be removed during construction. In order to perform this work temporary supports must be installed to ensure the truss remains in place. It is our recommendation to use (2) 6x6 solid sawn timber posts at a 45° angle off of the existing built up columns. The top of the temporary supports would be located below the location where the web diagonals meet approximately 6' off of the columns. These temporary supports would be required to remain in place until all the truss modifications are completed.

The existing columns in the rear section of the building that extend 16' +/- to the floor joists of the 3rd floor are built up 12x12 columns. After analysis it was found that these columns are adequate to carry the design loads, therefore no modifications are required for the 12x12 columns.

Once all of the above solutions were designed, Calderwood Engineering had a 3rd party perform a cost estimate for each of the options. The following are the estimates for each option.

Roof Truss Rehab Option 1-A (Sheet 2) $ 28,000.00
(Roof Truss Members & 2x4 Kickers Added)

Roof Truss Rehab Option 1-B (Sheet 2) $ 39,500.00
(Roof Truss Members & 11 7/8" x 1 /34" Versa-Lam Added)

Roof Truss Rehab Option 2-A (Sheet 2) $ 31,600.00
(2) 2x10's, (1) 2x6 & 2x4 Kickers Added)

Roof Truss Rehab Option 2-B (Sheet 2) $ 43,000.00
(2) 2x10's, (1) 2x6 & 11 7/8" x 1 /34" Versa-Lam Added)

F**loor Rehab Option 1 (Sheet 3)** $ 63,000.00
(Addition of Versa-Lam to each floor Joist & 5x5 Kickers to each Column)

F**loor Rehab Option 1 (Sheet 3)** $115,000.00
(Addition of Versa-Lam to each floor Joist & (2) C6x8.2 to Carrying Beams)

Truss rehab (Sheet 4 & 5) $ 7,200.00

Exterior sheathing (no finishes) $ 7,000.00

The least expensive of the options is the roof option 1-A and floor option 1. The estimator also advised that an additional $10,000 be added to the overall estimate for miscellaneous unseen items. This brings the least expensive project total budget to $115,200.

If head room is a concern in certain spans where the addition of the 5x5 kickers would not able to be used to maintain room for current needs, floor rehab option 2 may be implemented. For these locations an additional $650.00 per span should be added to the total.

In conclusion, the existing structure has not been designed or built to carry the anticipated design loads for the use of the structure. Many members are currently overstressed and if nothing is added to strengthen the structure or the building use is changed the structure is in danger of failure. Multiple rehabilitation options were explored and the most cost efficient options have been described above to reinforce the existing structure in order to prevent structural failure. With the cheapest options chosen for the structure the estimated cost of the project is $115,200.