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November 22, 2010 ADP #10198

Kathy Durgin-Leighton
Town Manager
Town of Bowdoinham
13 School Street
Bowdoinham, ME 04008

Re: Public Works Garage Roof Evaluation

Dear Kathy:

As outlined in our contractual scope of services, Associated Design Partners Inc. has performed a structural evaluation of a representative sampling of existing steel roof truss framing elements of the Bowdoinham Public Works Garage in Bowdoinham, Maine. It is my understanding that the town is considering adding roofing insulation in pursuit of potential energy savings opportunities. The purpose of this evaluation is to determine the in-place snow load capacity of the existing roof, because additional roof insulation is expected to increase potential snow loading conditions on the roof.

We have completed field investigation work and provided structural analysis for roof framing systems as stated within. This report does not address all aspects of the current building code or the many variable load combinations to which this structure might be subjected. This report focuses on the static dead load, and code specified snow load conditions applied to the roof framing members only. Lateral stability for wind – seismic loads, foundations, wall framing, and other building elements not specifically addressed within this report are excluded from this evaluation.

Summary of Findings

My analysis indicates that the approximate uniform snow load capacity of the existing steel trussed roof framing system is approximately 15 psf (pounds per square foot). My interpretation of the current (2006) International Building Code (IBC) indicates the uniform design snow load for this un-insulated and un-heated roof is 43 psf. <u>My findings and analysis indicate; the roof framing will require structural reinforcing and upgrading to meet the current IBC code specified uniform snow loads in addition to the added dead load imposed by the new insulation. A winter snow monitoring and removal program should be implemented until structural reinforcing / upgrade work is completed.</u>

Warning: Some of the steel frame bracing is missing or disconnected. Without the bracing being fully restored, this building is in jeopardy of collapse. I strongly urge the Town to have repairs made immediately before significant snow accumulations. Our analysis assumed all of the bracing to be in place.

Documents and Information Relied upon

1. AISC ASD steel design manual, 9th Ed
2. National Design Specification (NDS) for Wood Construction, 2005 Ed.
3. International Building Code, 2006 Ed.
4. ASCE 7-05 "Minimum Design Loads for Buildings and Other Structures"
5. Field measurements collect by Associate Design Partners personnel.

Building Description

The building is a one story pre-engineered steel truss structure with a total square footage of approximately 4000sf. The steel truss elements consist of painted steel angles of various sizes and lengths, oriented in a moment-resisting gable type frame (column with integral roof girder) configuration. The slope of the top chord of the trusses is approximately 5:12 (22.6 degrees from horizontal). The majority of the connections between angles are welded gusset plates, with the exception of the bolted splice connections at the top and bottom chords near the eaves.

The steel frame spacing varies from approximately 12ft-14ft o.c. 2x6 wood purlins spaced at approx. 24" o.c. span between the trusses at the roof and walls, and provide support for the corrugated metal wall and roof cladding. Currently there is no insulation installed at the roof, suspended ceiling or walls, and the building is unheated in the warehouse and heated in the mechanics bay area.

This building has one condition that must be recognized and considered in order for the calculated results to be valid and accurate.

1. Several frame braces have been cut disconnected or otherwise missing. These diagonal and horizontal member braces are critical to the performance of the structure. Our structural analysis assumed they were all in place and properly connected. Without all of the bracing reconnected, this building roof is in jeopardy of collapse. The photo to the right shows a missing brace and a broken purlin.

Evaluation

Roof loads used in my analysis were grouped into applied dead and live loads. Dead loads refer to the stationary or permanent weight applied to the roof structure, and may include the weight of roofing, permanent equipment, piping, electrical wiring, suspended ceilings and lights. Live loads include snow loading as outlined in the IBC 2006 code design uniform roof snow loads for buildings in or near Bowdoinham, Maine.

Code analysis

I reviewed the 2006 IBC code, and ASCE 7-05 "Minimum design loads for buildings and other structures". The 2006 edition of IBC lists ASCE 7-05 as an acceptable alternative reference for determination of the minimum design loads for buildings and other structures. Both codes have provisions for determining the minimum design snow load for buildings in Maine. Figure 1608.2 in IBC 2006 (see attached map) and Figure 7-1 in ASCE 7-05 both show the design ground snow load for Bowdoinham, ME to be 60 psf. To determine the design sloped roof snow, the ground snow is reduced by a factor of 0.7, then adjusted based on the exposure of the roof, temperature of the building, importance of the facility, and roof slope angle. My interpretation of the code yields the following:

1. Ce – Exposure adjustment = 1.0 (IBC Table 1608.3.1 (attached), ASCE Table 7-3)
2. I - Importance adjustment = 1.0 (IBC Table 1604.5, ASCE 7-05 Table 7-4)
3. Ct – Temperature adjustment = 1.2 at un-insulated roofs in buildings without permanent heat. (IBC Table 1608.3.2 (attached), ASCE Table 7-3)
4. Cs = 0.86 for a 5:12 pitched cold roof.

The analysis is based on our limited field measurements, the ASCE 7-05 "Minimum Design Loads for Buildings and Other Structures" code, as reference by IBC 2006. Per the ASCE 7-05 code, the current design uniform snow load for this roof, is Pf = 0.7x 60psf x 1.0 x 1.2 x 0.86 = 43psf. The dead load of the roof is estimated to be 5 psf +/-, including the weight of the structure. The dead load of the suspended ceiling at the mechanics room is estimated at 3 psf. If this building were to be built today, to the current code, the total design uniform (dead load + snow load) gravity load would be 48 psf at the main area (high bay) and 51 psf for the roof above the mechanics room.

The building code also specifies that unbalanced snow loading must be considered for gable roofs. Unbalanced snow can be defined as snow accumulation on one side of a gable roof only, due to windblown snow. My interpretation of the building code yields a theoretical maximum unbalanced snow load of 110 psf, much higher than the code uniform sloped snow loads of 48/51 psf.

Structural analysis

Based on the field measurements collected, I created a model of one trussed framing member, utilizing RISA 3d structural analysis software. I applied the uniform dead and snow loads, and also uniform dead with unbalanced snow load, until I reached a solution that yielded the highest allowable loads without overstressing any one framing member. The angles that make up the trusses are assumed to be Fy=36ksi steel.

Based on the analysis results, it is my opinion that the allowable snow load capacity of the Bowdoinham Public Works Garage is as follows:

1) Allowable uniform sloped snow load capacity = 15 psf, 12 psf above mechanics room.
2) Allowable unbalanced snow load capacity = 12 psf, 9 psf above mechanics room.

Recommendations
Based on my analysis results, the roof framing throughout the Public Works Garage appears to have a uniform snow load capacity of 9-15 psf. This is much less than the current code prescribed minimum design uniform sloped snow load of 48-51 psf, and unbalanced snow load of 110psf for this building. Also, the 2x6 purlins have a similar sub-code capacity.

If new insulation is provided in order to improve the thermal characteristics of the roof, the existing roof framing will be significantly overstressed under the increased code specified minimum design uniform snow load of 48-51 psf. It is recognized that by heating the entire building, even if insulation is provided, the theoretical design snow load will actual go down to 30 or 37 psf because the thermal factor Ct would change from 1.2 to 1.0 or 1.1 dependent upon position of the insulation layer. Adding insulation just above the suspended ceiling would likely change the thermal factor to 1.1 similar to a ventilated cold attic space. Regardless of the theoretical heated roof reduction factor, the amount of overstress is still too great in any scenario to remain unaddressed.

In order to upgrade the roof load carrying capacity, significant structural improvements will need to be considered. Given the disparity between allowable and required load carrying capacities, it will likely be required to add new frames between the existing frames, which will require foundation modifications to add footings. Adding frames between the existing frames increases the capacity of the existing purlins by cutting their span in half. This will make them about four times stronger than they currently are. Adding frames in between the existing frames will cut the workload requirement for these older frames in half. Even then, they will still fall slightly short of the required capacity; therefore, the new frames would have to be made stronger in order to compensate. Regardless of the compensation factor, the old frames will be under capacity unless they were upgraded. Upgrading the existing frames may be very costly and eventually prove uneconomical. Adding frames and upgrading the existing will both prove disruptive to use of the space. Adding frames between at existing over head doors will require some type of design variation.

The existing siding, roofing, mechanical heating, electrical, lighting, and interior finishes are of marginal quality and have a limited life expectance with diminishing expected performance levels.

I recommend that the structure be replaced. Otherwise, significant structural reinforcing and upgrades will be warranted. A cost replacement vs upgrade cost comparison can be developed upon request, but first, other alternatives should also be explored and considered.

Other alternatives are suggested as follows;

1. Change the building use to lower importance storage use and provide reduced level of upgrades commensurate with storage use.
2. Relocate the public works facility and provide a new structure designed for the intended use and in accordance with current codes and industry standards.
3. Abandon and sell the existing structure with some land along with full disclosure of the deficiencies. Use these proceeds to fund a new facility at this or an alternative site.
4. Abandon and sell the existing structure with the entire parcel of land along with full disclosure of the deficiencies. Use these proceeds to fund a new facility at an alternative site.

A snow monitoring and removal program should be implemented during the winter if the building is to remain occupied and in-service. A moderate snowfall or 8-12" could theoretically overstress some elements of the roof framing system. I recommend that all roof snow accumulations over 8" be promptly removed.

This evaluation is based on a limited amount of field measurements for a representative sample of framing elements in the areas described herein. A comprehensive evaluation of all joists, girders, connections, and columns has not been completed at this time. I reserve the right to change the findings and recommendations outlined herein and incorporate any new, previously un-foreseen information that may be discovered.

Sincerely,

James A. Thibodeau, P.E.
President
Associated Design Partners, Inc.

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LICENSED
PROFESSIONAL ENGINEER