SIMPSON GUMPERTZ & HEGER
Engineering of Structures
and Building Enclosures

11 April 2016

Mr. Charles Aspinwall
Town Administrator
Town of Millis
900 Main Street
Millis, MA 02054

Project 151186.01 – Department of the Works Building, 7 Water Street, Millis, MA

Dear Mr. Aspinwall:

Per your request, we provide the following summary of reports and recommendations for the Department of the Works (DPW) building at 7 Water Street in Millis, Massachusetts. This letter summarizes our roof leakage, structural, and mechanical investigation findings, and provides recommendations for repairs to the building to prevent further water leakage and condensation issues.

The referenced roofing report is our letter report to you dated 6 November 2015. The referenced structural evaluation report is our letter report to you dated 7 April 2016. A copy of each letter report is attached for your reference.

All roof repair options listed below will include the recommendations laid out in our mechanical evaluation report to you dated 8 April 2016. A copy of this letter report is attached for your reference. The mechanical system recommendations address code required ventilation, interior condensation and moisture issues, and air quality control. While ventilation will reduce the condensation potential, it may not completely manage moisture control if the actual moisture generation rate exceeds the drying potential of ventilation air.

Roof Repair Option	Leakage Investigation Recommendation	Structural Evaluation Implications	Comments
Option 1	Reinforced Elastomeric Roof Coating	No modifications to the existing roof structure	Middle roofing repair cost and the elastomeric roof system is monolithic, but not as durable as an EPDM roofing system. Addresses roof leakage, but may not eliminate all condensation.
Option 2	EPDM Membrane Flashing at All Roofing Seams	No modifications to the existing roof structure	Least roofing repair cost, but EPDM flashing strips will create water bucking edges. Addresses roof leakage, but may not eliminate condensation.
Option 3	EPDM Roofing and Dedicated Air Barrier	Extensive strengthening of the steel bents and doubling the number of roof purlins	Highest roofing cost along with high cost to restructure roofing system. Addresses roof leakage and improves air/vapor retarder to eliminate condensation.

SIMPSON GUMPERTZ & HEGER INC.
41 Seyon Street, Building 1, Suite 500, Waltham, MA 02453 main: 781.907.9000 fax: 781.907.9009 www.sgh.com
Boston | Chicago | Houston | New York | San Francisco | Southern California | Washington, DC

Option 3 is the only system that will address both water leakage and condensation potential in the roofing system. Should you wish a lower cost repair which may continue to have some roof deck condensation, we recommend roofing Option 1 accompanied by the mechanical system recommendations. While Option 1 is more costly, the roof system will require less maintenance than Option 2.

Sincerely yours,

Edward S. Farrington
Staff III – Building Technology

Edward G. Lyon, P.E.
Staff Consultant
MA License No. 40469

Erik W. Farrington, P.E.
Senior Project Manager
MA License No. 41508

I:\BOS\Projects\2015\151186.01-MECH\WP\002ESFarrington-L-151186.01.esb.docx

Encls.

6 November 2015

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

Mr. Charles Aspinwall
Town Administrator
Town of Millis
900 Main Street
Millis, MA 02054

Project 151186 – Leakage Investigation, Department of the Works Building, 7 Water Street, Millis, MA

Dear Mr. Aspinwall:

At your request, we visited the Department of the Works (DPW) building (Photo 1) at 7 Water Street in Millis, Massachusetts, to perform water leakage testing and to make interior openings at the building. This letter report summarizes our observations, provides discussion on possible causes of water leakage, and makes recommendations for repairs to the building to prevent further water leakage.

1. BACKGROUND

The Town of Millis contacted Simpson Gumpertz & Heger (SGH) in February 2015 to review a water leakage event at the above-referenced building. Mr. Charles Aspinwall, Town Administrator, informed us that during the past three years the building experiences water leakage after large snow events. Recent investigations and repair attempts to correct this leakage have not been successful. During a major snow event on 27 January 2015, the roof leaked and caused damage to the interior office spaces.

We visited the site on 30 January 2015 and observed ice dams (Photos 2 and 3) along both building eaves with icicles spanning and covering sections of the wall (Photo 4). We observed melting areas on the roof above purlins (Photo 5) and at areas in the field of the corrugated panels (Photo 6). We also observed ice and moisture on the interior of the corrugated metal panels at damaged insulation areas on the walls and the roof (Photo 7). We discussed our initial observations with you to determine the following investigation scope of work.

Our scope of work was to perform the following tasks:

- Water test the metal roof with a nozzle or a spray rack to replicate leakage during a rain event. This test was to verify whether the roof leaked but leakage was concealed and captured in the insulation during rain.
- Flood test the metal roof eave and transverse joints to replicate potential leakage caused by ice dams.
- Witness removal of a representative section of the metal roof panels to review the existing construction and identify potential leakage paths.
- Witness interior openings at the interior side of the metal roof panels to review the existing construction and identify potential leakage paths.

- Provide a summary of our observations and remedial repair recommendations.

1.1 Drawing Review

The Town of Millis provided drawings (dated 27 March 2002) prepared by KBA Architects for the purposes of recladding the building, which show the following relevant items (see Drawing A-3 attached):

- A dual sealant joint at all lapping corrugated ribs.
- 2 in. rigid insulation on the interior face of the panels.
- Alternate #3 – Delete metal liner panel at new exterior metal siding and roofing, provide vinyl lined insulation.

1.2 Information from Others

Charles Aspinwall and James McKay, Public Works, Deputy Director/Chief of Operations, told us that the main area of the DPW building is used for maintenance of DPW equipment and vehicles. They also informed us that the DPW washes their vehicles in the main area and is required to collect all wash water. In addition, they told us that the main area of the building does not experience any leakage during rain events.

2. OBSERVATIONS

We arrived on site 7 October 2015 at 8:30 a.m.to perform our water leakage investigation. The weather was clear with temperatures rising from 42°F to 68°F.

The Town of Millis DPW building is a prefabricated, steel structure with face-fastened corrugated metal panels for the roof and walls. The building is rectangular with a single gable and measures approximately 92 f by 120 ft in plan by15 ft tall at the eave and 20 ft tall at the gable peak (Photo 1). Interior offices are located on the southeast corner of the building and comprise approximately 15% area of the building. The office area has a mezzanine storage and mechanical area above matching the same approximate 60 ft by 25 ft area. The remainder of the building is an open-plan garage space with areas for equipment storage, material storage, vehicle maintenance, and a vehicle lift (Photo 8).

2.1 Roof Panels

The roof panels are corrugated metal that lap one corrugation at vertical seams; end laps at transverse joints are lapped 4 in. (Photo 9). We observed 1/8 in. thick by 1/2 in. wide butyl tape installed between laps in the vertical and transverse panel joints (Photo 10). The fasteners compress the butyl tape at those locations; at locations between fasteners we observed no adhesion between the butyl tape and the upper/lower corrugated panels (Photo 11). The corrugated panels overhang the wall approximately 5 in. at the eave-to-wall transition (Photo 12). The eave-to-wall transition is filled with rigid insulation (Photo 13).

2.2 Insulation

The insulation is fiberglass batt with a vinyl facer. The insulation is installed on the inside face of the metal panel walls and roof and spans between the purlins for the majority of the roof (Photo 14). Insulation sections above the mezzanine are held in place with wood strapping running perpendicular to the purlins (Photo 15). The insulation randomly varies in thickness from 4 in. to 7 in. above the mezzanine space. We did not make openings above the garage space to verify insulation thickness. We observed multiple penetrations and holes through the vinyl facer below the roof that are not sealed and multiple areas where insulation has fallen from the roof and where batts are not sealed at seams.

We observed multiple holes in the insulation facer where equipment and tools lean against the building walls (Photo 16).

We made openings in the insulation mounted to the underside of the roof panels and inside face of the wall panels. We observed dripping condensation on the underside of the metal roof panels prior to water testing (Photo 17). We checked weather data and determined the last precipitation event prior to our 7 October 2015 investigation was a light mist that occurred early the morning of 6 October 2015.

2.3 Water Testing

We performed a flood test of transverse and vertical seams in the metal roof panels to replicate probable conditions during ice dams. We created a pond of water over vertical and horizontal seams as well as over fastener locations. Water immediately leaked to the interior during our test (Photo 18).

While we understand that the building does not experience leakage during rain events, we performed a spray rack test at an intersection of the transverse and vertical seams in the metal roof panels. We set the spray rack on the roof to create a cascading flow of water over the surface of the roof. We ran the spray rack test for one hour and did not observe leakage to the interior of the building.

2.4 Temperature and Relative Humidity Monitoring

On 15 October 2015 we arrived on site at 7 a.m. to install temperature and relative humidity data loggers. The outside temperature was 39°F when we arrived. We made openings in the insulation above the mezzanine area to install two data loggers above the insulation. We observed ice on the underside of the roof panels (Photo 19). The roof insulation at the eave-to-wall transition was saturated with water (Photo 20) and began to drain to the floor while we made the opening.

We removed the data loggers on 26 October 2015. Data from the loggers is included in Appendix A to this report.

3. DISCUSSION

Prefabricated metal building roofs are designed to have a capacity that matches the maximum roof load, resulting in little opportunity to add weight of additional roofing materials. As such, roofing repair solutions that add weight to the roof require a full structural review of the building system

3.1 Leakage from Ice Dams

Ice dams form from roof water runoff that freezes at unheated surfaces, such as an overhang. One purpose of insulating roofs is to prevent heat from the interior reaching the roof surface to melt snow and ice (Photo 5), resulting in the water runoff. Insulation is only one means of preventing heat loss. An air barrier is also needed to prevent exfiltration of interior hot air to the exterior, resulting in melting of snow and ice (Photo 6) and formation of water runoff. Air exfiltration tends to occur at building transitions, including roof-to-wall transition.

Once an ice dam forms, it prevents water from flowing freely down the roof. As a result, water can build-up behind the ice dam until it is released by melting, removal of the dam itself, or it finds its way into the interior through a seam or lap.

Corrugated metal roofing and wall panel seams are not inherently waterproof. The vertical and transverse seams rely on continuous adhesion of seam tape or sealant to remain watertight. While the field of the corrugated metal panel is waterproof, any defect at the seams or any penetration through the panel provides a leakage path to the interior. Generally, these seams and laps are constructed to shed water such that water flowing from the roof cannot pass through the seams or laps. However, in a ponded water situation from an ice dam, water can build-up and get under the laps and seams, stressing any seam tape or sealant and eventually leak to the interior of the building.

During our ponding water test, we observed water bypass the butyl tape seal at the vertical seams and transverse laps in the metal panel roofing and leak to the interior. The butyl tape seal is not uniformly adhered to both the upper and lower corrugated panels. The lack of adhesion is the main source of water leakage to the interior. Installing a better butyl tape or a butyl sealant joint is one way to eliminate this leakage path by, but it would require removal and reinstallation of every roof panel. Installing new butyl tape or sealant will require adequate adhesion, which may be provided by the clamping action of the fasteners. Panel areas that are away from the fasteners will not have sufficient clamping to maintain adhesion. It is possible to include additional fasteners, especially along transverse laps; however, the roof will still rely on butyl tape and sealant joint to maintain water tightness.

Alternates to removing and reinstalling the panels with new tape or sealant seams include applying a coating to the existing metal roof panels, installing EPDM flashing at all seams, or installing a new conventional roofing system. We discuss each of these options further in the recommendations section.

3.2 Condensation

The building does not have a dedicated air barrier; warm humid air migrates to the inboard side of the metal panels where it can condense on the underside of the metal panels in cold weather conditions. Multiple holes and unsealed equipment penetrations in the vapor retarder for the building (the vinyl facer of the batt insulation) exacerbate the condensation problem.

We installed temperature and humidity data loggers above the insulation and in the main space of the building to determine existing conditions that may be contributing to the condensation observed at interior openings. The data loggers record temperature and relative humidity (RH) every 10 min. while installed. The data loggers recorded 50%-90% RH above the insulation; temperatures ranged from 17°F to 88°F. At multiple points during the installed period the temperature above the insulation, the RH, and the outdoor temperature (similar temperature to roof surface) reach dew point. When dew point is reached moisture can condense on the interior face of the metal panels.

While installing the data loggers, we noted ice and frost on the underside of the metal panels. On cold enough surfaces, condensation can become frost and also build up to form ice. Once the frost or ice melts, either from the heating of the substrate or through the introduction of warm air, it creates a leakage-like event, and may eventually saturate the insulation.

The interior conditions of the building, along with the lack of an air barrier and a compromised vapor retarder, contribute to the condensation issues and appearance of leakage within the building. Our scope of work did not include reviewing the air handling equipment within the building. However, given the existing conditions, some level of dehumidification is likely required during the wintertime months. This will likely not eliminate the condensation, but may reduce it.

4. RECOMMENDATIONS

We provide several repair options for your consideration. Estimated costs do not include roof design documents, bid documents, engineering fees, or construction administration costs. Our cost estimate is based on concepts, not schematic design. We referred to RS Means 2015 to develop our estimates, which are for budgetary purposes only. We suggest you talk with a contractor to get more accurate estimates based on their better understanding of the local market.

Option 1 – Reinforced Elastomeric Roof Coating

Estimated cost for repairs: $160,000 to $170,000

- Remove all wet fiberglass batt insulation at roof and wall areas. This may require removal of all fiberglass batt insulation given the condensation on the interior of the metal panels
- Install new vinyl faced fiberglass batt insulation on the underside of the roof and inside face of the walls; seal all penetrations to provide continuity of the vinyl. While not adhered to a hard surface, the vinyl vapor retarder will have to act as the default air barrier to eliminate condensation potential.
- Protect the new fiberglass batt insulation and vinyl from damage caused by equipment storage.
- Install an elastomeric roof coating, similar to TopCoat by GAF or HE687-Enviro White by Henry, on the entire roof skyward facing surface.

Option 1 – Pros	Option 1 – Cons
The roof coating is easier to install over an existing metal roof system.	This system will require increased maintenance in comparison to other roofing options.
The roof coating will reduce the impact of leakage from ice dams.	This system will likely not eliminate all ice dams and condensation.
An intact vinyl vapor retarder, properly sealed, may be able to act enough as an air barrier to reduce the potential for condensation.	The performance of this option is heavily dependent on the installers.
This system does not significantly increase the weight of the roof system likely avoiding a structural analysis of the building.	The roof coating is not as durable as an EPDM roofing system.

Option 2 – Install EPDM Membrane Flashing at All Roofing Seams

Estimated cost for repairs: $130,000 to $140,000

- Remove all wet fiberglass batt insulation at roof and wall areas. This may require removal of all fiberglass batt insulation given the condensation on the interior of the metal panels
- Install new vinyl-faced fiberglass batt insulation on the underside of the roof and inside face of the walls; seal all penetrations to provide continuity of the vinyl. While not adhered to a hard surface, the vinyl vapor retarder will have to act as the default air barrier.
- Protect the new fiberglass batt insulation and vinyl from damage caused by equipment storage.
- Install fully adhered EPDM flashing membrane at all roof seams excluding the ridge area.

Option 2 – Pros	Option 2 – Cons
Covering all seams in the metal roof will limit leakage from ice dams.	The performance of this option is heavily dependent on the installers and more complex than in Option 1 to get membrane within each corrugation.
This system does not significantly increase the weight of the roof system likely avoiding a structural analysis of the building.	Reverse lapping of materials at joints will create water bucking edges against roof drainage.
Less cost to install and less maintenance required than Option 1.	This system will likely not eliminate all ice dams and condensation.

Option 3 – EPDM Roofing and Dedicated Air Barrier

Estimated cost for repairs: $260,000 to $280,000

- Remove all wet fiberglass batt insulation at roof and wall areas. This may require removal of all fiberglass batt insulation considering the condensation issues on the interior of the metal panels.

- Install strengthening members to the roof structure to accept a new roofing system, including removing the existing corrugated roof panels and installing a new dedicated metal roof deck.
- Install new vinyl-faced fiberglass batt insulation on the inside face of the walls and seal all penetrations to provide continuity of the vinyl air barrier. While not adhered to a hard surface, the vinyl vapor retarder will have to act as the default air barrier.
- Install a fully-adhered code-compliant EPDM roof system. Including a roof air/vapor retarder, cover board, roof insulation, roof substrate, and EPDM roof membrane. The roof eave transition details will be critical to minimize future ice dams.

Option 3 – Pros	**Option 3 – Cons**
Less maintenance and more durable than Options 1 and 2.	More expensive to than Options 1 and 2
The roofing system can have a 20 yr warranty.	More disruptive to the building occupants and day to day operations.
Condensation potential on the underside of the metal deck is significantly reduced.	Will require a structural analysis of the building to confirm that the new weight from the additional materials can be accommodated and include structural reinforcement where needed.

In addition to the above repairs, we also recommend that you have a mechanical engineer review the existing air handling systems to better manage the relative humidity and interior air exhaust within the building including the office areas.

Sincerely yours,

Peter M. Babaian
Associate Principal

Edward S. Farrington
Staff III – Building Technology

I:\BOS\Projects\2015\151186.00-WATR\WP\001PMBabaian-L-151186.00.esb.docx

Photo 1

Millis Department of the Works Building.

Photo 2

Ice dam at eave edge.

Photo 3

Ice dam at eave edge.

Photo 4

Ice dam transitions down face of wall.

Photo 5

Snow melt above purlins.

Photo 6

Snow melt adjacent to roof and wall transition.

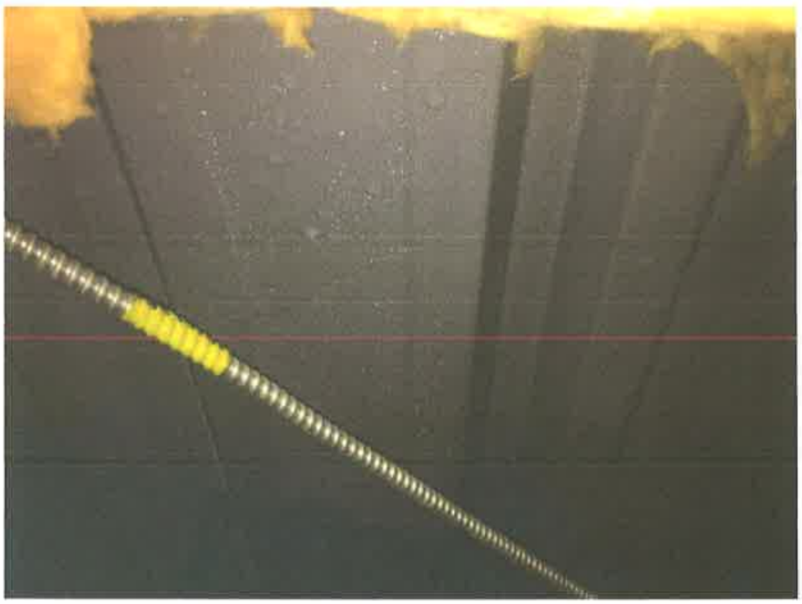


Photo 7

Condensation on the underside of the roof panel.

Photo 8

Open plan garage area.

Photo 9

Typical roofing joints.

Photo 10

Butyl tape at vertical metal roof seam – not adhered.

Photo 11

Butyl tape at transverse joint and vertical joint – not adhered.

Photo 12
Corrugated roof panel overhang at the wall.

Photo 13

Insulation at the roof-to-eave transition.

Photo 14

Vinyl faced batt insulation spans between purlins.

Photo 15

Vinyl faced batt insulation supported with wood strapping.

Photo 16

Equipment stored against the vinyl faced batt insulation.

Photo 17

Condensation on the underside of the corrugated metal roof panel.

Photo 18

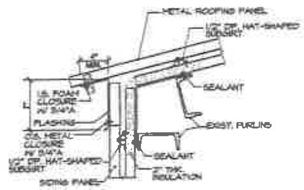
Leak during flood test.

Photo 19

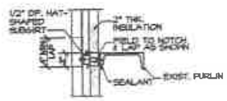
Ice on the underside of the roof insulation.

Photo 20

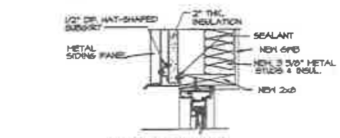
Saturated batt insulation at Data Logger #1.



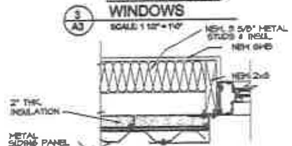
(1/A3) EAVE DETAIL
SCALE: 1 1/2" = 1'-0"



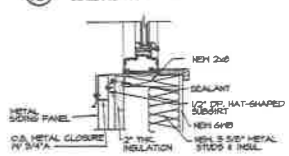
(2/A3) LAP IN PANEL
SCALE: 1 1/2" = 1'-0"



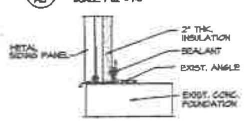
(3/A3) HEAD DETAIL @ WINDOWS
SCALE: 1 1/2" = 1'-0"



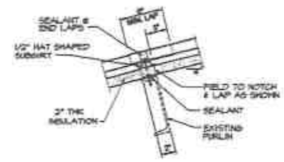
(4/A3) JAMB DETAIL @ WINDOWS
SCALE: 1 1/2" = 1'-0"



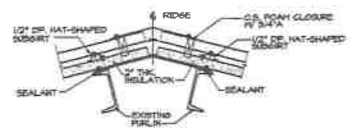
(5/A3) SILL DETAIL @ WINDOWS
SCALE: 1 1/2" = 1'-0"



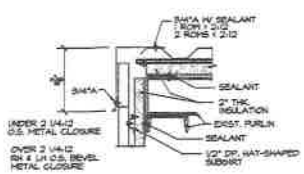
(6/A3) SILL DETAIL @ FOUNDATION
SCALE: 1 1/2" = 1'-0"



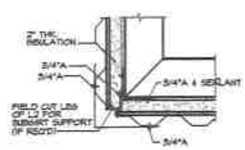
(7/A3) PANEL LAP DETAIL
SCALE: 1 1/2" = 1'-0"



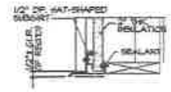
(8/A3) RIDGE DETAIL
SCALE: 1 1/2" = 1'-0"



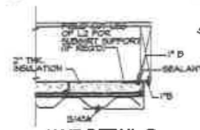
(9/A3) GABLE END DETAIL
SCALE: 1 1/2" = 1'-0"



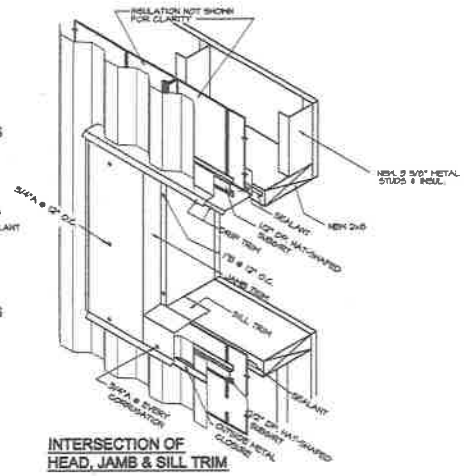
(10/A3) OUTSIDE CORNER DETAIL
SCALE: 1 1/2" = 1'-0"



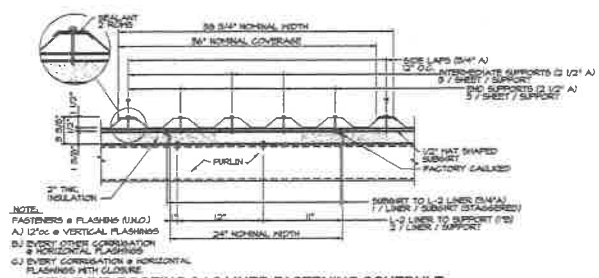
(11/A3) HEAD DETAIL @ OVERHEAD DOORS
SCALE: 1 1/2" = 1'-0"



(12/A3) JAMB DETAIL @ OVERHEAD DOORS
SCALE: 1 1/2" = 1'-0"



INTERSECTION OF HEAD, JAMB & SILL TRIM



STYLE RIB ROOFING & L2 LINER FASTENING SCHEDULE FOR ROOF SLOPES LESS THAN 2:12

ALTERNATE #1	-	PERFORM WORK AT TOILET ROOMS AS SHOWN.
ALTERNATE #2	-	REPLACE FLUORESCENT LIGHT FIXTURES WITH H.I.D. FIXTURES AS SHOWN.
ALTERNATE #3	-	DELETE METAL LINER PANEL AT NEW EXTERIOR METAL SIDING & ROOFING, PROVIDE VINYL LINED INSULATION.
ALTERNATE #4	-	CLEAN AND PAINT ALL EXPOSED COLUMNS, BEAMS & PURLINS IN GARAGE.

REVISIONS

NO.	DESCRIPTION	DATE

DESIGNED
DRAWN
CHECKED

ARCHITECTURAL
DETAILS

DPW BUILDING RENOVATIONS
TOWN OF MILLIS
7 WATER STREET
MILLIS, MASSACHUSETTS 02054

KBA ARCHITECTS
KNIGHT, BAGGE & ANDERSON, INC.
BOSTON, MASSACHUSETTS

JOB NO. M01401
DATE 03/27/02
PLAN NO. A-3
SHEET 4 OF 8

SIMPSON GUMPERTZ & HEGER
Engineering of Structures
and Building Enclosures

8 April 2016

Mr. Charles J. Aspinwall
Town Administrator
Office of the Board of Selectmen & Town Administrator
900 Main Street
Millis, MA 02054

Project 151186.01 – Mechanical Evaluation, Department of the Works Building, 7 Water Street, Millis, MA

Dear Mr. Aspinwall:

Simpson Gumpertz & Heger Inc. (SGH) has been investigating water leakage issues with the roof of the above-named building. Our 16 November 2015 proposal to you also includes a review of the existing mechanical systems. The following summarizes the results of our mechanical system investigation.

1. BACKGROUND

The Millis Department of the Works building is a typical steel-framed industrial structure with steel panel siding and roof that is approximately 11,500 sq ft in size. The roof and walls are insulated with glass fiber batt insulation held in place by a vinyl cover. About 1,500 sq ft of the space in the southeast corner of the building has been partitioned off for office space with the remaining 10,000 sq ft used as a heated garage for storage and maintenance of equipment.

During the winter, condensing moisture on the underside of the roof forms a layer of ice. When the ice melts in milder weather or sunny conditions, water drips from the vinyl insulation cover and wets whatever is below.

2. INFORMATION FROM OTHERS

2.1 Plan Review

We received four drawings prepared by Northeast Engineering and Commissioning Services Inc. titled Proposed Renovations & HVAC System Modifications, dated 10 September 2012.

- Drawing H-1 shows existing gas piping, unit heaters, garage exhaust fan on the north wall near the northwest corner, and through-wall air conditioner units. It notes removal and of the air conditioners and exhaust fan.

- Drawing H-2 shows new equipment to be installed in two phases.

    - Phase One installs two mechanical units with heating, cooling, and ventilation air supply serving the office spaces.
    - Phase Two installs an additional garage space heater and a CO/Nitrogen controlled ventilation system with one supply fan on the south wall and two

exhaust fans, one on the east wall near the north wall and one on the west wall near the north wall.

- Drawing H-3 includes specifications and equipment lists.
    - The new office HVAC system has a total flow of 1,975 cfm with 500 cfm of outdoor ventilation air.
    - The new lunch room HVAC system has a total flow of 650 cfm with 150 cfm of outdoor ventilation air.
    - The new garage heater does not have ventilation air.
    - The CO/Nitrogen supply air fan is 12,000 cfm interlocked with two exhaust fans that have a total capacity of 13,500 cfm.

- Drawing H-4 contains details for the HVAC system installation.

2.2 Conversation with Jim McKay

Mr. McKay, Deputy Director/Chief of Operations, Millis Public Works/Highway Department, told us that the office and lunch room HVAC systems became clogged with fine dirt and dust to the point of failing to operate even though the filters were routinely changed. A service company cleaned and repaired the system.

3. CODE REVIEW

The building has two different occupancies; garage space and office space. Although the garage space could be considered a semi-heated space, the International Energy Conservation Code (IECC) used by the Commonwealth of Massachusetts does not have provisions for reduced roof and wall insulation in spaces not heated and cooled to typical human occupancy temperatures. The International Mechanical Code (IMC) contains the following ventilation requirements:

- Office space (and lunch room) require 0.06 cfm per sq ft plus 5 cfm per occupant. The occupant density is as low as five per 1,000 sq ft for offices and ranges up to sixty per 1,000 sq ft.

- Toilets require 50 cfm exhaust.

- Garages (including spaces used for repair) require exhaust of 0.75 cfm per sq.ft while occupied. Exhaust can be reduced to 0.05 cfm per sq ft when unoccupied.

- Spaces adjacent to garages shall be positively pressurized.

ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality, has a higher garage exhaust rate of 1.5 cfm per sq ft.

4. ANALYSIS

The IMC garage exhaust air flow rate is 10,000 x 0.75 = 7,500 cfm with a minimum flow rate of 10,000 x 0.05 = 500 cfm.

Using the ASHRAE 62.1 rate the garage exhaust is 10,000 x 1.5 = 15,000 cfm.

The office base ventilation rate is 1,500 x 0.06 = 90 cfm. If we assume fifteen office occupants there is an additional 15 x 5 = 75 cfm for a total of 165 cfm.

5. OBSERVATIONS

Edward G. Lyon of SGH visited the building on 24 March 2016. He observed the following:

- The garage space is used for parking vehicles, storing equipment and supplies, and repairing equipment. There was no active human occupancy or vehicle traffic in the space during the hour we were in site.
- There is a heavy coating of dust on all horizontal surfaces inside the garage.
- There is standing water adjacent to a floor drain near the center of the building.
- The Phase Two garage ventilation has not been installed. The Phase One systems for the office are in place, but the locations of the units differs from the drawings. Outside ventilation air comes from a louver located high on the south wall.
- The existing heating units in the garage are indirect gas fired heaters with no outdoor ventilation air provisions.
- The existing garage exhaust fan remains in the north wall. It is a propeller fan with gravity louvers and was not running during our visit.

6. DISCUSSION

The garage portion of the building is not being ventilated per code requirements. We did not verify the operational status or capacity of the existing garage exhaust fan, but it did not appear to be large enough for a 7,500 cfm flow rate.

The Phase Two design for garage ventilation is deficient. While it has sufficient total air flow and supply/exhaust flow differential to meet the code intent for maximum air flow and pressure differential to the office, it has no provision for the required minimum air flow. It will turn on manually or automatically on detection of high CO/Nitrogen concentrations, but has no provision to sense or schedule human occupancy for which the code requires higher ventilation rates. The outside air supply fan should have provisions to temper the ventilation air and avoid excessively cold drafts on occupants when the system runs.

We did not verify the outside air flow rates of the office HVAC systems, but the stated design outdoor ventilation rates exceed the ventilation air flow we calculate for our assumed maximum occupancy. The excess ventilation may be intended to produce a positive pressure in the office relative to the garage, but it will only be effective when the system runs with ventilation.

The typical garage activities include wet work to wash equipment as part of routine maintenance. This work in a heated space generates a large amount of moisture in the garage area. Without ventilation, this moisture accumulates in the air and raises the interior air relative humidity and dewpoint temperature. Although intended to be a vapor barrier, the vinyl cover on the metal panel insulation performs poorly, allowing vapor to pass and liquid/solid moisture to accumulate on cold metal panels during winter weather. Lack of proper ventilation greatly contributes to the winter water leakage issues. Code minimum ventilation of the garage may not be sufficient to completely eliminate condensation issues if the actual moisture generation rate exceeds the ventilation dehumidification capacity, but it will reduce the moisture accumulation and wetting potential.

Dust control in the office is a matter of maintaining continuous positive air pressure in the office relative to the garage. An exhaust fan in the garage that operates with the garage doors closed can make the office positively pressurized relative to the garage, but that pressure is lost when a garage door opens. The office mechanical system can pressurize the space with ventilation air, but that only occurs when the system operates with ventilation dampers open. Additionally, all parts of the return air and outdoor ventilation air ducts are negatively pressurized and can suck in dust at any portion of the unsealed ductwork in the garage space. Operating the office mechanical system continuously with outside ventilation air or installing a dedicated fan system to constantly pressurize the office space are the only ways to maintain positive pressure in the office relative to the garage.

Increasing ventilation air flow during cold weather will increase heating energy costs. The ventilation air needs to be heated and heated air is exhausted from the building without recovering any energy. Installing an energy recovery system will likely be problematic given the dust generated in the garage during typical activities. The dust will likely clog the recovery systems making them less effective and increasing system maintenance.

7. CONCLUSIONS

We have the following conclusions:

- The garage is not properly ventilated for occupancy.
- Lack of ventilation is contributing to the winter water leakage issues.
- Correcting deficient ventilation will increase the operating expenses for the building.

8. RECOMMENDATIONS

We have the following recommendations:

Short-Term Immediate Action

If the existing exhaust fan on the north wall is operational, turn it on and let it run continuously. This will provide some of the required ventilation and will also make the garage more negative relative to the office space to help control dust. If the fan is broken, repair or replace it. Replacing it should be coordinated with an eventual upgrade of the garage ventilation.

Office and Lunch Area Mechanical Systems

Verify that the as-designed outside ventilation flow is actually met when the systems operate. The systems should operate continuously during occupied hours and not just cycle on and off for heating and cooling calls. Consider adding occupancy sensors to control the systems.

Check the direction of air flow at a door with tracer smoke. When operating with sufficient outside ventilation air, there should be air flowing from the office to the garage at cracks around doors.

Investigate the return air and outdoor air duct work for gaps, breaches, or lack of duct sealant. Dust entering these systems has to come from the negative pressure side of the equipment and any portion of the systems run through the garage space can be suspect.

Verify code-required bathroom ventilation.

Since air to pressurize the space to control dust is only available when the system operates with outdoor ventilation air, consider adding a small ventilating fan system to pressurize the office space when the main systems are not operating with ventilation.

Garage Ventilation Upgrade

The garage exhaust should be upgraded to be code compliant. We recommend using the higher ASHRAE Standard 62.1 ventilation rate, though you may choose to use the lower IMC ventilation rate to reduce energy costs. The system should run continuously on a low volume exhaust setting to purge moisture and other contaminants in the garage continuously. It should speed up to the higher ventilation rate when CO/Nitrogen sensors detect excessive concentrations, but it should also have occupancy sensors at entry doors and in common work spaces so the system speeds up automatically when humans are present in the garage. At least two exhaust fans should be used. One should operate continuously to provide minimum exhaust air. This should be a heavy duty fan with a high efficiency motor. The second fan should bring the combined exhaust flow up to the design maximum air flow. The high exhaust flow setting should interlock with a 100% outdoor supply air system with filters and heating capability to discharge tempered air at 45°F to 50°F for design cold conditions. Locate the supply air close to the offices and blow air toward the interior office wall. The supply air flow should only be one half to three quarters of the total exhaust air flow. This arrangement should help to maintain a negative pressure when the garage doors are closed and sweep dust away from the office area when the doors are open and negative pressure for dust control is lost.

Sincerely yours,

Ned Lyon

Edward G. Lyon
Staff Consultant
I:\BOS\Projects\2015\151186.01-MECH\WP\001EGLyon-L-151186.01.esb.docx

7 April 2016

SIMPSON GUMPERTZ & HEGER
Engineering of Structures
and Building Enclosures

Mr. Charles Aspinwall
Town Administrator
Town of Millis
900 Main Street
Millis, MA 02054

Project 151186 – Structural Evaluation, Millis Department of Public Works, 7 Water Street, Millis, MA

Dear Mr. Aspinwall:

At your request, we visited the Department of the Works (DPW) building (Photo 1) at 7 Water Street in Millis, Massachusetts, to observe the condition and configuration of the existing structure. As there were no original structural documents available, we took this opportunity to measure the structural elements for our analysis. This letter report summarizes our observations, provides discussion of the structural analysis, and makes recommendations for potential strengthening of the building to support new roof loads.

1. BACKGROUND

The Town of Millis contacted Simpson Gumpertz & Heger Inc. (SGH) in February 2015 to review a water leakage event at the above-referenced building. We visited the site on 30 January 2015 to perform initial observations and on 7 October 2015 to perform water leakage investigation. We then provided a letter report dated 6 November 2015 with recommendations for repairs to the building to prevent further water leakage. These are named Roof Repair Options 1 through 3. The most involved repair (Roof Repair Option 3) would increase the load on the structure to an extent that we would need to analyze and perhaps reinforce the existing structure. To better inform your decisions regarding repairs to the roof, you asked us to undertake a structural evaluation of the building.

Per our 16 November 2015 proposal, our scope of work for the structural evaluation was to perform the following tasks:

- Document existing structural member sizes, configurations, and conditions.
- Take samples of each type of framing member for material testing in our lab.
- Prepare material samples for testing. This is a service provided to us by an outside vendor.
- Perform strength testing of material samples in our lab. The results of our testing is provided in this letter report.
- Perform analysis of typical building framing members for code prescribed loads under proposed building alterations.
- Provide a summary of our findings and concept level recommendations for strengthening existing framing where required.

1.1 Drawing Review

The Town of Millis provided drawings prepared by KBA Architects and dated 27 March 2002. These drawings were for recladding the building, which show the following relevant items:

- Plan and elevation dimensions of the building.
- Schematic representation of the structural framing.
- Spacing of built-up metal bents.

2. OBSERVATIONS

We arrived on site 25 February 2016 at 8:00 a.m.to perform our structural investigation.

The Town of Millis DPW building is a prefabricated, steel structure with face-fastened corrugated metal panels for the roof and walls (Photo 2). The building is rectangular with a single gable and measures approximately 92 f by 120 ft in plan by15 ft tall at the eave and 20 ft tall at the gable peak. The roof panels are supported by purlins spaced approximately 5 ft on center spanning between six steel built-up bents spaced 20 ft on center. The east gable wall is framed with steel c-shaped columns as opposed to a built-up bent. The wall panels of the structure span vertically between an approximately 4 ft tall concrete wall and the tops of the columns of the bents. An intermediate wind purlin spans between bents and braces the metal walls approximately 7 ft above the top of the concrete wall.

The built-up steel bents provide a lateral load resisting system in the form of moment frames that act in the north-south direction of the building (Photo 3). In the east-west direction of the building, 3/4 in. diameter cross-bracing on the bents along gridlines B and C provide lateral load resistance (Photo 4).

In general, the building structure is in good condition. We observed no evidence of deterioration or significant damage to the structural elements.

We observed a bend in the top flange of one of the bents (Photo 5).

2.1 Roof Panels

The roof panels are 22 gauge corrugated metal roofing panels that lap one corrugation at vertical seams; end laps at transverse joints are lapped 4 in. (Photo 6). The deck is 1-1/2 in. deep, with 2-1/2 in. wide ribs on a 9 in. pitch.

2.2 Roof Purlins

The roof purlins are steel z-girts approximately 0.075 in. thick, 8 in. deep, with 3 in. flanges (Photo 7). This profile corresponds to a Z8x4.2 shape. The z-girts are spliced longitudinally with a 4 bolt connection (Photo 8). The roof panels are fastened to the top flange of the z-girts with screws.

2.3 Built-Up Steel Bents

Built-up steel bents are the primary structural supports for all loads imposed on the structure. Each bent is split into five segments made up of three different elements: two columns (Photo 9), two pitched beams connected to the columns (Photo 10), and a double-pitched section at the mid-span (ridge) of the beams, spliced to each of the pitched beams (Photo 11).

Each of the elements described above is built up by welding steel plates into an I-shaped member. All flanges are 8 in. wide. The column depth tapers from 13 in. deep at the base to 42.5 in. deep at the eave. The pitched beam depth tapers from 41.75 in. deep at the eave to 30.5 in. deep at the splice. The double-pitched element at the ridge is 30.5 in. deep for its full length.

The bottom flanges of the beams are braced by kickers to the roof purlins, and the top flanges are braced by roof purlins (Photo 11). The beams are connected to the columns by a bolted, stiffened connection that is braced by kickers to the roof purlins and wall purlins (Photo 12). The column base is connected to the foundations by four closely spaced anchors (Photo 13). The splice between the double-pitched middle beam and single-pitched beams is a six-bolt connection (Photo 14).

3. CODE DISCUSSION

We evaluated the impact of the Eighth Edition of the Massachusetts State Building Code (MSBC) on the project noted above. The proposed work includes alterations to the roof. This section outlines our analysis of the impact on the work of the applicable sections of the building code.

The Eighth Edition of the Massachusetts Building Code is based on the International Building Code (IBC) 2009 with Massachusetts amendments. The Massachusetts amendments to IBC 2009 strike Chapter 34, "Existing Structures," from 780 CMR Base Volume and replace it with the International Existing Building Code (IEBC) 2009 with Massachusetts amendments.

IEBC COMPLIANCE METHODS

Section 101.5 requires selection of one of three listed compliance methods for repair, alteration, change of occupancy, addition, or relocation of all existing buildings. The compliance methods to be selected by the "applicant" (presumably the building Owner) are:

1. Prescriptive Compliance Method.
2. Work Area Compliance Method.
3. Performance Compliance Method.

Based on the scope of this project, we recommend that this project consider the work area compliance method.

IEBC SECTION 202 GENERAL DEFINITIONS

The work described in all three Roof Repair Options does not fall under the definition for addition or repairs. Therefore, the work will be classified as an alteration.

IEBC SECTION 403 ALTERATIONS – LEVEL 1

Section 403.1 defines the type of projects included in Level 1 alterations. Level 1 alterations include the removal and replacement or the covering of existing materials, elements, equipment, or fixtures using new materials, elements, equipment, or fixtures that serve the same purpose.

Section 403.2 requires that Level 1 alterations comply with the provisions of Chapter 6 for Level 1 alterations.

IEBC SECTION 606 STRUCTURAL

This section includes the following applicable provisions:

Section 606.2 Addition or replacement of roofing or replacement of equipment: Where addition or replacement of roofing or replacement of equipment results in additional dead loads, structural components supporting such reroofing or equipment shall comply with the gravity load requirements of the *International Building Code*.

The code includes the following applicable exceptions:

1. Structural elements where the additional dead load from the roofing or equipment does not increase the force in the element by more than 5 percent. The cumulative effects since original construction shall be considered.

2. Addition of a second layer of roof covering weighing 3 pounds per square foot (0.1437 kN/m^2) or less over an existing, single layer of roof covering.

For further discussion of the impact of these code provisions, see the Analysis section below.

4. ANALYSIS

In order to understand the behavior of the existing structure and determine its adequacy to support the load associated with the proposed roofing alterations, we performed an analysis of the main structural elements under the original design loads and the proposed design loads.

4.1 Loads Comparison

We reviewed the dead loads associated with the typical structural framing members. Chapter 34 of the International Existing Building Code (IEBC) dictates that when the dead load on a structural element is increased by 5%, that element must be analyzed using current code loads. Table 2 provides the percentage increase in dead load from Roof Repair Options 1-3.

Roof Repair Option	Increase in Dead Load (psf)	% Dead Load Increase to Roof Panels	% Dead Load Increase to Purlins	% Dead Load Increase to Bents
Option 1	0.128	4.3	3.8	2.3
Option 2	0.28	9.3	5	4.9
Option 3	5	167	147	88

Table 1 – Increase in Dead Load for Options 1-3

The shaded cells in Table 2 indicate structural elements for which the proposed roof alteration increases the dead load by at least 5%. For Roof Repair Option 2, since the additional load is less than 3 psf and is essentially roofing added over the existing roof covering, Exception 3 of Section 606.2 applies. Roof Repair Option 3 requires that all three elements must be analyzed and reinforced if necessary.

We assume that the original structural design was carried out in the 1970s, so we reviewed the relevant sections of the Massachusetts State Building Code (MSBC), 1st Edition (1974) and 2nd Edition (1975, 1977). Table 1 compares the loads prescribed by the 1975 2nd Edition of the MSBC to loads calculated using current codes, ASCE/SEI 7-10, which is referenced by the 8th edition of the MSBC. The proposed dead load is based on Roof Repair Option 3.

Load	Original (psf)	Current/Proposed (psf)
Dead (incl. roof panels)	3.5	8.5
Snow	30	35
Wind (design pressure)	17	25.7

Table 2 – Original and Current/Proposed Design Loads

4.2 Analysis of Individual Elements

Where necessary as shown in Table 2, we have analyzed the typical individual elements under current code snow loads with the increased dead load.

Table 3 summarizes our findings, indicating whether a structural element is found to be inadequate under the proposed loads and a reinforcing scheme is required for that element. As we have not yet taken coupons of the various elements to determine their yield strength, Table 3 has two columns for potential yield strengths of an element.

Structural Element	Requires Reinforcing Per Option 3	
	If 33 ksi	If 50 ksi
Roof Panel	N	N
Purlin	Y	Y
Bent	Y	Y

Table 3 – Analysis Results: Strengthening Requirements

The shaded cells in Table 3 indicate structural elements for which reinforcing will be required. Where reinforcing is required, the strength of the structural element will determine the extent of the reinforcing, as described in our recommendations.

5. DISCUSSION

5.1 Analysis

Prefabricated metal buildings are typically designed to have a capacity that closely matches the maximum design loads often with little overstrength. This results in little opportunity to add loads to the structure. In addition, buildings in Eastern Massachusetts that were designed under earlier codes were typically designed for snow loads of 30 psf. More recent codes require higher snow loads. Therefore, for an existing building to be considered adequate under the existing building code requirements, it needs to be adequate for the increase in both dead load and snow load. Under these circumstances, roofing repair solutions that add weight to the existing roof can typically require some level of reinforcement. Our analysis of the existing structure indicates that this is the case for this building.

While Roof Repair Options 1 and 2 add loads to the existing structure, the exceptions included in the work area method for Level 1 alterations do not require a structural analysis for those options, and therefore those options can ignore current code snow loads.

Our analysis of the existing building with the loads associated with Roof Repair Option 3 indicate that that both the purlins and the bents are inadequate under the proposed loads and will require strengthening. Prior to extracting samples of the existing steel, we performed our analysis of the structural members assuming normal strength (33 ksi or 36 ksi) and high strength (50ksi) steel. The results indicate that regardless of the strength of the steel, neither the purlins, nor the bent, are adequate. While the strength of the existing steel will be required to complete the final design of a strengthening scheme, that information is not required to determine whether the structure requires strengthening nor to develop a conceptual strengthening scheme. For this reason, we do not believe that it is worthwhile to expend the effort of sampling and material testing for this initial evaluation.

There are several things that could have caused the bent flange shown in Photo 5. The flange could have been bent during fabrication or shipping. It could be the result of sling pinching during the erection of the frame, or of being struck during erection of the rest of the structure. It is an isolated case that occurs away from concentrated suspended loads so it is unlikely that it is the result of a local or building-wide overstress condition. The bent flange occurs in the tension region of the bent and is therefore not a sign of significant structural distress or a cause for concern.

5.2 Strengthening

Roofing Repair Option 3 requires strengthening of the roof purlins and the steel bents. The simplest reinforcement scheme for the purlins is the addition of purlins between each of the existing purlins. This alteration will reduce the level of load in the exist purlins below their current design loads.

The solution to strengthen the steel bents is to weld additional T-shaped steel members to the inner flanges of the full lengths of the beams and columns of all but one existing bent, thereby increasing their strength and stiffness. These t-shaped members will need to be continuous along the entire length of each roof beam and column. The splice connections near the ridge will need to be modified so that the new steel shape can be connected as if it were continuous, similar to the existing splice connection. Our preliminary analysis indicates that the addition of a continuous WT12X47, welded to the bottom flange of the existing beam and inner flange of the existing columns could be considered as a conceptual strengthening detail. This modification is a 12 in. deep T-shaped member weighing 47 lb/ft and is required at all of the steel bents except the steel bent at the west end of the building.

The connection of the roof beams to the columns will also require strengthening by adding welds to the existing bolted connection at the outer bolted connection in the joint.

6. CONCLUSIONS AND RECOMMENDATIONS

Our review of the existing building code indicates that both Roof Repair Options 1 and 2 do not require modifications to the existing roof structure. Roof Repair Option 3 requires extensive strengthening of the steel bents as well as doubling the number of roof purlins.

We do not recommend extracting samples for material testing unless you decide to implement Option 3, in which case, the design of the reinforcement will depend on the strength of the existing steel. The current reinforcement design is based on the assumption that all components of the bents are high-strength steel. The T-shaped member would increase in size if material testing reveals that any components of the bents are actually normal strength steel.

There are many factors that need to go into the decision of how to proceed with the roof repairs. We have completed roofing, mechanical, and structural investigations to inform this decision. In a separate letter, we will provide an integrated recommendation based on the findings of all three of our investigations.

Sincerely yours,

Pedro J. Sifre, P.E.
Senior Principal

Erik W. Farrington, P.E.
Senior Project Manager

Clayton M. Brown
Staff I - Structures

I:\BOS\Projects\2015\151186.00-WATR\WP\002PJSifre-L-151186.00.ras.docx

Photo 1

Interior of the Millis DPW building

Photo 2

Corrugated metal wall panels spanning vertically

Photo 3

The built-up steel bents provide lateral load resistance in the north-south direction.

Photo 4

¾ in. diameter cross-bracing (arrow) on the bents along gridlines B and C provide lateral load resistance.

Photo 5

Roof purlins are spliced longitudinally over the tops of bents. The top flange of the bent has a bent flange near the purlin connection.

Photo 6

The roof is corrugated metal panels fastened to the roof purlins below.

Photo 7

The roof purlins are steel z-girts spaced approximately 5 ft on center.

Photo 8

Tapered, built-up steel columns support the horizontal elements of the bents.

Photo 9

Tapered, pitched, built-up steel beams run from the eaves to the splice plate of the double-pitched mid-span of the bents.

Photo 10

A double-pitched, built-up steel beam is spliced to each of the pitched members shown in Photo 9 at the mid-span of the bent. The splice plate is indicated by the red arrow. Also shown, the bottom flanges of the beams of the bent are braced by kickers to the roof purlins.

Photo 11

The connections between beams and columns of the bent are stiffened and braced by kickers.

Photo 12

The base of the bents are anchored to the foundation by four closely spaced anchors.

Photo 13

A six-bolted splice plate connects the double-pitched middle beam and single-pitched end beams of the steel bents.

7 April 2016

SIMPSON GUMPERTZ & HEGER

Engineering of Structures and Building Enclosures

Mr. Charles Aspinwall
Town Administrator
Town of Millis
900 Main Street
Millis, MA 02054

Project 151186 – Structural Evaluation, Millis Department of Public Works, 7 Water Street, Millis, MA

Dear Mr. Aspinwall:

At your request, we visited the Department of the Works (DPW) building (Photo 1) at 7 Water Street in Millis, Massachusetts, to observe the condition and configuration of the existing structure. As there were no original structural documents available, we took this opportunity to measure the structural elements for our analysis. This letter report summarizes our observations, provides discussion of the structural analysis, and makes recommendations for potential strengthening of the building to support new roof loads.

1. BACKGROUND

The Town of Millis contacted Simpson Gumpertz & Heger Inc. (SGH) in February 2015 to review a water leakage event at the above-referenced building. We visited the site on 30 January 2015 to perform initial observations and on 7 October 2015 to perform water leakage investigation. We then provided a letter report dated 6 November 2015 with recommendations for repairs to the building to prevent further water leakage. These are named Roof Repair Options 1 through 3. The most involved repair (Roof Repair Option 3) would increase the load on the structure to an extent that we would need to analyze and perhaps reinforce the existing structure. To better inform your decisions regarding repairs to the roof, you asked us to undertake a structural evaluation of the building.

Per our 16 November 2015 proposal, our scope of work for the structural evaluation was to perform the following tasks:

- Document existing structural member sizes, configurations, and conditions.
- Take samples of each type of framing member for material testing in our lab.
- Prepare material samples for testing. This is a service provided to us by an outside vendor.
- Perform strength testing of material samples in our lab. The results of our testing is provided in this letter report.
- Perform analysis of typical building framing members for code prescribed loads under proposed building alterations.
- Provide a summary of our findings and concept level recommendations for strengthening existing framing where required.

1.1 Drawing Review

The Town of Millis provided drawings prepared by KBA Architects and dated 27 March 2002. These drawings were for recladding the building, which show the following relevant items:

- Plan and elevation dimensions of the building.
- Schematic representation of the structural framing.
- Spacing of built-up metal bents.

2. OBSERVATIONS

We arrived on site 25 February 2016 at 8:00 a.m.to perform our structural investigation.

The Town of Millis DPW building is a prefabricated, steel structure with face-fastened corrugated metal panels for the roof and walls (Photo 2). The building is rectangular with a single gable and measures approximately 92 f by 120 ft in plan by15 ft tall at the eave and 20 ft tall at the gable peak. The roof panels are supported by purlins spaced approximately 5 ft on center spanning between six steel built-up bents spaced 20 ft on center. The east gable wall is framed with steel c-shaped columns as opposed to a built-up bent. The wall panels of the structure span vertically between an approximately 4 ft tall concrete wall and the tops of the columns of the bents. An intermediate wind purlin spans between bents and braces the metal walls approximately 7 ft above the top of the concrete wall.

The built-up steel bents provide a lateral load resisting system in the form of moment frames that act in the north-south direction of the building (Photo 3). In the east-west direction of the building, 3/4 in. diameter cross-bracing on the bents along gridlines B and C provide lateral load resistance (Photo 4).

In general, the building structure is in good condition. We observed no evidence of deterioration or significant damage to the structural elements.

We observed a bend in the top flange of one of the bents (Photo 5).

2.1 Roof Panels

The roof panels are 22 gauge corrugated metal roofing panels that lap one corrugation at vertical seams; end laps at transverse joints are lapped 4 in. (Photo 6). The deck is 1-1/2 in. deep, with 2-1/2 in. wide ribs on a 9 in. pitch.

2.2 Roof Purlins

The roof purlins are steel z-girts approximately 0.075 in. thick, 8 in. deep, with 3 in. flanges (Photo 7). This profile corresponds to a Z8x4.2 shape. The z-girts are spliced longitudinally with a 4 bolt connection (Photo 8). The roof panels are fastened to the top flange of the z-girts with screws.

2.3 Built-Up Steel Bents

Built-up steel bents are the primary structural supports for all loads imposed on the structure. Each bent is split into five segments made up of three different elements: two columns (Photo 9), two pitched beams connected to the columns (Photo 10), and a double-pitched section at the mid-span (ridge) of the beams, spliced to each of the pitched beams (Photo 11).

Each of the elements described above is built up by welding steel plates into an I-shaped member. All flanges are 8 in. wide. The column depth tapers from 13 in. deep at the base to 42.5 in. deep at the eave. The pitched beam depth tapers from 41.75 in. deep at the eave to 30.5 in. deep at the splice. The double-pitched element at the ridge is 30.5 in. deep for its full length.

The bottom flanges of the beams are braced by kickers to the roof purlins, and the top flanges are braced by roof purlins (Photo 11). The beams are connected to the columns by a bolted, stiffened connection that is braced by kickers to the roof purlins and wall purlins (Photo 12). The column base is connected to the foundations by four closely spaced anchors (Photo 13). The splice between the double-pitched middle beam and single-pitched beams is a six-bolt connection (Photo 14).

3. CODE DISCUSSION

We evaluated the impact of the Eighth Edition of the Massachusetts State Building Code (MSBC) on the project noted above. The proposed work includes alterations to the roof. This section outlines our analysis of the impact on the work of the applicable sections of the building code.

The Eighth Edition of the Massachusetts Building Code is based on the International Building Code (IBC) 2009 with Massachusetts amendments. The Massachusetts amendments to IBC 2009 strike Chapter 34, "Existing Structures," from 780 CMR Base Volume and replace it with the International Existing Building Code (IEBC) 2009 with Massachusetts amendments.

IEBC COMPLIANCE METHODS

Section 101.5 requires selection of one of three listed compliance methods for repair, alteration, change of occupancy, addition, or relocation of all existing buildings. The compliance methods to be selected by the "applicant" (presumably the building Owner) are:

1. Prescriptive Compliance Method.

2. Work Area Compliance Method.

3. Performance Compliance Method.

Based on the scope of this project, we recommend that this project consider the work area compliance method.

IEBC SECTION 202 GENERAL DEFINITIONS

The work described in all three Roof Repair Options does not fall under the definition for addition or repairs. Therefore, the work will be classified as an alteration.

IEBC SECTION 403 ALTERATIONS – LEVEL 1

Section 403.1 defines the type of projects included in Level 1 alterations. Level 1 alterations include the removal and replacement or the covering of existing materials, elements, equipment, or fixtures using new materials, elements, equipment, or fixtures that serve the same purpose.

Section 403.2 requires that Level 1 alterations comply with the provisions of Chapter 6 for Level 1 alterations.

IEBC SECTION 606 STRUCTURAL

This section includes the following applicable provisions:

Section 606.2 Addition or replacement of roofing or replacement of equipment: Where addition or replacement of roofing or replacement of equipment results in additional dead loads, structural components supporting such reroofing or equipment shall comply with the gravity load requirements of the *International Building Code*.

The code includes the following applicable exceptions:

1. Structural elements where the additional dead load from the roofing or equipment does not increase the force in the element by more than 5 percent. The cumulative effects since original construction shall be considered.

2. Addition of a second layer of roof covering weighing 3 pounds per square foot (0.1437 kN/m^2) or less over an existing, single layer of roof covering.

For further discussion of the impact of these code provisions, see the Analysis section below.

4. ANALYSIS

In order to understand the behavior of the existing structure and determine its adequacy to support the load associated with the proposed roofing alterations, we performed an analysis of the main structural elements under the original design loads and the proposed design loads.

4.1 Loads Comparison

We reviewed the dead loads associated with the typical structural framing members. Chapter 34 of the International Existing Building Code (IEBC) dictates that when the dead load on a structural element is increased by 5%, that element must be analyzed using current code loads. Table 2 provides the percentage increase in dead load from Roof Repair Options 1-3.

Roof Repair Option	Increase in Dead Load (psf)	% Dead Load Increase to Roof Panels	% Dead Load Increase to Purlins	% Dead Load Increase to Bents
Option 1	0.128	4.3	3.8	2.3
Option 2	0.28	9.3	5	4.9
Option 3	5	167	147	88

Table 1 – Increase in Dead Load for Options 1-3

The shaded cells in Table 2 indicate structural elements for which the proposed roof alteration increases the dead load by at least 5%. For Roof Repair Option 2, since the additional load is less than 3 psf and is essentially roofing added over the existing roof covering, Exception 3 of Section 606.2 applies. Roof Repair Option 3 requires that all three elements must be analyzed and reinforced if necessary.

We assume that the original structural design was carried out in the 1970s, so we reviewed the relevant sections of the Massachusetts State Building Code (MSBC), 1st Edition (1974) and 2nd Edition (1975, 1977). Table 1 compares the loads prescribed by the 1975 2nd Edition of the MSBC to loads calculated using current codes, ASCE/SEI 7-10, which is referenced by the 8th edition of the MSBC. The proposed dead load is based on Roof Repair Option 3.

Load	Original (psf)	Current/Proposed (psf)
Dead (incl. roof panels)	3.5	8.5
Snow	30	35
Wind (design pressure)	17	25.7

Table 2 – Original and Current/Proposed Design Loads

4.2 Analysis of Individual Elements

Where necessary as shown in Table 2, we have analyzed the typical individual elements under current code snow loads with the increased dead load.

Table 3 summarizes our findings, indicating whether a structural element is found to be inadequate under the proposed loads and a reinforcing scheme is required for that element. As we have not yet taken coupons of the various elements to determine their yield strength, Table 3 has two columns for potential yield strengths of an element.

Structural Element	Requires Reinforcing Per Option 3	
	If 33 ksi	If 50 ksi
Roof Panel	N	N
Purlin	Y	Y
Bent	Y	Y

Table 3 – Analysis Results: Strengthening Requirements

The shaded cells in Table 3 indicate structural elements for which reinforcing will be required. Where reinforcing is required, the strength of the structural element will determine the extent of the reinforcing, as described in our recommendations.

5. DISCUSSION

5.1 Analysis

Prefabricated metal buildings are typically designed to have a capacity that closely matches the maximum design loads often with little overstrength. This results in little opportunity to add loads to the structure. In addition, buildings in Eastern Massachusetts that were designed under earlier codes were typically designed for snow loads of 30 psf. More recent codes require higher snow loads. Therefore, for an existing building to be considered adequate under the existing building code requirements, it needs to be adequate for the increase in both dead load and snow load. Under these circumstances, roofing repair solutions that add weight to the existing roof can typically require some level of reinforcement. Our analysis of the existing structure indicates that this is the case for this building.

While Roof Repair Options 1 and 2 add loads to the existing structure, the exceptions included in the work area method for Level 1 alterations do not require a structural analysis for those options, and therefore those options can ignore current code snow loads.

Our analysis of the existing building with the loads associated with Roof Repair Option 3 indicate that that both the purlins and the bents are inadequate under the proposed loads and will require strengthening. Prior to extracting samples of the existing steel, we performed our analysis of the structural members assuming normal strength (33 ksi or 36 ksi) and high strength (50ksi) steel. The results indicate that regardless of the strength of the steel, neither the purlins, nor the bent, are adequate. While the strength of the existing steel will be required to complete the final design of a strengthening scheme, that information is not required to determine whether the structure requires strengthening nor to develop a conceptual strengthening scheme. For this reason, we do not believe that it is worthwhile to expend the effort of sampling and material testing for this initial evaluation.

There are several things that could have caused the bent flange shown in Photo 5. The flange could have been bent during fabrication or shipping. It could be the result of sling pinching during the erection of the frame, or of being struck during erection of the rest of the structure. It is an isolated case that occurs away from concentrated suspended loads so it is unlikely that it is the result of a local or building-wide overstress condition. The bent flange occurs in the tension region of the bent and is therefore not a sign of significant structural distress or a cause for concern.

5.2 Strengthening

Roofing Repair Option 3 requires strengthening of the roof purlins and the steel bents. The simplest reinforcement scheme for the purlins is the addition of purlins between each of the existing purlins. This alteration will reduce the level of load in the exist purlins below their current design loads.

The solution to strengthen the steel bents is to weld additional T-shaped steel members to the inner flanges of the full lengths of the beams and columns of all but one existing bent, thereby increasing their strength and stiffness. These t-shaped members will need to be continuous along the entire length of each roof beam and column. The splice connections near the ridge will need to be modified so that the new steel shape can be connected as if it were continuous, similar to the existing splice connection. Our preliminary analysis indicates that the addition of a continuous WT12X47, welded to the bottom flange of the existing beam and inner flange of the existing columns could be considered as a conceptual strengthening detail. This modification is a 12 in. deep T-shaped member weighing 47 lb/ft and is required at all of the steel bents except the steel bent at the west end of the building.

The connection of the roof beams to the columns will also require strengthening by adding welds to the existing bolted connection at the outer bolted connection in the joint.

6. CONCLUSIONS AND RECOMMENDATIONS

Our review of the existing building code indicates that both Roof Repair Options 1 and 2 do not require modifications to the existing roof structure. Roof Repair Option 3 requires extensive strengthening of the steel bents as well as doubling the number of roof purlins.

We do not recommend extracting samples for material testing unless you decide to implement Option 3, in which case, the design of the reinforcement will depend on the strength of the existing steel. The current reinforcement design is based on the assumption that all components of the bents are high-strength steel. The T-shaped member would increase in size if material testing reveals that any components of the bents are actually normal strength steel.

There are many factors that need to go into the decision of how to proceed with the roof repairs. We have completed roofing, mechanical, and structural investigations to inform this decision. In a separate letter, we will provide an integrated recommendation based on the findings of all three of our investigations.

Sincerely yours,

Pedro J. Sifre, P.E.
Senior Principal

Erik W. Farrington, P.E.
Senior Project Manager

Clayton M. Brown
Staff I - Structures

I:\BOS\Projects\2015\151186.00-WATR\WP\002PJSifre-L-151186.00.ras.docx

Photo 1

Interior of the Millis DPW building

Photo 2

Corrugated metal wall panels spanning vertically

Photo 3

The built-up steel bents provide lateral load resistance in the north-south direction.

Photo 4

¾ in. diameter cross-bracing (arrow) on the bents along gridlines B and C provide lateral load resistance.

Photo 5

Roof purlins are spliced longitudinally over the tops of bents. The top flange of the bent has a bent flange near the purlin connection.

Photo 6

The roof is corrugated metal panels fastened to the roof purlins below.

Photo 7

The roof purlins are steel z-girts spaced approximately 5 ft on center.

Photo 8

Tapered, built-up steel columns support the horizontal elements of the bents.

Photo 9

Tapered, pitched, built-up steel beams run from the eaves to the splice plate of the double-pitched mid-span of the bents.

Photo 10

A double-pitched, built-up steel beam is spliced to each of the pitched members shown in Photo 9 at the mid-span of the bent. The splice plate is indicated by the red arrow. Also shown, the bottom flanges of the beams of the bent are braced by kickers to the roof purlins.

Photo 11

The connections between beams and columns of the bent are stiffened and braced by kickers.

Photo 12

The base of the bents are anchored to the foundation by four closely spaced anchors.

Photo 13

A six-bolted splice plate connects the double-pitched middle beam and single-pitched end beams of the steel bents.

6 November 2015

SIMPSON GUMPERTZ & HEGER

Engineering of Structures
and Building Enclosures

Mr. Charles Aspinwall
Town Administrator
Town of Millis
900 Main Street
Millis, MA 02054

Project 151186 – Leakage Investigation, Department of the Works Building, 7 Water Street, Millis, MA

Dear Mr. Aspinwall:

At your request, we visited the Department of the Works (DPW) building (Photo 1) at 7 Water Street in Millis, Massachusetts, to perform water leakage testing and to make interior openings at the building. This letter report summarizes our observations, provides discussion on possible causes of water leakage, and makes recommendations for repairs to the building to prevent further water leakage.

1. BACKGROUND

The Town of Millis contacted Simpson Gumpertz & Heger (SGH) in February 2015 to review a water leakage event at the above-referenced building. Mr. Charles Aspinwall, Town Administrator, informed us that during the past three years the building experiences water leakage after large snow events. Recent investigations and repair attempts to correct this leakage have not been successful. During a major snow event on 27 January 2015, the roof leaked and caused damage to the interior office spaces.

We visited the site on 30 January 2015 and observed ice dams (Photos 2 and 3) along both building eaves with icicles spanning and covering sections of the wall (Photo 4). We observed melting areas on the roof above purlins (Photo 5) and at areas in the field of the corrugated panels (Photo 6). We also observed ice and moisture on the interior of the corrugated metal panels at damaged insulation areas on the walls and the roof (Photo 7). We discussed our initial observations with you to determine the following investigation scope of work.

Our scope of work was to perform the following tasks:

- Water test the metal roof with a nozzle or a spray rack to replicate leakage during a rain event. This test was to verify whether the roof leaked but leakage was concealed and captured in the insulation during rain.
- Flood test the metal roof eave and transverse joints to replicate potential leakage caused by ice dams.
- Witness removal of a representative section of the metal roof panels to review the existing construction and identify potential leakage paths.
- Witness interior openings at the interior side of the metal roof panels to review the existing construction and identify potential leakage paths.

- Provide a summary of our observations and remedial repair recommendations.

1.1 Drawing Review

The Town of Millis provided drawings (dated 27 March 2002) prepared by KBA Architects for the purposes of recladding the building, which show the following relevant items (see Drawing A-3 attached):

- A dual sealant joint at all lapping corrugated ribs.
- 2 in. rigid insulation on the interior face of the panels.
- Alternate #3 – Delete metal liner panel at new exterior metal siding and roofing, provide vinyl lined insulation.

1.2 Information from Others

Charles Aspinwall and James McKay, Public Works, Deputy Director/Chief of Operations, told us that the main area of the DPW building is used for maintenance of DPW equipment and vehicles. They also informed us that the DPW washes their vehicles in the main area and is required to collect all wash water. In addition, they told us that the main area of the building does not experience any leakage during rain events.

2. OBSERVATIONS

We arrived on site 7 October 2015 at 8:30 a.m.to perform our water leakage investigation. The weather was clear with temperatures rising from 42°F to 68°F.

The Town of Millis DPW building is a prefabricated, steel structure with face-fastened corrugated metal panels for the roof and walls. The building is rectangular with a single gable and measures approximately 92 f by 120 ft in plan by15 ft tall at the eave and 20 ft tall at the gable peak (Photo 1). Interior offices are located on the southeast corner of the building and comprise approximately 15% area of the building. The office area has a mezzanine storage and mechanical area above matching the same approximate 60 ft by 25 ft area. The remainder of the building is an open-plan garage space with areas for equipment storage, material storage, vehicle maintenance, and a vehicle lift (Photo 8).

2.1 Roof Panels

The roof panels are corrugated metal that lap one corrugation at vertical seams; end laps at transverse joints are lapped 4 in. (Photo 9). We observed 1/8 in. thick by 1/2 in. wide butyl tape installed between laps in the vertical and transverse panel joints (Photo 10). The fasteners compress the butyl tape at those locations; at locations between fasteners we observed no adhesion between the butyl tape and the upper/lower corrugated panels (Photo 11). The corrugated panels overhang the wall approximately 5 in. at the eave-to-wall transition (Photo 12). The eave-to-wall transition is filled with rigid insulation (Photo 13).

2.2 Insulation

The insulation is fiberglass batt with a vinyl facer. The insulation is installed on the inside face of the metal panel walls and roof and spans between the purlins for the majority of the roof (Photo 14). Insulation sections above the mezzanine are held in place with wood strapping running perpendicular to the purlins (Photo 15). The insulation randomly varies in thickness from 4 in. to 7 in. above the mezzanine space. We did not make openings above the garage space to verify insulation thickness. We observed multiple penetrations and holes through the vinyl facer below the roof that are not sealed and multiple areas where insulation has fallen from the roof and where batts are not sealed at seams.

We observed multiple holes in the insulation facer where equipment and tools lean against the building walls (Photo 16).

We made openings in the insulation mounted to the underside of the roof panels and inside face of the wall panels. We observed dripping condensation on the underside of the metal roof panels prior to water testing (Photo 17). We checked weather data and determined the last precipitation event prior to our 7 October 2015 investigation was a light mist that occurred early the morning of 6 October 2015.

2.3 Water Testing

We performed a flood test of transverse and vertical seams in the metal roof panels to replicate probable conditions during ice dams. We created a pond of water over vertical and horizontal seams as well as over fastener locations. Water immediately leaked to the interior during our test (Photo 18).

While we understand that the building does not experience leakage during rain events, we performed a spray rack test at an intersection of the transverse and vertical seams in the metal roof panels. We set the spray rack on the roof to create a cascading flow of water over the surface of the roof. We ran the spray rack test for one hour and did not observe leakage to the interior of the building.

2.4 Temperature and Relative Humidity Monitoring

On 15 October 2015 we arrived on site at 7 a.m. to install temperature and relative humidity data loggers. The outside temperature was 39°F when we arrived. We made openings in the insulation above the mezzanine area to install two data loggers above the insulation. We observed ice on the underside of the roof panels (Photo 19). The roof insulation at the eave-to-wall transition was saturated with water (Photo 20) and began to drain to the floor while we made the opening.

We removed the data loggers on 26 October 2015. Data from the loggers is included in Appendix A to this report.

3. DISCUSSION

Prefabricated metal building roofs are designed to have a capacity that matches the maximum roof load, resulting in little opportunity to add weight of additional roofing materials. As such, roofing repair solutions that add weight to the roof require a full structural review of the building system

3.1 Leakage from Ice Dams

Ice dams form from roof water runoff that freezes at unheated surfaces, such as an overhang. One purpose of insulating roofs is to prevent heat from the interior reaching the roof surface to melt snow and ice (Photo 5), resulting in the water runoff. Insulation is only one means of preventing heat loss. An air barrier is also needed to prevent exfiltration of interior hot air to the exterior, resulting in melting of snow and ice (Photo 6) and formation of water runoff. Air exfiltration tends to occur at building transitions, including roof-to-wall transition.

Once an ice dam forms, it prevents water from flowing freely down the roof. As a result, water can build-up behind the ice dam until it is released by melting, removal of the dam itself, or it finds its way into the interior through a seam or lap.

Corrugated metal roofing and wall panel seams are not inherently waterproof. The vertical and transverse seams rely on continuous adhesion of seam tape or sealant to remain watertight. While the field of the corrugated metal panel is waterproof, any defect at the seams or any penetration through the panel provides a leakage path to the interior. Generally, these seams and laps are constructed to shed water such that water flowing from the roof cannot pass through the seams or laps. However, in a ponded water situation from an ice dam, water can build-up and get under the laps and seams, stressing any seam tape or sealant and eventually leak to the interior of the building.

During our ponding water test, we observed water bypass the butyl tape seal at the vertical seams and transverse laps in the metal panel roofing and leak to the interior. The butyl tape seal is not uniformly adhered to both the upper and lower corrugated panels. The lack of adhesion is the main source of water leakage to the interior. Installing a better butyl tape or a butyl sealant joint is one way to eliminate this leakage path by, but it would require removal and reinstallation of every roof panel. Installing new butyl tape or sealant will require adequate adhesion, which may be provided by the clamping action of the fasteners. Panel areas that are away from the fasteners will not have sufficient clamping to maintain adhesion. It is possible to include additional fasteners, especially along transverse laps; however, the roof will still rely on butyl tape and sealant joint to maintain water tightness.

Alternates to removing and reinstalling the panels with new tape or sealant seams include applying a coating to the existing metal roof panels, installing EPDM flashing at all seams, or installing a new conventional roofing system. We discuss each of these options further in the recommendations section.

3.2 Condensation

The building does not have a dedicated air barrier; warm humid air migrates to the inboard side of the metal panels where it can condense on the underside of the metal panels in cold weather conditions. Multiple holes and unsealed equipment penetrations in the vapor retarder for the building (the vinyl facer of the batt insulation) exacerbate the condensation problem.

We installed temperature and humidity data loggers above the insulation and in the main space of the building to determine existing conditions that may be contributing to the condensation observed at interior openings. The data loggers record temperature and relative humidity (RH) every 10 min. while installed. The data loggers recorded 50%-90% RH above the insulation; temperatures ranged from 17°F to 88°F. At multiple points during the installed period the temperature above the insulation, the RH, and the outdoor temperature (similar temperature to roof surface) reach dew point. When dew point is reached moisture can condense on the interior face of the metal panels.

While installing the data loggers, we noted ice and frost on the underside of the metal panels. On cold enough surfaces, condensation can become frost and also build up to form ice. Once the frost or ice melts, either from the heating of the substrate or through the introduction of warm air, it creates a leakage-like event, and may eventually saturate the insulation.

The interior conditions of the building, along with the lack of an air barrier and a compromised vapor retarder, contribute to the condensation issues and appearance of leakage within the building. Our scope of work did not include reviewing the air handling equipment within the building. However, given the existing conditions, some level of dehumidification is likely required during the wintertime months. This will likely not eliminate the condensation, but may reduce it.

4. RECOMMENDATIONS

25-30K design & con $60,000

We provide several repair options for your consideration. Estimated costs do not include roof design documents, bid documents, engineering fees, or construction administration costs. Our cost estimate is based on concepts, not schematic design. We referred to RS Means 2015 to develop our estimates, which are for budgetary purposes only. We suggest you talk with a contractor to get more accurate estimates based on their better understanding of the local market.

-25,500 design

Option 1 – Reinforced Elastomeric Roof Coating

Estimated cost for repairs: $160,000 to $170,000

- Remove all wet fiberglass batt insulation at roof and wall areas. This may require removal of all fiberglass batt insulation given the condensation on the interior of the metal panels
- Install new vinyl faced fiberglass batt insulation on the underside of the roof and inside face of the walls; seal all penetrations to provide continuity of the vinyl. While not adhered to a hard surface, the vinyl vapor retarder will have to act as the default air barrier to eliminate condensation potential.
- Protect the new fiberglass batt insulation and vinyl from damage caused by equipment storage.
- Install an elastomeric roof coating, similar to TopCoat by GAF or HE687-Enviro White by Henry, on the entire roof skyward facing surface.

Option 1 – Pros	Option 1 – Cons
The roof coating is easier to install over an existing metal roof system.	This system will require increased maintenance in comparison to other roofing options.
The roof coating will reduce the impact of leakage from ice dams.	This system will likely not eliminate all ice dams and condensation.
An intact vinyl vapor retarder, properly sealed, may be able to act enough as an air barrier to reduce the potential for condensation.	The performance of this option is heavily dependent on the installers.
This system does not significantly increase the weight of the roof system likely avoiding a structural analysis of the building.	The roof coating is not as durable as an EPDM roofing system.

Option 2 – Install EPDM Membrane Flashing at All Roofing Seams

Estimated cost for repairs: $130,000 to $140,000

- Remove all wet fiberglass batt insulation at roof and wall areas. This may require removal of all fiberglass batt insulation given the condensation on the interior of the metal panels
- Install new vinyl-faced fiberglass batt insulation on the underside of the roof and inside face of the walls; seal all penetrations to provide continuity of the vinyl. While not adhered to a hard surface, the vinyl vapor retarder will have to act as the default air barrier.
- Protect the new fiberglass batt insulation and vinyl from damage caused by equipment storage.
- Install fully adhered EPDM flashing membrane at all roof seams excluding the ridge area.

Option 2 – Pros	Option 2 – Cons
Covering all seams in the metal roof will limit leakage from ice dams.	The performance of this option is heavily dependent on the installers and more complex than in Option 1 to get membrane within each corrugation.
This system does not significantly increase the weight of the roof system likely avoiding a structural analysis of the building.	Reverse lapping of materials at joints will create water bucking edges against roof drainage.
Less cost to install and less maintenance required than Option 1.	This system will likely not eliminate all ice dams and condensation.

Option 3 – EPDM Roofing and Dedicated Air Barrier

Estimated cost for repairs: $260,000 to $280,000

- Remove all wet fiberglass batt insulation at roof and wall areas. This may require removal of all fiberglass batt insulation considering the condensation issues on the interior of the metal panels.

- Install strengthening members to the roof structure to accept a new roofing system, including removing the existing corrugated roof panels and installing a new dedicated metal roof deck.

- Install new vinyl-faced fiberglass batt insulation on the inside face of the walls and seal all penetrations to provide continuity of the vinyl air barrier. While not adhered to a hard surface, the vinyl vapor retarder will have to act as the default air barrier.

- Install a fully-adhered code-compliant EPDM roof system. Including a roof air/vapor retarder, cover board, roof insulation, roof substrate, and EPDM roof membrane. The roof eave transition details will be critical to minimize future ice dams.

Option 3 – Pros	Option 3 – Cons
Less maintenance and more durable than Options 1 and 2.	More expensive to than Options 1 and 2
The roofing system can have a 20 yr warranty.	More disruptive to the building occupants and day to day operations.
Condensation potential on the underside of the metal deck is significantly reduced.	Will require a structural analysis of the building to confirm that the new weight from the additional materials can be accommodated and include structural reinforcement where needed.

In addition to the above repairs, we also recommend that you have a mechanical engineer review the existing air handling systems to better manage the relative humidity and interior air exhaust within the building including the office areas.

Sincerely yours,

Peter M. Babaian
Associate Principal

Edward S. Farrington
Staff III – Building Technology

I:\BOS\Projects\2015\151186.00-WATR\WP\001PMBabaian-L-151186.00.esb.docx

Photo 1

Millis Department of the Works Building.

Photo 2

Ice dam at eave edge.

Photo 3

Ice dam at eave edge.

Photo 4

Ice dam transitions down face of wall.

Photo 5

Snow melt above purlins.

Photo 6

Snow melt adjacent to roof and wall transition.

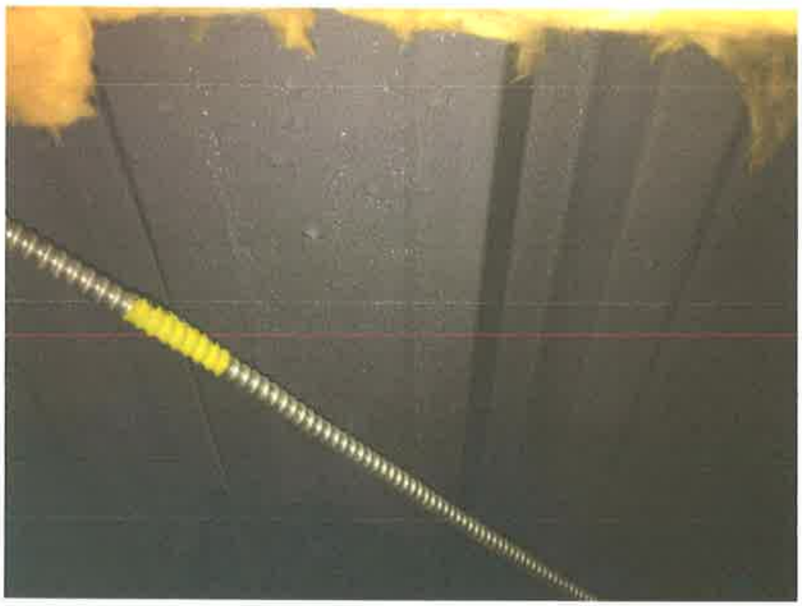


Photo 7

Condensation on the underside of the roof panel.

Photo 8

Open plan garage area.

Photo 9

Typical roofing joints.

Photo 10

Butyl tape at vertical metal roof seam – not adhered.

Photo 11

Butyl tape at transverse joint and vertical joint -- not adhered.

Photo 12
Corrugated roof panel overhang at the wall.

Photo 13

Insulation at the roof-to-eave transition.

Photo 14

Vinyl faced batt insulation spans between purlins.

Photo 15

Vinyl faced batt insulation supported with wood strapping.

Photo 16

Equipment stored against the vinyl faced batt insulation.

Photo 17

Condensation on the underside of the corrugated metal roof panel.

Photo 18

Leak during flood test.

Photo 19

Ice on the underside of the roof insulation.

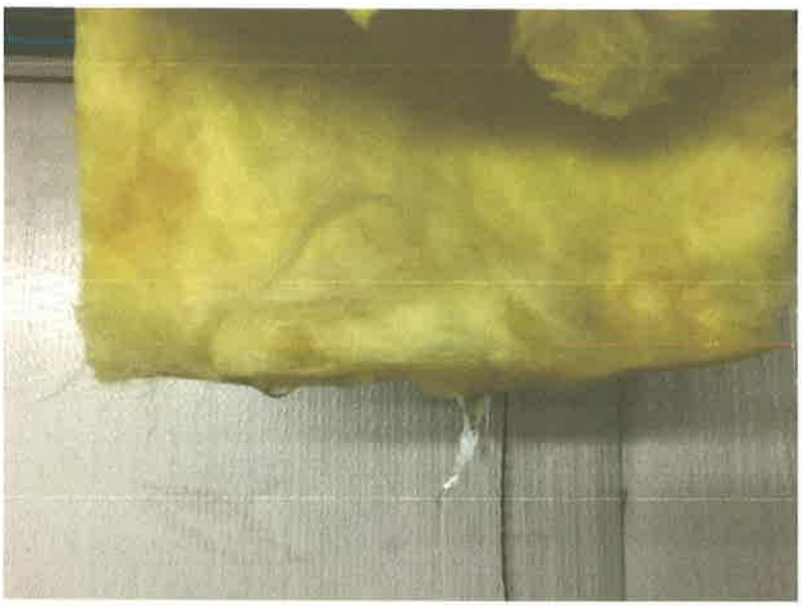
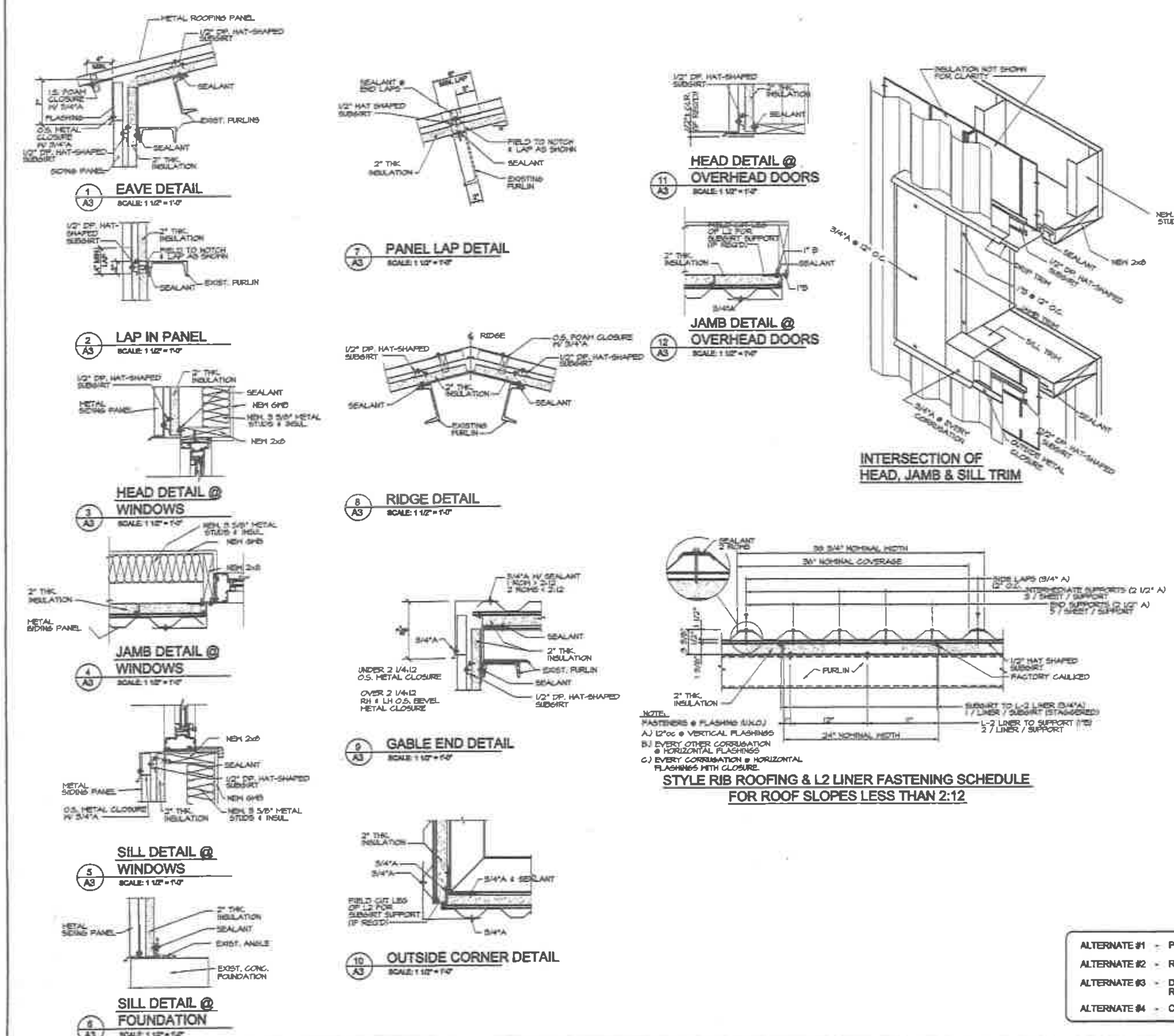


Photo 20

Saturated batt insulation at Data Logger #1.



ALTERNATE #1 - PERFORM WORK AT TOILET ROOMS AS SHOWN.
ALTERNATE #2 - REPLACE FLUORESCENT LIGHT FIXTURES WITH H.I.D. FIXTURES AS SHOWN.
ALTERNATE #3 - DELETE METAL LINER PANEL AT NEW EXTERIOR METAL SIDING & ROOFING, PROVIDE VINYL LINED INSULATION.
ALTERNATE #4 - CLEAN AND PAINT ALL EXPOSED COLUMNS, BEAMS & PURLINS IN GARAGE.

REVISIONS		
NO.	DESCRIPTION	DATE

DESIGNED
DRAWN
CHECKED

ARCHITECTURAL
DETAILS

DPW BUILDING RENOVATIONS
TOWN OF MILLIS
7 WATER STREET
MILLIS, MASSACHUSETTS 02054

KBA ARCHITECTS
KNIGHT, BAGGE & ANDERSON, INC.
BOSTON, MASSACHUSETTS

JOB NO. M01401
DATE 09/27/02
PLAN NO.
A-3
SHEET 4 OF 8

SIMPSON GUMPERTZ & HEGER
Engineering of Structures
and Building Enclosures

12 February 2015

Mr. Charles Aspinwall
Town Administrator
Town of Millis
900 Main Street
Millis, MA 02054

Project 150119 – Leakage Pre-Investigation at the Department of the Works Building, 7 Water Street, Millis, MA

Dear Mr. Aspinwall:

At your request, we visited the Department of Works (DPW) building at 7 Water Street in Millis, Massachusetts, to review reports of water leakage. This letter report summarizes our observations, provides discussion on likely causes of the water leakage, and makes recommendations for an investigation to confirm the causes and develop remedial repairs.

1. BACKGROUND

You informed us that the Department of the Works (DPW) building at 7 Water Street in Millis, Massachusetts, has leakage issues after large snow events in the past 3 yrs. Prior investigation and repair attempts made in 2012 to correct this leakage were unsuccessful. The roof is currently leaking and causing damage to the interior office spaces from the recent major snow event on 27 January 2015.

The DPW building is a prefabricated metal building with a 4 ft high exposed concrete foundation wall (Photo 1). Original construction date and documents were not available to us.

1.1 Information from Others

We received the following information during our site visit from both Jim McKay, the Assistant Director of the DPW, and workers at the facility:

- The building was constructed during the 1970s.
- The finished office space has been repaired multiple times (2009, 2012, and 2013) because of leakage.
- A large amount of water came through the HVAC duct and the smoke detector hole in the ceiling of the office on 27 January 2015 (Photos 2 – 4).
- The building leaks mainly during large snow events but only during some wind-blown rain events.
- Leakage came out from an HVAC duct and behind the furred out column cover at the column in the machine room on 27 January 2015 (Photo 5).

- A section of vinyl-faced roof insulation detached above the mechanics cage at the northwest corner of the building and dispersed a large amount of water on 27 January 2015 (Photo 6).

1.2 Drawing Review

You provided us with drawings dated 27 March 2002 by KBA Architects. The drawings show the following scope of work to the roofing and wall system:

- Removal and replacement of the exterior metal panels with new metal panels and continuous insulation on walls and roof.
- Lapped corrugated metal roof and wall panels, face fastened, with continuous beads of sealant in the lapping metal panel ribs.
- Foam channel ends at terminations of the metal roof and wall panels.
- 2 in. rigid insulation on the interior face of the roof and wall panels.
- Continuous metal liner panel on the interior face of the insulation, with an alternate to delete the continuous metal liner and install vinyl-lined insulation.

2. OBSERVATIONS

When we arrived on site, it was snowing outside with an ambient temperature of 34°. The Town of Millis provided a boom truck for our investigation. We were unable to access the metal roof directly because of snow cover and lack of safe access and safety tie-offs.

2.1 Interior Observations

- The electricity to the office space has been shut off because of leakage into the finished walls and ceiling.
- Damp areas at the floor in the office and the mechanics office where leakage was reported from above (Photo 2).
- Water stains at HVAC duct where leakage was reported (Photo 3).
- Water stains at the smoke detector where leakage was reported (Photo 4).
- Damp insulation and water-stained ceiling tiles in the mechanics office (Photo 5).
- Detached insulation above the mechanics equipment storage area (Photo 6).
- The loft storage area above the finished spaces has water stains and damp plywood located above the leakage reported below (Photos 7 and 8).
- The exposed vinyl-faced fiberglass insulation is damaged and has open seams in multiple locations (Photo 9).

- The metal panels and insulation above and behind the damaged or open seam areas of insulation is wet and frozen (Photo 10).
- Daylight is visible at the roof-to-wall intersection in multiple areas (Photo 11).
- Equipment and tools leaning on the wall insulation causing damage to the vinyl insulation liner.

2.2 Exterior Observations

- The roof is face-fastened overlapping corrugated metal sheets with a transverse joint at the roof slope midpoint. The eave channels are closed with foam insulation (Photos 12 – 14).
- The visible fasteners are coated with sealant (Photo 15).
- The existing building fastener spacing does not reflect the spacing shown in the drawings.
- The snow on the roof is approximately 6 in. deep.
- The metal roof is visible at melted areas above and adjacent to damaged insulation and open laps in the insulation directly below (Photo 16).
- Ice dams are approximately 2 in. thick and extend 2 ft or more from the roof eave toward the roof ridge (Photo 17).
- The internal purlins transmit heat through the roof, and their locations are visible from melted areas of snow (Photo 18).
- After removing icicles at the end of a few corrugated ribs, water began flowing off the eave from below the ice dams (Photo 19).

3. DISCUSSION

The 2002 construction documents provided to us do not have specific information regarding the installed metal roofing system. We determined that the type of metal roofing system called for in the drawings appears to be installed on the building. Face-fastened lapped corrugated metal panel roofing is a difficult system to maintain watertight. The system depends on seals at all fastener penetrations and lap seams. In addition, fastening patterns are not uniform as they are dependent on the panel shape so unsealed fasteners may exist if they are located in nontypical locations. Snow buildup can cause the laps in the metal panels to flex and open under the increased surface load, stressing seals at lap seams and providing a direct path for water infiltration.

The insulation facer is intended to work as a vapor barrier. Damage to the insulation facer and gaps in the insulation allow warm moist air to reach the face of the metal wall and roof panels, where it can condense. As a result, condensation may exacerbate the water leakage problems.

Insufficient insulation and insulation gaps cause snow to melt on the roof, creating liquid water to form ice dams. Ice dams form when melting snow (warmed from the building interior) refreezes at the edge of a roof damming water drainage off the roof. The water collects and freezes, increasing the ice dam and the reservoir of water on the roof. Ice dams can allow water to build up and completely submerge the metal ribs and face fasteners, putting added pressure on fastener and lap seam seals.

4. FURTHER INVESTIGATION

In order to fully determine the causes of water leakage, we recommend a further in-depth investigation utilizing the following methods:

- Water testing the roof above leakage areas using spray rack and flooding joints in the roofing
- Removal of insulation on the interior to view the underside of the roof and wall panels
- Removal of roof panels to verify the roofing construction including verification of sealant joints

We recommend performing the investigation when the roof is safely accessible and temperatures allow for water testing (35° and rising). We also recommend performing the investigation when removal of roofing panels will not adversely affect the use of the building.

At the conclusion of our investigation, we will provide you with repair options to address the water leakage. These may range from the most economical and least durable (adding sealant) to the most invasive and most durable (replace the roofing). We will discuss the costs of each in relation to the expected service life of the repairs to allow you to make an informed decision about which to implement.

We would be glad to provide you with a proposal to perform the investigation and provide a report with repair recommendations. We will require contractor assistance for access and making openings during the investigation.

Thank you for the opportunity to continue to be of service to the Town of Millis. We look forward to assisting you on the next phase of this project.

Sincerely yours,

Peter M. Babaian
Associate Principal

Edward S. Farrington
Staff III – Building Technology

I:\BOS\Projects\2015\150119.00-WORK\WP\001PMBabaian-L-150119.00.rbc.docx

Encls.

Photo 1

7 Water Street.

Photo 2

Office leakage area.

Photo 3

HVAC vent where leakage came through.

Photo 4

Smoke detector where leakage came through.

Photo 5

Mechanics area leakage at HVAC duct.

Photo 6

Detached insulation above mechanics tool storage area.

Photo 7

Loft area above mechanics work area.

Photo 8

Wet loft area floor above office area.

Photo 9

Open insulation at leak area above mechanics room.

Photo 10

Wet metal panel and insulation.

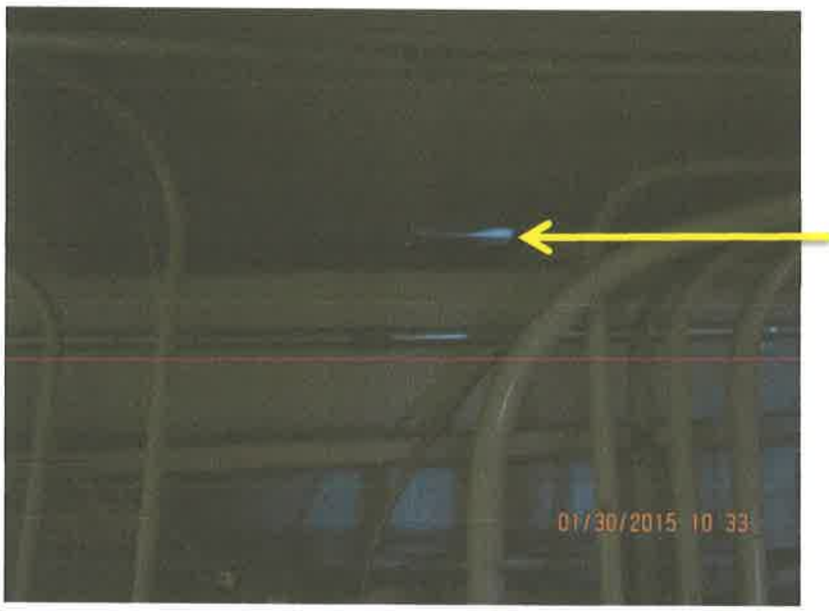


Photo 11

Daylight visible at wall-to-roof transition.

Photo 12

Transverse lap in corrugated metal roofing.

Photo 13

Corrugated metal roofing lap.

Photo 14

Insulation end cap at channel.

Photo 15

Face fasteners at corrugated metal roofing. Insulation below is open.

Photo 16

Melted snow above insulation gap.

Photo 17

Ice dam at eave edge.

Photo 18

Perlin spacing transmitting through snow.

Photo 19

Water draining from ice dam.