Case Study – When A Roof is More Than a Roof

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Abstract. The repurposing of existing buildings is becoming more prevalent. But changing a buildings use is not without concern. A European Company purchased an existing warehouse located north of Chicago, Illinois, USA as the space filled their needs for the layout of their manufacturing equipment. Producing medical grade synthetic mesh requires interior temperatures of 90°F (32.2C) with a relative humidity of 90%. The roof of the facility was low-sloped trapezoidal standing seam metal roof system that was watertight in all types of precipitation: Rain, snow, ice. The insulation, below the roof panels and above the steel purlins, was vinyl face fiberglass batt laid over the structural steel bar joist and pinned by the metal roof panels. Shortly after manufacturing commenced, water build-up in the batt insulation during winter started and was so severe that the vinyl facing would belly downward and split the lap seams, which would release the water, soiling the 2m wide rolls of mesh that then did not meet medical standards and had to be discarded. This case study will review the issues that arose out of repurposing a warehouse to a manufacturing facility and what the solution to correct moisture related issues. Hutchinson Design Group, Ltd. of Barrington, Illinois, was retained to investigate the conditions, determine the causes and develop a corrective solution.

1 Introduction

Roof leaks in the dead of winter was the client's concern. Interesting when the exterior ambient is below -17.78°C (0°F) and any precipitation would be in the form of snow and melt water freezing into ice. A European Company had purchased an existing metal building several years earlier and moisture intrusion from the roof had occurred every winter. (In the US a metal building is one constructed of steel columns, beams and steel purlins, vinyl-faced fiberglass insulation and then metal wall siding and roof panels. Metal building are most often utilitarian structures for warehousing.) The roof was watertight the remainder of the year, never leaking under intense rains or snow melt. A key piece of evidence was that the original building was used for storage. The new entity purchased the building for manufacturing. Not just any manufacturing, manufacturing of medical grade textiles that require the use of humidity to reduce static electricity. Not just humidity, but 90% RH where visible water is sprayed into the air (see photo 1), humidity greater than that of a pool. Interior temperatures. Not just warm temperatures, but 32.22°C (90°F). With 32.22°C (90°F), 90% RH, interior conditions -17.78°C (0°F), degrees outside, and 15.24 cm (6") of vinyl-faced fiberglass batt insulation compressed at the purlins by the roof panels, with aged and open lap seams, is not a good scenario. The owner was confused, concerned and wanted a solution to eliminate moisture intrusion from a roof that was watertight. The purpose of this case study is to show, by

example how re-purposing an existing building for a new use, without due diligence on whether the new use will detrimentally affect structure can lead to unintended consequences and costly results.

Photo 1. To facilitate the production, humidity is added to the interior air to a level around 90%.

2 Contractor/Roof consultant proposed solutions

Prior to the engagement of the author, the building owner had solicited numerous proposals from roofing contractors and roof consultants, none of whom understood the issues. Proposed solutions ranged from

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coating the metal, to filling in between the standing seams with insulation and installing a cover board and mechanically attaching a reflective roof membrane, to panel filler 5.08 cm (2") of insulation and adhered thermoplastic. (Panel Filler: A piece of insulation of thickness to match the standing seam roof panel and which is cut close to the profile of the standing seam so the board insulation or cover board can be installed.) None of the proposals identified the cause of the interior leaking or the extremely high interior's relative humidity and heat as a concern, and thus it was not addressed. The client thus required education as to the issues that required addressing. But imagine if the company had spent a great deal of money on a roof solution that would not have worked.

3 Existing conditions

The existing building was a metal building system: Steel structure, wall and roof panels. The original structure is rectangular in plan with a simple two-way sloped to roof edge gutters. The roof panel was 60.96 cm (24") wide and consisted of a trapezoidal standing seam. The roof slope was 1.27 cm (1/2") per 30.48 cm (12") and sloped from ridge toward a roof edge. The panels run from ridge to eave and were 60.96 m (200') to the north and 30.48 m (100') to the south. The roof drained to a gutter on the north and lower metal roof on the south. The east and west roof edges were standard metal building rake metal. The walls were vertical metal siding with exposed screws. The roof and metal wall panels were set over 15.24 cm (6") of vinyl-faced insulation draped over purlins. The new owners installed exhaust fans to remove interior air which were typically used in the summer and some provisions for adding exterior air in the winter and summer, there was no overall automated mechanical control of the interior.

4 The issues

Where a freezer building has extreme energy low trying with every ounce of its being to pull hot humid air in, this structure has extreme energy high (warm moist interior air) trying to 'get out'. On this repurposed building with its new interior environment, the warm, humid air seeks to move towards equalization with the cold exterior temperatures. At this building the warm, humid interior air was making its way to the underside of the metal roof panels, where the dew point was met and condensation occurred. The condensate water ran down the underside of the sloped metal roof panel until it dropped off into the fiberglass batt insulation below the roof panel. The result was an accumulation of the water on the vinyl facer of the insulation where it 'bellied' until the vinyl facer split or lap seam breaks and large amounts of water comes cascading down onto equipment and product. Soiled product had to be discarded. With rolls 1.524 m (5'-0") wide and a 1.8288 m (6'-0") diameter, the losses were substantial. Water on the floor was also a safety issue. Additionally, when this occurred the insulation layer facer now had another

opening which 'sucked' even more interior air up into the insulation layer and the condensation on the underside of the metal roof panel and dripping to the floor increased. This was occurring in numerous locations across the plant with the greatest moisture accumulation of water in the insulation near the ridge (see photo 2).

Photo 2. Moisture intrusion in the winter is the result of the interior humid air (see photo 1) condensating on the metal roof panels above.

5 Determining the solution

Field investigation revealed that air transport of warm moist air was moving past deficiencies in the roof insulation vapor barrier to the underside of the metal panel where condensation occurred on the panel. The condensation was substantial enough to drip down onto the insulation, where the water moved to the vinyl insulation facer. Over time the volume of water was sufficient enough to break the seal of the vapor retarder. It was a multifaceted concern: Extreme humidity and air temperature, damage vapor retarder, insufficient insulation.

Prior to delving into a potential solution or parti, a concept had to be developed. In this case the concept was to make the metal roof become the vapor retarder for a new roof cover. Simple enough. If the metal roof is to become the new vapor retarder, the key was to keep it warm enough so that even if it came in contact with the interior air, it would not result in condensation. We did this by determining the dew point for several insulation scenarios and found that with the batt insulation still in place, 90% RH with 32.22°C (90°F) temperatures with an exterior design temperature of -23.33°C (-10°F), that 15.24 cm (6'-0") of insulation above a 6.35 cm (2.5") flute filler was required [1].

6 The solution

All roof system designs, not only this high-performance roof system, need to be thought of holistically as the success depends on the sum of all the components working together. First the existing metal roof structure needed to be analyzed for the addition weight of the new insulation. Metal buildings are notorious for minimizing

each and every structural member to minimize costs. A structural check found that the existing structure was able to handle the weight of a new roof system. Second, to verify that the metal roof panel would provide the required fastener pull out resistance, a mechanical fastener pull out test was performed by a manufacturer of the fasteners. The results showed that the 22-gauge metal roof panel was able to engage with the buttress threaded insulation screws and provided the required wind uplift resistance.

To be effective, a vapor retarder and in this case, it needed to be a vapor barrier, needs to be airtight; no permeability at all. The steel roof panel itself is impermeable, but the trapezoidal seams, though mechanically locked, have the potential under interior pressure to allow air to pass, so the trapezoidal seam locks needed to be sealed. The mechanical fasteners designed to secure the new insulation would be penetrating the metal roof panel and needed to be sealed as well. The roof transitions at the vertical rake walls, gutter and low roof all needed to be sealed 'airtight'. So, looking at the roof panel seams, it was decided that they could not be assumed to be airtight, so they were designed to be sealed with a liquid flashing. As the mechanical fasteners would penetrate the roof panels and needed to be sealed; a bituminous self-adhering, self-sealing vapor retarder was placed on the roof panel (see figure 1 and photo 3).

Transverse laps, removing the ridge cap and infilling the opening were all addressed. The rake roof edges presented unique challenges which took some good thinking on how to seal. Ultimately it was a combination of removing the rake metal, installing a prefabricated insulated roof curb and a membrane vapor retarder (see figure 2).

Photo 3. Crews work to install a self-adhering vapor barrier over the standing metal seam roof panels

The thermal layer started with a layer of expanded polystyrene (EPS) designed to fit in between the trapezoidal seam profile (see photo 4).

FIGURE 1 - TYPICAL ROOF SYSTEM SECTION

RAKE EDGE DETAIL

Figure 2: To prevent condensation from occurring at the rake edges, an insulated roof edge curb was designed to keep all existing metal at the rake below the dew point.

Photo 4: Expanded polystyrene (EPS) was custom cut to fit around the trapezoidal seam of the existing metal roof panels. The top of the standing seam, between the insulation has been sealed with spray foam insulation.

Fabricators of this infill unfortunately could not accomplish this, so the void between the trapezoidal seam and EPS was designed to be sealed with spray foam insulation. The thickness of the EPS was 0.9525 cm (3/8") greater in height than the standing seam to compensate for varying seam heights. Over the EPS one layer of 6.604 cm (2.6") fiberglass coated faced, 25 psi polyisocyanurate insulation was designed to be mechanically fastened to the roof panel with a top layer of 6.604 cm (2.6") fiberglass coated faced, 25 psi polyisocyanurate insulation set in full spatter cover flexible polyurethane foam adhesive [2]. A cover board with the receiver (hook and loop) facer to which the fleece backed membrane would be attached was designed to be set in a full coverage of splatter applied polyurethane insulation (see photo 5) [3].

Photo 5. The top two layers of coated fiberglass faced polyisocyanurate insulation have been mechanically attached and the 'hook and loop' faced cover board set in full coverage polyurethane adhesive in a spatter application. The buckets filled with water weigh down the insulation and compress it into the adhesive until set.

Fiberglass coated facer in the iso insulation was chosen as it does not get saturated, lose integrity or support mold growth. As the installation was to take place in late fall and during the winter, adhesive use was determined to be challenging, if not impossible, so the roof cover selected was a 90-mil FleeceBACK black EPDM. The fleece would engage with a unique hook and loop facer on the cover board in which the fleece on

the membrane would engage and reduce by 95% the amount of adhesives required. 15.24 cm (6") seam taped end lap seams with self-adhering cover strips were designed, while the butt seams were also double sealed with 15.24 cm (6") and 30.48 cm (12") cover strips.

The rake edge was designed to be sealed at the top of the metal panels and raised with an insulated metal curb. The wall panels reverse batten seams and bowed inward panel were designed to be sealed with a foam closure set in sealant. The architectural sheet metal on the rakes was a four-piece system of fascia and coping. The roof edge gutter was enlarged and reinforced to hold up to solid ice.

7 Construction

The project was bid out to the finest union contractors in Chicago and the bids came in substantially over the owner's budget. Thus, it was rebid to several non-union contractors with whom the author had good experiences with, and AR Commercial, of Aurora, Illinois, was selected. The project started in October 2018 and finished in April 2019.

At the pre-construction meeting in which the contractor's superintendent and foreman for the project were required to attend, the goal and scope of the project were reviewed. The critical importance of the vapor barrier was reviewed as was the importance of the crews' skills. The installation of the self-adhering vapor barrier on the trapezoidal seam roof panel was a challenge. The contractor first tried cutting the membrane and installing a single strip down the center of the panels and then applying thinner strips up the trapezoidal shaped seam. While this worked it was very time consuming. Ultimately the contractor ended up installing shorter full width pieces and worked them up and over the seam. The installation of the self-adhered vapor retarder took nearly as long as the installation of the insulation and membrane.

The next challenge was to get the EPS insulation infill correct. Sample after sample was incorrect: Height was incorrect, width. Critical time in the fall was being passed by and finally some tough talk with the manufacturer got the material manufactured to the correct dimensions.

The amount of new roof insulation and roofing installed daily was smaller than anticipated. The crew size was small 5-6, versus the 8-9 which is typical, and they moved cautiously to be correct and thorough. During the installation of the roof membrane the foreman noticed that there was a small area of approximately 2.54 cm (1") between where the fleece stopped, and the seam tape started. This area would not be adhered and when heated would expand and create a wrinkle. To prevent this the crew adhered this area. At the end of seam tape, there was ± 1.27 cm ($\pm 1/2$ ") of excess membrane. As the lap seam was being covered with a self-adhering cover strip, this excess membrane was cut off to prevent linear lines of non-adhered membrane below another membrane that could rise. Both efforts took time.

Like any project, various miscellaneous items not anticipated arose, such as extreme cold early in the fall that precipitated the mechanically attaching of the insulation in lieu of cold adhesive application. As this was a new roof membrane, there was a learning curve in regard to its installation. A faux pas on the author's part was forgetting about the residual water in the existing batt insulation. While we designed for 90% RH and 32.22°C (90°C), we didn't anticipate the 100% RH condition where the soaked batt insulation was located which resulted in a small amount of condensation occurring during the first deep freeze. You're never too old to learn something new. The batts vinyl facing on the insulation was cut open, allowed to drip dry and then sealed. Sometimes you need a good roof over your head to keep you dry, even when it doesn't rain.

8 Conclusions

- Before re-purposing an existing structure for new use/occupancy, determine the existing construction.
- Review and determine if the new use conditions will detrimentally affect the existing construction.
- Build in costs to remediate the existing structure to prevent deterioration of the existing structure in the initial planning and build out phase.
- When necessary, perform computer simulations (WUFI) to determine the potential for long-term moisture gain in the existing structure due to the new interior use.
- . Prepare comprehensive details of the required remediations so the contractors have a clear idea of what is required, as often the repairs will be unique.

References

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