A Guide to Protecting Your Roof from a Snow-Related Failure

Facility Manager
November/December 2003

LANHAM, Maryland (CNN) – Search-and-rescue crews were sorting through the unstable wreckage of a Toys "R" Us store Saturday, looking for customers who might have been inside when the store's roof collapsed under the weight of rain and melting snow. Authorities are "cautiously optimistic" that no one is trapped inside.

The preceding news story is not what you want to see in the newspaper or on television concerning your institution's facilities. Snow-related roof failures of buildings that vary from hen houses to classroom buildings to shopping centers have cost hundreds of millions of dollars in damage in the last few years. These catastrophic events can cause serious damage to property, and more importantly to occupants, resulting in a debilitating effect on your operations.

Code and Theoretical Implications

The causes of snow load collapses are typically understood by structural engineers and roofing professionals because model building codes contain specific reference to snow load design. The more recently adopted codes are significantly more stringent than previous codes in the requirement for snow load analysis. Prior to 1968-1970, almost no U.S. building codes required structural engineers to consider the increased loads from snow drifting that can occur on roofs as a result of their geometry and proximity to other structures. Depending on the time when the specific codes were adopted, a building that was properly designed prior to 1975 was not likely designed to safely withstand the type of snowdrifts that can accumulate on its roof, according to current codes.

The 2000 International Building Code (IBC), which is in effect throughout much of the United States, requires that design snow loads be determined in accordance with Section 7 of the American Society of Civil Engineers (ASCE) 7 Minimum Design Loads for Buildings and Other Structures. Therefore, to bring your building up to current code requirements, you must perform a separate analysis to check the structure and possibly design reinforcements to the structure.

The IBC and the ASCE-7 standard base their requirements on a "50-year" storm. The East Coast of the United States had a storm over President's Day weekend in 2003 that resembled this severity. There were more than half a dozen buildings in the region that sustained newsworthy damage, including at least one fatality. A portion of the B&O Railroad Museum, constructed in 1884 and housing the oldest and most comprehensive railroad artifacts in the country, collapsed under the weight of the snow and the heavy winds. Is this to say that there will not be another storm of this magnitude until 2053? Nobody really knows for sure. Furthermore, the failures of the roofs in the region are currently under forensic investigation as to what mechanisms caused the catastrophic collapses. The issues may be related more to the heavy rain on top of the snow than the high drifts.

The flat roof snow load is calculated to yield the likely conditions for the life of the structure. The engineering judgment of the design professional is critical in deciding how conservative this load is based on adjustment factors. The current roof snow load determination factors described by ASCE include the following:

- Ground snow load is depicted on a map of the United States based on a statistical 50-year storm. This is a storm that has a 2 percent probability of occurring. The value varies from 0 pounds per square foot (psf) in Florida, southern Louisiana and Texas, and parts of the southwestern states to 100 psf in the Upper Peninsula of Michigan and northernmost Maine. The ground snow loads in Alaska can reach 300 psf in Whittier, Alaska, or be as low as 25 psf in Cold Bay, Alaska. A significant portion of the United States has a value between 10 to 30 psf.
- Snow exposure factor is dependent on the terrain category and the effects of wind shelter provided by adjacent structures, etc. Buildings in city centers are afforded more wind protection than isolated buildings. Isolated “wind swept” buildings actually have a reduction in snow load since the snow will blow off the building. This can add load to lower buildings and will be accounted for in the drifting calculations.
- Thermal factor is dependent on the interior thermal conditions of the facility. A continuously heated greenhouse with low R-values, which is the measure of thermal resistance to heat flow, will get a reduction in load as the snow is allowed to melt while an unheated structure or one that is intentionally kept below freezing will need to have an increase in loading. Most buildings will simply have the thermal value at 1.0.
- Importance factor is the magnification of the snow loads (or the decrease) based upon the use of the building. The importance factor is assigned based on the nature of the occupancy and the hazard to humans. For example, a structure in a college or university with a capacity of 500 or greater is given a Category III exposure that requires a 10-percent increase in calculated snow load over a standard Category II building. If the building is a hospital, a 20-percent load increase is required.

Based on the ground snow load and certain geometric characteristics of the building, the minimum flat roof snow load may be increased beyond the calculated ground snow load. Additionally, roofs with slopes greater than five degrees are adjusted with a slope factor that is primarily due to wind action. The roof pitch, the type of roof covering, and the thermal conditions of the roof all affect the roof slope factor. After all is said and done, the calculated flat roof snow load is checked against a minimum value depending on whether the ground snow load is above or below 20 psf.

After the roof snow load is determined, calculations for unbalanced loading (due to partial removal or melting) and drifting (due to roof projections or adjacent buildings) must be performed.

Steep roofs that shed their snow onto lower roofs do so at a rate of 40 percent of their total surface area load. The snow is expected to extend out from the end of the eaves to a distance of 15 feet; therefore, a sloped roof that is only 40 feet from eave to ridge can be expected to discard at least 320 pounds of snow per foot of edge. This will add over 21 psf of snow to the structure below. You can see how significant this is considering that the flat snow load was previously calculated to be about 20 psf. In addition to this extra load for sloped roofs shedding their snow load, you then need to add in the snow drifting conditions.

Windward and leeward drift each need to be considered. The drift height can be determined by a graph or an equation stipulated by ASCE-7. The variables that must be considered for the determinations are the ground snow load in the region and the lengths of the roof area that are causing the drift. The length of the upper roof governs the leeward drift. The length of the lower roof governs the windward drift. Roof projections that form inside corners may even have drifts in more than one direction.

After the heights of the drift(s) are determined, the weight of the snow is calculated by multiplying the height by the density of the snow. This will ultimately be the information that is needed to analyze the capacity of the existing structural supports to withstand the snow load.

Lastly, a surcharge from rain-on-snow should be considered on roofs with relatively low ground snow load values. A 5-psf load must be added in certain circumstances where there is a possibility of rain over the snow or snowmelt is expected, especially in very low-slope configurations.

Protecting Your Building From Harmful Snow Loads

To prevent the sudden collapse of roof structures, building owners and managers need to perform the following steps to prepare for future weather events.

- Check the original design documents to ensure that the roof was properly designed. The General Notes of many structural drawings state the design roof live load, the design snow load, and a statement about “drifting conditions.” Contact the original architect or structural engineer to inquire about modifications made during the design that resulted in roof projections or the drifting effects of adjacent buildings.

- Review subsequent renovation/modification drawings for conditions that could result in ponding or drifting situations. Ponding conditions due to renovations or additions are typically the result of impeding the originally designed drainage patterns (i.e., a structure or a roof-mounted unit is placed in an area that blocks the existing drains). Drifting conditions can result from new screen walls, new structures, or superimposed sloped roofing panels.

- Ensure that the drainage components are not undersized, blocked, or easily frozen, allowing them to hold excessive quantities of water. If necessary, snake out the drains. If frozen pipes will impede the flow or burst the pipes, consider heat-tracing systems to warm the drainage component. Consult a roofing professional if the drains appear to be undersized or incorrectly located to remove most of the water. Small ponded areas can have a detrimental effect on the roofing membrane while large or deep ponded areas may have serious structural implications known as ponding instability.

- Inspect the roof periodically to ensure that prior events did not weaken or over-stress the components. Incessant roof leaks over the life of the structure may have caused deterioration and decreased capacity to the structural elements. A structural engineer should analyze cracked beams, deflected joists, and the like immediately.

- Determine a safe depth of snow for the roof in general and some specific drifting areas.Monitor the roof during heavy snowstorms to check that these depths are not exceeded.

- Develop a snow removal plan. If it is structurally safe to do so, consider shoveling snow off the roof onto the ground or onto areas of less accumulation. Remember that the roof is going to be slippery and the heavy snow may collapse the structure. Therefore, consider the safety of the workers when deciding if you should remove the snow. Take care not to damage the roof membrane during removal operations.

- Canopies and overhangs are especially susceptible to excessive loading of snow. Keep the areas beneath the canopy clear of stored goods and traffic. If it can be performed safely, shore up areas that are in danger of imminent collapse.

- Inspect the structure after the storm to ensure that the elements are able to perform adequately in the future.

A Facility Manager's Checklist

To prevent a future roof collapse due to snow or ice accumulations, you should commence preparations and precautions as soon as possible. The actions may be as simple as good housekeeping or as complex as structural analysis and augmentation. Even if your structure has already withstood the onslaught of blizzards, there are warning signs to be aware of for the future.

- If the building was constructed prior to 1975, it was most likely not designed to withstand the code-prescribed snow loads.

- If there have been renovations to the building, including the installation of retrofit roof membranes without regard to the considerations of the existing structure, there may be far-reaching ramifications. Ensure existing roof drains were not covered over with subsequent roof systems. Also make certain that the new structures do not form barriers for drifting unless the supports beneath the drift areas are thoroughly checked.

- If the waterproofing elements have been compromised to the point that the structure is deteriorating, there may be diminished capacity. Typically, this is evidenced by oxidized (rusted) metal decking or joists; sagging wood decks or saturated wood framing; or concrete supports that are spalled or delaminated.

- If there is no provision for overflow, or if drain leaders have experienced blockage, the likelihood for ponding instability is increased.

- If snow or live loading in the past have caused excessive deflection or creep in the structure, additional ponding may result, exceeding the capacity of the structure.

- It may be advisable to consult with a structural engineer and/or a roof consultant with expertise in these areas should these warning signs be present.

Conclusion

The model building codes prescribe the performance of a building under extreme conditions that are only expected to occur at infrequent intervals. Typically, the loads due to snow, rain, and wind work in combination of varying degrees with each other and result in circumstances that may even be counterintuitive to ordinary observations. Even though the circumstances for failure are rare, they do happen.

A building owner or facility manager can mitigate the effects of these rare occurrences by taking proper precautions. At a minimum, the building should be designed, constructed, and maintained to meet the code requirements. The maintenance of structures includes careful inspection of structural members to ensure that the strengths of the materials anticipated during the original design and construction activities are still being achieved. Additional preparations can be made when a significant snow event is forecasted in the same manner that building owners protect against forecasted hurricanes or other predicted events. The best time to prevent building failures due to snow is during the spring, summer, and fall seasons.