# Snow-Related Roof Collapse during the Winter of 2010–2011

## IMPLICATIONS FOR BUILDING CODES


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# Contents

# Executive Summary

The purpose of this report is to investigate the very large number of roof collapses and other snow related roof problems that occurred in the Northeast during the 2010-2011 Winter. The key issue is whether the collapses and poor roof performance was due on the one hand to snow loads well in excess of that prescribed in building codes, or due on the other hand to structural capacity significantly less than envisioned by building codes.

Weather data from multiple sources is used to estimate both the ground snow load and roof top drift loads for the 2010-2011 Winter. These in turn are compared to requirements in the current ASCE 7 load standard. Ground snow load simulated from weather data showed that 2010-2011 winter values were less those from the ASCE 7-10 map. The ratio of simulated 2010-11 ground snow load to ASCE mapped ground snow load ranged from about 85% for Connecticut to about 59% for Rhode Island. Hence the structural performance problems in 2010-11 were not due to ground snow loads well in excess of those in ASCE 7-10.

Similarly, weather information – specifically snowfall, wind speed, wind direction and duration of wind storms – was used to simulated 2010-11 drift snow loads for various roof geometries, at selected locations in southern New England. Although the simulated drifts were in some cases substantial, they were not significantly larger than those prescribed by the ASCE 7-10 provisions.

Building performance databases from state officials in Connecticut and Massachusetts were gathered as well as case histories from structural engineering practitioners. These databases proved useful in three ways. First, they allowed determination of the typical "problem" building. The majority of the problem structures were single story, wood framed buildings with pitched roofs. Roof structural components were most commonly wood beams and roof surface materials were most commonly reported as non-slippery. Also somewhat surprisingly, about 40% of the problem structures were unheated.

Secondly, the practitioner case histories allowed determination of the apparent failure mechanism. For case histories where the apparent failure mechanism was known, approximately half were attributed to large snow loads, either uniform or drifts, which apparently exceeded the current structural capacity. For the other half of the case studies, the failure was apparently due to structural capacity problems such as an initial construction deficiency, a man-made reduction in structural capacity, or natural deterioration of the structure over time.

Finally some of the practitioner case histories included roof snow load measurements. These in turn were compared to the flat roof snow load prescribed in ASCE 7-10. Separate comparison were made for heated and unheated structures since the ASCE 7 flat roof snow load is a function of the roof thermal condition. For both groups, the majority of the roof load measurements were less than or reasonably close to those proscribed in ASCE 7-10. In a limited number of cases, the measured roof load was significantly larger than the ASCE 7 flat roof load. However, in each of the "outlier" cases, the measured load was also in excess of the estimated ground snow load. As such they were not consistent with a flat roof load and conceivably include a drift surcharge or impounded roof snow melt due to clogged or inadequate drainage.

In summary, although the 2010-11 winter in southern New England was quite snowy, the estimated ground snow loads were less than design values in the ASCE 7 load standard. Similarly, simulated roof snow drift loads for the 2010-11 wither were substantial in selected locations and for selected wind direction. However, again, they did not significantly exceed the prescribed design loads in ASCE 7-10. Finally, measured roof loads were generally less than those prescribed in the ASCE 7-10 In general the 2010-11 winter roof problems were due to initial construction defects, poor maintenance, improper modification of the structure, and natural deterioration of structural capacity over time. It seems likely that "problem" roofs for which localized drift loads were the apparent failure mechanism, were designed prior to the adoption of modern (post 1988) snow drift provisions.

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# Chapter 1
# Introduction

The winter of 2010-2011 was particularly snowy in the Northeast. Heavy snows resulted in nearly 500 problem roofs, of which 382 were full or partial collapses in the states of Connecticut, Massachusetts, New York and Rhode Island. This large number of roof problems lead to questions being raised by engineers and state building code officials as to the adequacy of current building codes in relation to roof snow loads. Specifically, were the 2010-2011 winter roof problems due mainly to roof components not being as strong as envisioned by current codes, or were the 2010-2011 roof snow loads larger than those envisioned by building codes?

The purpose of this report is to answer these key questions by providing the structural engineering community with data and analysis on the ground and roof snow loads in the Northeast during the 2010-2011 winter.

This report is subdivided into six chapters. Chapter 2 presents ground snow load measurements from three national sources: Local Climatological Data Center, COOPerative weather stations and the National Operational Hydrologic Sensing Center. Chapter 2 also presents local databases of roof problems and cases studies of measured roof loads at selected structures. In Chapter 3, the design ground snow loads as specified in by building code are compared with simulated ground snow load estimates from local weather data. In Chapter 4, the so called "balanced" roof loads – nominally uniform snow loads across the whole roof – are examined. Building code provisions are compared with measurements taken on some of the case study roofs. Chapter 5 examines snow drift loads. Design snow drift loads as prescribed by code provisions are calculated for various roof geometries. Estimated 2010-2011 winter drift loads are then simulated for these same roofs, using a previously developed model, and compared with the "building code" drifts. Chapter 6 gives a summary of the findings and draws some conclusions about the adequacy of current codes. Finally, various databases and tables are provided in the appendices.

# Chapter 2
# Data Sources and Available Information

There were 9 prime sources of information on ground and roof snow loads during the 2010-2011 winter. In relation to roof snow loads and structural collapse, these include the Connecticut Office of the State Building Inspector database, the Massachusetts Emergency Management Agency (MEMA) database, the New York State Division of Code Enforcement and Administration (DCEA) database, as well as individual case histories from Simpson Gumpertz & Heger (SGH), Wiss Janey Elstner Associates, Inc., DiBlasi Associates, PC., and Odeh Engineers Inc. In relation to ground snow loads, the primary sources are the Local Climatological Data station sheets, COOPerative station data sheets, and the National Operational Hydrologic Remote Sensing Center (NOHRSC) website. Finally, FM Global provided detailed information of the dollar losses associated with these 2010-2011 winter roof problems in the Northeast. Information from each of these data sources is presented in this chapter.

## 2.1 – Weather Data

Weather data is used in this study to simulate the ground snow load and roof snow drift loads for the 2010-2011 Winter. Data was collected from 14 weather stations in the region as shown in the map in Figure 2.1 (2 in RI, 3 in NY and CT, and 6 in MA). A combination of COOP stations and Local Climatological Data stations (LCD) were used to estimate the ground snow load. Specifically, both types of stations were used to determine the maximum ground snow load for the winter. COOP stations provide infrequent but direct measurement of the snow water equivalent (SWE) of the ground snow pack. The LCD stations provide measurements of the daily precipitation. These daily values can be summed to provide an estimate of the ground snowpack SWE. Wind speed and direction information from LCD stations were used to simulate drift loads.

Figure 2.2 shows the first page of the LCD sheet for Albany NY in January 2011. Note that as with all the LCD datasheets, column 12 – water equivalent of snow/ice on the ground at 1 pm on a particular day – unfortunately is not recorded. As will be described in more detail later, the ground snow loads will be estimated from column 14 – water equivalent of daily precipitation, column 13 – depth of daily precipitation, and column 2 – maximum daily temperature.