Roof Failure

Interactive Qualifying Project Report
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Abstract

Roofs can collapse due to weather when snow, ice, and rain build up. Building codes are in place to specify the loads roofs must be built to handle. This project is investigating the causes of roof failures with the goal of decreasing the threat to human safety from roof failures. After interviewing engineers and building inspectors, it was determined that existing building codes do not need to be changed. However, there is still a problem with roof failures that needs to be addressed.

Through much deliberation this group found two main solutions for the prevention of roof failures. The first is regular inspection that lasts longer than initial approval of the blueprints. During construction, buildings need to be inspected to assure that no unapproved changes have been made to the design. The second occurs after construction, when buildings need to be inspected regularly to make sure nothing has failed creating a situation that is hazardous to the building. An alternative to regular inspection could be an early warning detection system that will alert building owners in the instance where the structural integrity of their roof may be in jeopardy.

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Executive summary

Introduction

New England winters can be very hard on buildings. In December 2008 an ice storm struck New England, leaving many structures and trees in north central Massachusetts and southern New Hampshire destroyed. The goal of this project is to investigate causes of weather related roof failures and attempt to issue recommendations to reduce the risk to human safety and monetary loss from roof collapses.

Background

Building construction in the United States is regulated by state building codes. Prior to 1994, there were three major code development groups which states referenced when writing their building codes. In 1994, the International Code Council unified these three groups into one, creating a building code which is today used as the basis for building codes in all 50 states. New Hampshire has a basic building code which only specifies that the ICC code should be followed. Massachusetts has a longer building code which specifies the wind and snow loads that roofs must be able to support, based on location.

Methodology

Initially, the focus of this project was to find faults or weak points in the building codes that allowed unsafe buildings to be constructed. We first researched building codes and became familiar with the background of building codes both in the United States and in other countries. We then began contacting experts to schedule interviews to learn more from the people who work with buildings.

The first interviews we conducted were with Municipal Building Inspectors. These Inspectors are not engineers, but they do follow building codes and work closely with builders. We quickly learned from these building inspectors that the building codes are sufficient, and in many cases they consider the codes to be too strict. Because of this, we did not interview any of the contacts we had located who develop building codes.

Our next interview was with an engineer from the Massachusetts Department of Public Safety (DPS). This engineer was very familiar with building construction and codes, including code development. He also believed that the building codes were not too weak, and was able to suggest other causes of building failures. He shared several examples of building failures and their causes. We used these examples to create our recommendations and conclusion.

Results and Recommendations

Based on our interviews and specific examples of building failures, we were able to create some recommendations. Due to the fact that no engineer or inspector we talked to thinks there is any weakness in the codes, we are focusing our recommendation on regular inspection. Several of the building failures investigated failed due to bad construction caused by changes made during construction that were not approved by an engineer. Other failures were due to unsuccessful roof systems that allowed water and ice to build up on a roof.

Building failures due to improper construction can be reduced by increased involvement of engineers during the building process. The engineer we met with was working on a construction site where he could watch construction. In every building construction changes are made to the original blueprints after they are signed by an engineer. Inspectors must be aware of the changes to the blueprints as they are made.

The other preventable cause of roof failure was buildup of snow and ice. Regular inspection of roof water drainage systems can identify a water buildup before it becomes a hazard. Also, sensors could be added to a roof to detect water pooling. For some types of roof construction, there are also sensors that can detect deflection in the roof support system that would indicate overloading. These systems could give advance notice to roof failures and allow time to move people to safety or clear whatever is overloading the roof.

Conclusion

There are several reasons why roofs and buildings can fail. Building codes are in place to address most of the possible causes of roof failures, but there are some things that cannot be prevented by codes. Some of these failures can be prevented by increased inspection and involvement of engineers in the construction process

Chapter1: Introduction

It is common knowledge that in New England, the weather can change as fast as anything. With the blistering heat waves that can hit during the summer it is sometimes a shock at just how cold and harsh the weather can be during the winter. During the winter months of December 2008 – February 2009, the weather in New England was especially unforgiving. Ice storms and snow fall combined with freezing temperatures and gusting winds to create one of the worst winters in quite some time.

It is often weather like this that makes people question how prepared they are for the elements, whether it means buying a new wardrobe to fit the weather, getting a car with 4-wheel drive, or just making sure your house will be able to stay heated throughout the season. An often overlooked precaution is checking the house that you are trying to heat to make sure it can withstand the unkind weather. Many times people assume that if a building is standing its sturdy, but over the course of the last winter structural failures of all kinds proved otherwise.

This project is devoted to researching one specific type of structural failure, roof failure. There are many possible causes of roof failures. Everything from falling branches and telephone poles to improper construction and too much weight being supported can lead to the failure of a roof. In all cases the results are potentially fatal. The loss of a roof can mean very terrible things economically as well as personally. If a business owner finds that their roof has collapsed they will not only be set back money by fixing the roof, but they will also lose business for the entire time that the building must be repaired, not to mention what can happen if some unsuspecting target is below a roof when it collapses. The outcome will certainly lead to severe injury and in some cases even death. With this being said, it is imperative that some solution be created to prevent these occurrences from happening in the future.

The goal of this project is to do just that. Having researched roof failures including their cause and effect, our goal is to form a solution that will prevent future roof failures. It is also a hope that we will be able to shed light on a relatively unrealized problem. Complacency is a large problem and when it comes to endangering lives this should not occur. With our research and solutions, we hope that people will realize what a hazard an unsafe building can be, eventually leading to the advanced notice of these unsafe conditions with time to prevent worse problems.

In this report the reader will be able to follow our process through its entirety. The process will begin with background research in building codes. This background research will provide our group with information on exactly how buildings should be made in order to determine later whether failures occurred due to complacency with the codes or codes which are not strict enough. Following this research the group will conduct a series of interviews with Town Inspectors and Civil Engineers with the hopes that they will be able to cite specific examples of roof failures and provide details about them. Following these interviews will be research by the group in the field of roof failure cause and effect, with the intention of determining a trend or pattern of failure causes. Finally, the group will use these findings to form conclusions and recommendations on what is the true cause and how it can be prevented. In the end, the group hopes to show that there is a concern for roof failures and that it can be prevented using simple but effective procedures.

Chapter 2: Literature Review and Background Information

Although roof failures rarely occur, when they do occur it is a major topic of concern, discussion, and investigation. Since the overall goal of this project is to identify causes and effects of roof failures as well as preventative measures to combat roof failures, this chapter will provide an overview of building code history, current building codes, causes of roof failures, and their effects. This chapter starts off by investigating the history of the building codes and regulations for various locations, specifically the codes and regulations for the United States, Massachusetts, Canada, and Europe. This section will also look into the current building codes and regulations of the aforementioned locations. Having done so, it will also describe what regulations are currently addressed during roof assembly for each of the places researched. The chapter then ends with an examination of the different causes of roof failures that are currently afflicting homes and buildings in the United States.

2.1 Building Codes

Building codes are not a recent phenomenon. King Hammurabi of Babylon first instituted his building codes in the *Code of Hammurabi* nearly 4000 years ago. Although Hammurabi's building code differs from the modern building codes of our era in several ways, such as being concise and simple as opposed to "voluminous, wordy, and technically complex", it still took into consideration the structural stability of the buildings and the safety of the individual (Joseph P. McEvoy, 1991, p. 3). An excerpt from the *Code of Hammurabi* pertaining to Hammurabi's building code can be seen in Appendix P.

Building codes are developed, adopted, and implemented by local and state governments all around the world in order to minimize and hopefully prevent any hazard from befalling on the life, wellbeing, and safety of the people within and around the structures. One prime example, which shows the importance of building codes, is the events that took place during and after Hurricane Katrina in 2005. After the aftermath of Katrina it was found that several parishes in Louisiana had insufficient building codes and some didn't even require building inspections ("A Growing Emphasis," 2006, ¶ 1). Had Louisiana adopted the I-Codes prior to Hurricane Katrina, fewer lives might have been lost and fewer people injured.

2.1.1 History of Building Codes in the United States

Prior to the establishment of the International Code Council (ICC) in 1994, the United States building regulations and standards were derived from three separate model building codes. The first of the three was developed by the Building Officials Code Administrators International (BOCA), which was established in 1915. Their model building code, the *BOCA Basic/National* Building Code, first published in 1950, was adopted by various states and cities within the Northeastern to Midwestern regions of the United States. The second was developed by the International Conference of Building Officials (ICBO), which was established in 1922. The ICBO's building code, the *Uniform Building Code*, first published in 1927, was adopted by the states in the Western region of the United States, including Alaska and Hawaii. The last of the three was developed by Southern Building Code Congress International (SBCCI), which was established in 1940. Their building code, the *Standard Building Code*, published in 1945, was adopted by the various cities and states of Southeastern and South Central United States (Kote & Bugbee, 1998).

In addition to the three code writing organizations listed above, two other code writing organizations existed prior to the ICC. The first was the American Insurance Association (AIA), formerly known as the National Board of Fire Underwriters (NBFU), and the second was the Council of American Building Officials (CABO). Accepted as the first building code of the United States, AIA's *National Building Code* (NBC), which was published in 1905, was developed for two reasons. The first was in hopes that state and local governments would use their code as a basis when drafting and designing their own building codes. The second was to use this new code as a basis to evaluate the building regulations and standards of the state and local governments. However, in 1976, AIA decided to discontinue publishing the NBC and shortly afterwards BOCA bought the rights to use the name. In 1972, with the joint cooperation between BOCA, ICBO, and SBCII, CABO was formed. The purpose of CABO was to develop a code for "One- and Two-Family Dwellings" that could be used in all three regions of the United States. This code was later published in 1983 and was called the *CABO One- and Two-Family Dwelling Code*. Finally, in 1994, ICC was formed when the three major coding organizations decided that it would be more effective to have a single set of codes as opposed to three regional codes. This new set of codes, which they call the International Codes (I-Codes), has had a new edition published every three years since its first publication in 2000 (Kote & Bugbee, 1998).

2.1.2 United States Building Codes

Currently all 50 states, including Washington, D.C., have adopted their own building codes, although with slight changes to accommodate for state regulations, one or more of the I-Codes, which is a series of codes developed to set regulations for building systems, both commercial and residential, new or existing, as well as fire systems, plumbing systems, and much more. However, there are only two codes in the I-Codes series that explicitly set regulations for roof assemblies and they are the *International Building Code* (IBC) and the *International Residential Code* (IRC).

The IRC, a code developed for "detached one- and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories above grade plane," (International Code Council, 2009, p. 1), is a replacement to CABO's code with several new changes to not only roof assemblies but other sections as well. Please refer to Appendix O for a table showing a comparison between the *CABO One- and Two-*

Family Dwelling Code and the first edition of the IRC involving roof assembly regulations. The IBC is a code developed for "all occupancies, including one- and two-family dwellings and townhouses that are not within the scope of the IRC" (International Code Council, 2009, p. v). As you can see from Figure 1, all 50 states, including Washington D.C, have adopted into their own building codes the IBC. For a table of what I-Codes are currently adopted by which state, please refer to Appendix N.

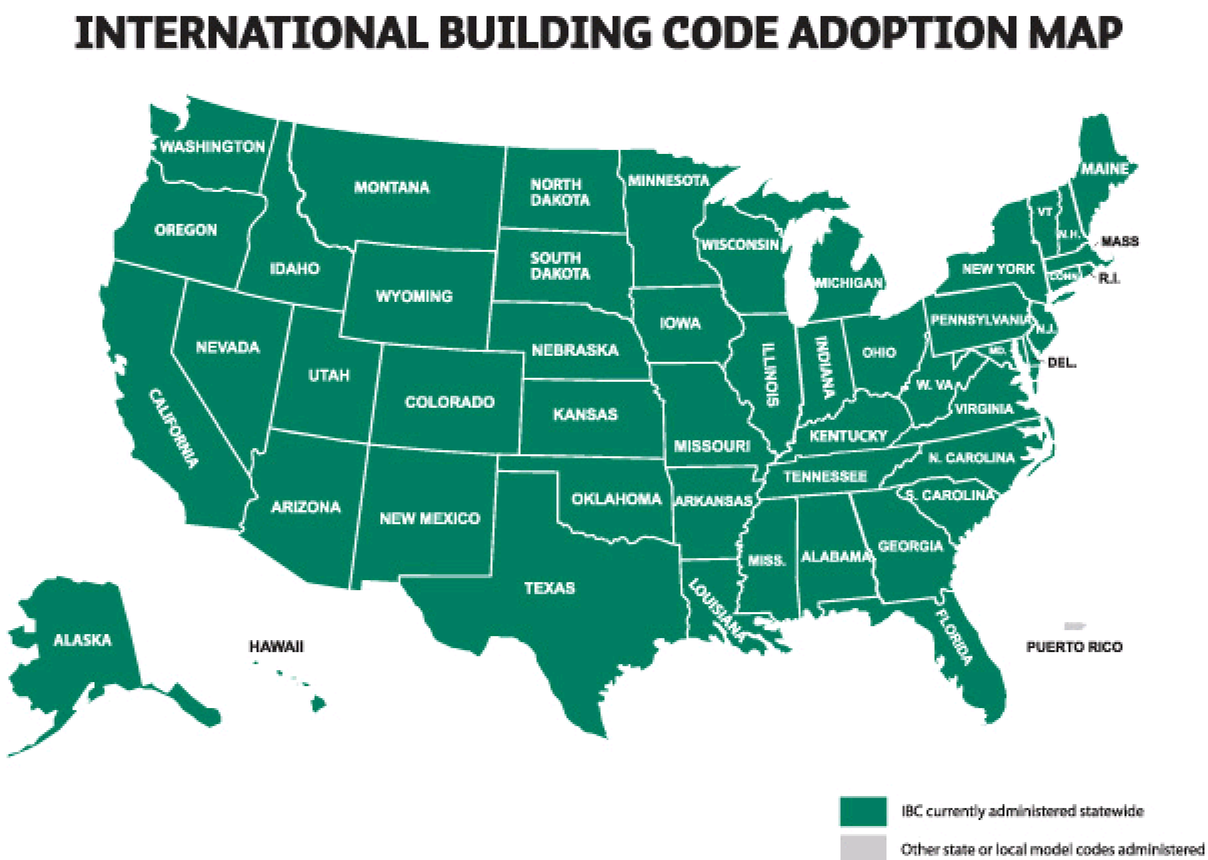


Figure 1 - International Building Code Adoption Map

Both the IBC and the IRC addresses the same issues concerning roof assembly. However, only the IBC addresses the issues of performance requirements, fire classification, and roof top structures, such as towers, spires, and water tanks. The following is a list of concerns covered by both the IBC and IRC:

- Weather Protection
- Materials
- Requirements for Roof Coverings
- Roof Insulations
- Reroofing

2.1.3 Massachusetts Building Codes

The state of Massachusetts shares one common building code, the Massachusetts Statewide Building Code (MSBC). The first statewide code was adopted in 1975 and was based on the BOCA Basic/National Building Code. Today's version of the code is based on the code written by the International Code Council. The building code is contained in the Code of Massachusetts Regulations (CMR) Chapter 780. Sections 50-93 are dedicated to single family residential structures, while sections 1-35 cover regulations for all other structures. Building ratings are divided by towns. Buildings in the northern part of the state are required to withstand larger snow loads than buildings in the southern part of the state. Buildings closer to the ocean are required to withstand higher wind loads than buildings in the western part of the state. Snow and wind load requirements for these buildings are seen in appendix L. Single family residential structures are subject to slightly lower snow and wind load ratings than other structures. The snow and wind load requirements for these residential structures can be seen in appendix K.

2.1.4 History of Canadian and European Building Codes

According to the Constitution of Canada, the Supreme Law of Canada, building regulation is the responsibility of the province. Some municipalities were even given the right to create their own set of building codes. In the first stages of building regulation, this caused an inconsistency among building codes throughout Canada. It was not until 1941 that the Canadian Federal Government published the first National

Building Code (NBC), the model code which sets the basis for all Canadian codes. Over the next twenty years the NBC was adopted by most of the provinces and municipalities of Canada. Since 1960, the NBC has been updated every five years, with a ten year gap from 1995-2005. The 2005 edition of the NBC is the most current edition with the next edition planned to be published in 2010.

Since the 2005 edition of the NBC, all of Canada uses the NBC as their building code except for Ontario and Alberta. Ontario does not use the NBC but has created their own code, the Ontario Building Code, with the 2006 edition as the most recent. This 2006 edition has been edited to make the codes more acceptable by the NBC. Alberta, through agreement with the National Research Council of Canada (NRC), created in 1916, has to use the NBC as the basis for its building code. However, Alberta is able to modify the codes and has done so previously so that they may be applied to specific conditions in the province. Similar to the situation with Alberta, some provinces and territories are required by law to use the NBC as their building code. Territories which are required by law include Prince Edward Island, Nova Scotia, Newfoundland, Labrador, Manitoba, and British Columbia.

In Europe there is a movement to standardize building codes among all countries. This unified set of building codes is known as the Eurocode. There are ten sections of the Eurocode which were published and released on an annual basis from 1990-1999. These codes were developed by and are maintained by the European Committee for Standardization (CEN), which was established in 1961 as a non-profit group devoted to creating a unified set of standards for all European nations. By 2010, the Eurocode will be adopted across all of Europe for all public works and is likely to become the primary building code, replacing existing building codes in private sections as well.

2.1.5 Canadian Building Codes

With the exception of Ontario and Alberta, Canada has accepted the NBC as their official building code. The NBC makes mention of roof design and specifically what types of loading to protect against. The code includes sections on loading due to ice, rain, snow, wind and earthquakes and within these sections there are subsections on specified loading as well as full and partial loading. The section concerned with this project is snow loading. Specific recommendations by the NBC state that roofs should be able to support 80% of the ground snow load if the building is unexposed to wind and 60% of the ground snow load if the building is exposed to wind. Finally, the code mentions three specific cases to consider when designing a roof. The first case is where the snow is uniformly distributed across the roof, the second case is when the snow drifts due to wind and the wake areas have a snow load that can reach up to three times the ground load, and the third case is when there is a degree of unevenness in the loading, specifically full loading and half loading. Each of these considerations mentioned in the NBC are also adjusted for different styles of roofs including flat roofs, sloped roofs, gable roofs, etc.

2.1.6 European Building Codes: The Eurocode

Currently, the Eurocode is not the primary code used in Europe. Some European nations have their own code however by 2010 it is predicted that the Eurocode will become standardized throughout Europe. There are ten parts to the Eurocode, Eurocodes 0-9, with each covering a specific topic. The topic most concerned with this project falls within Eurocode 1: Actions on Structures. This part of the Eurocode deals specifically with different types of loading on structures, in particular roofs, and includes sections on self-weight and imposed loads, structures exposed to fire, snow loads, wind loads, and thermal actions. According to the Eurocode 1-3, snow loads can be classified as several different types of actions. Evenly spread snow loads are classified as variable fixed actions and can also be classified at static actions whereas drifting and uneven snow loads are classified as accidental actions, but can change based on their geographical location.

In addition to snow loads on roofs, Eurocode 1-3 covers snow loading on the ground as well. The main aspect of ground loads is known as the characteristic value and is represented by the symbol S_k. The ground load is used to help determine what amount of snow loading a roof should be built to support. There are three more coefficients that are used to help determine snow loading, the combination value ψ_0, the frequent value ψ_1, and the quasi-permanent value ψ_3. These values will change based on the geographical location of the building. Similar to the Canadian NBC, the snow load in the Eurocode is determined using the ground load. The equation is based on the snow load shape coefficient μ_i , S_k, the exposure coefficient C_e, and the thermal coefficient C_t. Finally, the Eurocode gives specific snow loads for areas throughout Europe in a graph form, and also gives a table explaining the density of snow as it changes from fresh snow to wet snow. The specific sections of the Eurocode pertaining to snow loads can be seen below in Appendix M.

2.2 Causes of Roof Failures

This section discusses the different possible causes of roof failures, obvious or obscure, that afflict hundreds and thousands of roofs annually. Since there are numerous possible causes of roof failures, minor or major, outside the more common causes, this section will group the main causes of roof failure into two different categories with descriptions of resulting causes explained in each. The two categories, in no particular order, are as follows: improper installation or design and weather. Of course, the two main causes can also result in the same minor causes; however, they will only be mentioned in one category.

2.2.1 Improper Installation or Design

Improper installation and/or design of a structure's roofing system are very common causes of roof failures. Due to human fallibility or negligence of the architect, building engineer, and/or construction workers a list of roof related problems can arise from these two root causes. The following is a list of problems that can cause roof failures which stem from improper installation and/or design:

- Blisters
- Splitting
- Roof Ponding
- Open Laps
- Penetrations
- Loose Fasteners
- Ridging/Wrinkles/Fish Mouthing
- Flashing Problems

Blisters, one of the more common problems that afflict a roof, usually Built-Up Roofs (BUR), are pockets of water vapors that have become trapped between the roof membranes. They are typically caused by "inadequate attachment of hot bituminous roof systems" (C.A.R.E., as cited by Jana Madsen, 2004), which allow air and moisture to penetrate the roof membrane. When the pocket of air and moisture is exposed to intense heat from the sun, it results in an expansion that causes the surrounding roofing plies to push apart, resulting in a blister (Warseck, 2003).

Splitting, a similar problem to blisters that usually affect BURs, are cracks that appear on the roof or the roof membrane. One reason why splitting occurs at the roof membrane is because of the inability of the roof to sustain a certain load, which resulted from poor workmanship and design. Another reason why splitting occurs in a roof is because they weren't designed to properly accommodate for the expansion and contraction of roof joints, which is a result from a poorly designed roof (Warseck, 2003).

Roof ponding, a hazardous problem that can afflict low-sloped roofs or flat roofs, like BURs, is the retention of water in areas of the roof. It is typically caused by an inadequate roof drainage system, poor roof slopes, and sagging roofs, which are results of improper design and installation. If roof ponding isn't treated, problems such as structural settlements, roof leakage, and ultimately a roof collapse.

Problems similar to blistering, splitting, and roof ponding that also affect BURs are flashing problems, open laps, penetrations, loose fasteners, and ridging/wrinkles/fish mouthing (Warseck, 2003). As mentioned previously, each of these problems are a byproduct of inadequate installation or design of the roof system. However, some of these problems may also be attributed to the weather and aging. The end results of these "minor" causes are further "minor" causes in the surrounding area, leakage into the roof system, and eventually roof failure.

2.2.2 Weather

Aside from human fallibility and negligence, Mother Nature may also cause roof failures. Roofs are constantly being exposed to the weather, which results in the deterioration of the materials used to sustain the roof and with some roofs being decades old it is only a matter of time before one fails. The following is a list of weather patterns that can cause result in roof failure if it is neglected:

- Snow
- Ice
- Rain
- Wind

During the winter season, snow, ice, and rain can be a deadly combination that can cause flat roofs and roofs with complex multiple elevations to fail. If you've done any calculations concerning snow loads before, you would know that a cubic foot of snow weighs approximately seven pounds for new light snow, to roughly thirty pounds for compacted old snow. Adding to the fact that rain and ice sometimes accompany snow fall, the end result is most likely roof damage if not a roof collapse. Of course, this is not including the fact that wind also accompanies snow storms, which result in snow drifts that add to the previously mentioned snow loads. In addition, wind alone could pose a problem for roofs where high enough wind speeds could potentially remove weakened or improperly installed asphalt shingles and metal roofing from residential homes.

Another cause of roof failure that is related to snow, ice, and rain is frozen water in the roof drainage system. When the drainage system of a BUR freezes up it allows for a buildup of snow and rain, which can in turn cause a ponding that adversely affects ones roof. Similar to the BUR drainage system, if the gutters of a residential building are frozen, the roof will also be damaged. For example, if ice were to accumulate in the gutters, it would eventually overflow into the first few rows of singles. This can cause the shingles to loosen if not completely break off from its location, which can cause water leakage into the roof ("The Hazards of Ice", 2008).

Chapter 3: Methodology

The method by which things happen often determines how efficiently they are completed. Following a set of instructions or guidelines is only beneficial if those instructions are proper for the job at hand. This project would not have been completed without an organized plan. Although the course of action may have changed some from start to finish, three main methods remained throughout the project. The first method was building code research. The reason for doing this research is simple; buildings that collapse fall into one of two main categories, poor construction or circumstances that the buildings were not prepared for. Knowing the building codes will allow the group to determine whether buildings collapse because they are not built to follow these codes or they collapse because the codes are not strict enough to prevent it. The second method is a series of unstructured interviews with building inspectors and civil engineers. It is always beneficial to have an expert in a field to give clarity to a group, and this is the reason we chose to conduct interviews with building inspectors and civil engineers. The goal of the interviews is insight into causes of failures that inexperienced researchers, such as our group members, would not normally see. The final method was building failure causes and effect research. The overall goal of the project is to find a solution to prevent building failures in the future. In order to do this we must first find out why buildings fail in the first place, giving the reason for this research. In the end these three methods of combining research and interviews will allow the group to fulfill its goal of building failure prevention.

3.1 Interview Process

When researching a topic it is near impossible to think of every aspect on your own. Because of this fact, it is often a good idea to find outside help. The project we are working on falls within the field of civil engineering and the members of the group are all Electrical and Computer Engineers who have little or no experience in civil engineering. Knowing this we felt it best to consult with Civil Engineers who can provide expertise in the area and shed light on aspects of roof failures that we had not previously thought of. To add to these interviews with the Civil Engineers, the group decided to talk with individual Building Inspectors. The feeling was that these Building Inspectors would have firsthand experience with roof failures and could tell the group how and why roofs fail as well as give potential recommendations that they feel would prevent future failures. Together, the interviewees were chosen based on their knowledge in the field of civil engineering and on the recommendations from Professors Robert Labonté and Robert Fitzgerald.

The interviews were conducted with a specific order in mind. The order was to interview Professor Robert Fitzgerald first and then using his guidance and knowledge the group would go on to interview other Civil Engineers and Building Inspectors. Professor Fitzgerald's knowledge in the field of civil engineering and his knowledge of WPI and IQPs were extremely useful in guiding the group towards asking the right questions to future interviewees. Using the guidance of Professor Fitzgerald the group interviewed individual Building Inspectors in the towns of West Boylston, Holden, and Shrewsbury next and ended with interviewing state inspector and code developer Joe McEvoy, a contact given by Professor Fitzgerald. The interview with Joe McEvoy was conducted last because his expertise in the area of code development and building inspection were essential in directing the group's next segment of research. In all, the interviews were held in a specific order and were able to help guide the outcome of both research and further interviews.

All interviews conducted were done in an unstructured format. The interviewees were given background information about the project and what goals and outcomes we were looking for, and then they were simply asked to speak on this subject matter without a specific set of questions. The interviews were held in this fashion due to the inexperience of the group members in the subject field. Since the interviews were conducted with professionals, the group felt it was best to let them talk about what they knew rather than try and have them answer questions that they may not have answers for. There was some structure to the interviews in that all interviewees were asked if they had any experience with roof failures and if they had any recommendations for the project but overall they were just given a topic and the freedom to talk about it. In the end, this method enabled the group to discover more areas to research than previously thought of, as well as gain valuable information about topics relevant to the project.

3.2 Code Research

The first part of our work was background research on building codes. The group decided to split our research into three categories. Erik researched codes in other developed countries, specifically European Union codes and Canadian building codes. Erik also searched for codes from countries that have less snow, such as Mexico, but discovered that most of these countries do not have well established building codes. There were several books in the WPI library that were used for this research. Erik also located the European Union (EU) building code online.

David was assigned the task of researching building codes throughout the United States. He discovered that there were three different building codes which were taken by each state and adapted for their own use. After 1994 the ICC created a unified code which is now used as the basis for each state building code. David was able to locate the ICC building code at the WPI library.

Ben researched building codes in Massachusetts and New Hampshire. It was discovered that the New Hampshire building code is very short and only references standards included in the ICC building code. Because the New Hampshire code contains little state specific information, it was moved to David's research with the rest of the United States for our report. The Massachusetts code is much longer, but still references the ICC building code most of the time. The Massachusetts building code was found to be available on the state web site.

The group also researched the history of these building codes. Because the Massachusetts code has a very similar history to most of the rest of the country, there was no separate section for the history of building codes in Massachusetts. David and Erik were able to find information sources on the internet that helped them to write about the history of building codes.

3.3 Causes of Roof Failure

Since the overall goal of this project was to determine different ways in which we could prevent future roof failures from happening, we believed that determining the different causes of roof failure that have and could afflict building owners was an essential and necessary task to complete. However, due to our inability to find an available and willing contact from Factory Mutual (FM Global), an insurance company whom we believed would have statistical data and common causes of roof failures, we had to rely on other means of determining the different reasons for roof failures. In the end we came up with two approaches to accomplish this objective.

The first approach required us to ask the interviewees, Professor Robert Fitzgerald, Joe McEvoy, and the various Town Building Inspectors of Holden, West Boylston, and Shrewsbury if they could tell us about the possible causes of roof failures.

Since the individuals we interviewed have had experience with building related issues, we believed that they would have been one of the more suitable people to speak with. Having reviewed the interviews we were able to come up with a small list of possible reasons why a roof failure would occur.

However, we decided to gather additional information from the World Wide Web (WWW), since the first approach only produced a fair amount of reasons for why a roof would fail. The WWW was also an appropriate place to gather additional information due to the fact that various data could be obtained from the Web, which includes causes of roof failures that the individuals we inquired might possibly have missed or overlooked. From the second approach we were able to obtain additional reasons as to why roof failures occurred; however, a number of them were relatively similar such that they were grouped together as similar causes.

Having researched roof failures as thoroughly as we could we were able to come up with a list of various reasons to why a roof would fail. When the list was complete we decided to sift through it in order to filter out repeated reasons for roof failures. The list sifting also enabled us to group together causes which we believed to be similar. In the end we were able to come up with a list of twelve causes.

Chapter 4: Conclusions and Recommendations

When this project set out, the goal was to analyze the main causes of roof failures and provide recommendations on how to prevent them from happening in the future. After many weeks of research and interviews, the group has come to many conclusions and found recommendations that satisfy the project's goal. The group has found that the building codes used are plenty sufficient enough to protect against roof failure and in some cases are even too strict. Recommendations that the group suggest include regular inspection and early warning alert systems. Overall, the group has met the goals set out at the beginning of the project.

The first step that the group agreed on was researching building codes. The feeling was that there might be something within these codes that showed they were not sufficient and did not protect against roof failures as well as they could. After interviews with multiple building inspectors and code developers, we have come to the conclusion that this is not the case. The main example of this was brought to our attention during the interview with Professor Fitzgerald. During the interview, our group asked Professor Fitzgerald if the codes were not strict enough. As a rebuttal, Professor Fitzgerald used some quick conversions and calculations to show that the codes allow for over five feet of snow from one storm before there would be a problem with the roof. This high level of snow is almost unheard of within New England and specifically Massachusetts. The other building inspectors were asked the same question and all felt the same way, that the codes were very sufficient, some even saying that the codes were too conservative and could be lessened. The results of these interviews can be seen below in Appendices B-H.

After determining that the building codes were not the problem, the group realized that the problem was with the homeowner. The group determined that the homeowner was not able to tell if their roof was safe or not. Based on this conclusion, our group has come up with two recommendations, regular inspection and early warning systems. The first recommendation is to have regular inspections of roofs. In a climate like New England where the weather changes so frequently and ranges from bad to good, buildings are exposed to excessive wear and tear. Most homeowners are not experts when it comes to construction and cannot decide whether or not something is safe. These two facts put together shows that there is a need for a way to warn these homeowners. If there are regular inspections, professionals can diagnose a warning early and recommend ways to fix the problem and prevent futures problems. In essence it is like yearly check-ups with a doctor. There is not always something wrong with people when they go to see a doctor, but in case there is something wrong, a doctor, who is a professional, can prevent something worse from happening. With regular yearly building inspections, the chances of any roof failures will seriously decrease and could disappear all together.

The second recommendation is for early warning systems to be installed in houses. Since there are so many buildings in a given city and only a handful of inspectors, it would be much easier to have a device that could detect a problem before it happens. There are products on the market now that can perform such a task. Of them, there are two main applications. The first is a serious of sensors in the roof that can detect the amount of weight. These sensors are then calibrated so that they trigger an alarm if the weight on the roof gets too great. The second form of early warning is a laser. The laser runs from one end of the roof to the other just below the trusses. In the event of too much weight on a roof, the trusses will bow and break the plain of the laser, causing an alarm to trigger. In both cases, the homeowner is notified by some sort of alarm. After hearing this, the homeowner can then call for a further inspection, or in the case of snow, the homeowner can clear the roof and relieve some of the strain on the roof.

These conclusions and subsequent recommendations have fulfilled the goals set out at the beginning of the project. The two early warning systems mentioned will allow any person who owns a building to rest easy knowing they do not have to worry about the roof failing. The conclusions and causes that the group has found show that there is a concern about roof failure, and teach homeowners what to look for and how to prevent roof failure from happening. In the end, even with the tasks we have accomplished, the overall objective is the safety and well being of people everywhere and this project is an aid to getting one step closer to reaching the goal of universal safety.

Appendix A: Acronyms

AIA	American Insurance Association
BOCA	Building Officials Code Administrators International
BUR	Built-Up Roofs
CABO	Council of American Building Officials
CEN	European Committee of Standardization
CMR	Code of Massachusetts Regulation
EU	European Union
IBC	International Building Code
ICBO	International Conference of Building Officials
ICC	International Code Council
IQP	Interactive Qualifying Project
IRC	International Residential Code
MSBC	Massachusetts Statewide Building Code
NBC	National Building Code
NBFU	National Board of Fire Underwriters
NRC	National Research Council Canada
SBCCI	Southern Building Code Congress International
WPI	Worcester Polytechnic Institute
WWW	World Wide Web

Appendix B: Professor Robert Fitzgerald Interview

Professor Robert Fitzgerald is a former WPI graduate who now works for the school as a Professor Emeritus. Professor Fitzgerald was recommended to us by our project advisor Professor Robert Labonté, who has known Professor Fitzgerald since their time together as students at WPI. Professor Fitzgerald has over 60 years of experience in structural engineering ranging everywhere from code research and development to building inspection and design. Our group chose to interview him first in the hopes that his vast knowledge of the area of study would help us to focus our approach for future interviews as well as provide us with useful information and ideas we had not thought of.

The interview was conducted on June 23, 2009 at 10:00 am on the WPI campus in Kaven Hall. The meeting began with Professor Fitzgerald asking our group what our area of focus was with the project, specifically what the problem we were looking to prevent was. It was determined that the project was being done with a look at safety and right away Professor Fitzgerald was helpful by telling us to look at all the aspects of a roof failure, including the effects; for example what is the economic effect on a business if their roof were to collapse. After explaining our project a little more, Professor Fitzgerald gave us a few suggestions of areas to study, including flat roofs, unequal loads, and roofs with certain types of trusses. These were areas that he felt as a structural engineer could be hazardous towards roof failures.

As he did with every question we asked, Professor Fitzgerald was very helpful when talking about codes. Though he did not see any problems with the current codes and their roof specifications, he did tell us to also focus on the standards that are used. At that point we had not researched standards and did not know what the difference was between standards and codes. Once again Professor Fitzgerald was able to help explain that codes give the specifications on what you need to build to protect against and standards tell you how to build following the codes for different materials. He also mentioned that the current codes protect against more than necessary loading. Using some calculations involving knowledge that one inch of water covering a square foot of area weighs about five pounds and that the lowest amount that the codes specify is 25 pounds per square foot (psf), we were able to determine that to break this code, over four feet of snow would need to accumulate.

The last aspect of the interview, and the most helpful one, was that Professor Fitzgerald was able to give us contacts as possible interviewees in the future. Of these were Factory Mutual Insurance Company, specifically Dick Davis, State Inspector Joe McEvoy, and code developer Norton Remmer. Of these contacts, our group was able to arrange a meeting with Joe McEvoy whose interview can be read about in further sections of this report. Overall, the interview with Professor Fitzgerald was a success. Although he had no personal experience with roof failures he was able to help us focus our research and even gave us a few areas to consider that we previously had not. His knowledge in the field of structural engineering is vast and he should be recommended as an aid for anyone who has a project in that area.

Appendix C: Holden Building Inspector Interview

Name: Dennis J. Lipka

Job Title: Building Commissioner

Director of Growth Management for the Town of Holden

Office: 1196 Main Street

Holden, MA 01520

Phone: 508-829-0243

Fax: 508-829-0252

Email: djlipka@townofholden.net

Date: Tuesday, June 30, 2009

Interviewer: David

On Tuesday, June 30, 2009 an interview was conducted by telephone with Mr. Lipka, who was given a brief overview of the project prior to any discussion. The topic of discussion focused on roof failures in the Town of Holden, and Mr. Lipka's personal view of the current Massachusetts Building Code and how it addressed roof construction and roof loadings. From the telephone discussion, it was gathered that very few roof failures had occurred in the Town of Holden, even during the ice storm of December 2008. When questioned about his opinion of the current Massachusetts Building Code, he replied that it was too conservative; however no further detail could be given since no more questions were asked in reference to his response. Having finished the interview, it was asked if future contact by email would be possible such that more thorough answers could be given. Having received a confirmation on the request, an email request was sent promptly re-asking the same questions posed to Mr. Lipka during the phone interview. From this email response, more information was able to be gathered than that from the phone interview. For a copy of the email request and response, please refer to Appendix D.

Appendix D: Email Response From Holden Building Inspector

From: Dennis J. Lipka [djlipka@townofholden.net]
Sent: Friday, July 03, 2009 9:01 AM
To: Truong, David
Subject: RE: Roof Failures

David,
In my experience in Holden and as a building/construction consultant, I have seen very few
roof failures. I would point out that there are two general types of roof failures. The first is the collapse or failure of structural elements usually caused by substantial snow loads coupled with rain events, these are most common on complex structures with multiple roof elevations where prediction of drifted snow loads may be difficult to predict. The second type of failure relates to the materials constituting the weathering surface of roof. This second type is much more common. Ice dams, leaks, and roof coverings damaged by weathering events such as wind or freezing conditions are much more typical.

The roof failure I mentioned was at Alden Laboratories here in Holden, not Alden Hall. The building in question was a manufactured building where the snow load on the roof overloaded the steel frame connections at the foundation anchorage and the building essentially fell over.

Regarding the relevant building codes, the current MA code and the IBC and IRC have taken steps to address roof failures, both types of failures I raised earlier. When the building envelope is compromised, the insurance loss to interiors increase substantially. Many of the current changes to the building codes are driven by insurance companies or their lobby groups seeking to reduce insurance exposure by upgrading building codes relative to building envelope. Clearly roofs are a major concern for them. Increased attention to lateral bracing, anchorage, air borne debris, and wind driven rain as well as ice dam protection, roof covering protection are all addressed in substantial detail in the current codes. In the case of MA, extensive changes have been made in these areas compared to the previous edition of the code, particularly in the one and two family code.

I hope this is useful.

Dennis J. Lipka
Building Commissioner
Director, Growth Management
Town of Holden

-----Original Message-----
From: Truong, David [mailto:cheung@WPI.EDU]
Sent: Tuesday, June 30, 2009 2:35 PM
To: djlipka@townofholden.net
Subject: Roof Failures

Hello Mr. Lipka,

My name is David and I had just contacted you today about roof failures in the area of Holden. I am currently working on a project that looks at roof failures and was hoping to get some information from you. However during our brief conversation I wasn't able to write down all of the information you had given me. So I was hoping that you may send an email retelling me about roof failures in Holden, roof failures in general, the fact that roof failures aren't common, and the roof failure of Alden Hall at WPI.

Also, prior to answering this email, I feel that it is necessary to tell you that I am currently working on an IQP for WPI which this is the focus of. So if possible I was wondering if I would be able to incorporate your response to our paper as a reference which would be greatly appreciated.

In addition I was wondering if there was anything in your opinion that should be changed in the Massachusetts Building Codes involving roof assemblies and roof loading or that should be in the International

Building/Residential Code.

Finally, I was wondering if you knew of any place where I could get a hold of statistical data of roof collapses in the Massachusetts area, or should I just contact the Massachusetts DPS.

Thank you for your time and have a great summer.

David Truong
WPI Class of 2010

Appendix E: West Boylston Building Inspector Interview

Name: Mark Brodeur

Job Title: Building Commissioner

Zoning Enforcement Officer for the Town of West Boylston

Office: 127 Hartwell Street, Suite 100

West Boylston, MA 01583

Phone: 508-835-6091

Fax: 508-835-4102

Email: mbrodeur@westboylston-ma.gov

Date: Wednesday, July 01, 2009

Interviewer: David

On Wednesday, July 1, 2009 an interview was conducted by telephone with Mr. Brodeur, who was given a brief overview of the project prior to any discussion. The topic of discussion focused on roof failures in the Town of West Boylston and Mr. Brodeur's personal view of the current Massachusetts Building Code and how it addressed roof construction and roof loadings. From the telephone discussion, it was gathered that, like the Town of Holden, very few roof failures had occurred in the Town of West Boylston, even during the ice storm of December 2008. Having been told that there have been no roof failures in the past few years, David proceeded to ask Mr. Brodeur about his opinion of the current Massachusetts Building Code in relation to roof loading. In response to the question, Mr. Brodeur said that he believed the new edition, the 7th edition, was too excessive in terms of snow and wind loads and that there were too many unnecessary equations. One final question was asked on how such codes were developed or changed, and like Mr. Lipka, Mr. Brodeur responded by saying that the main advocators for change were the insurance companies. When the interview was finished, Mr. Brodeur was also asked if it would be possible to send an email that would restate his telephone response. The email request by David and Mr. Brodeur's response can be read in Appendix F.

Appendix F: Email Response From West Boylston Building Inspector

From: Mark Brodeur [MBrodeur@westboylston-ma.gov]
Sent: Wednesday, July 08, 2009 12:33 PM
To: Truong, David
Subject: RE: WPI Project Concerning Roof Failures and Massachusetts Roof Codes

There have been no failures in recent memory in the Town of West Boylston. I also spoke to one of the former inspectors for this town and we think as far back as ten years, no roof failures.

The regulations presented for wind and snow loads under the 7th edition are, in my opinion, excessive. I cannot fathom the circumstances where a 100 MPH wind speed is contemplated for normal life in central Massachusetts. Having lived through several hurricanes and been an Insurance Adjuster in several more I just don't see the point.

It's all driven by insurance companies to seek to protect their assets not people.

-----Original Message-----
From: Truong, David [mailto:cheung@WPI.EDU]
Sent: Tuesday, July 07, 2009 10:18 AM
To: mbrodeur@westboylston-ma.gov
Subject: RE: WPI Project Concerning Roof Failures and Massachusetts Roof Codes

Hello Mr. Brodeur,

I was unsure if you had received this message and I had tried calling today but was unable to reach you. I was just wondering if you had received this email and if so could you please reply telling me so, your reply to the former email would be greatly appreciated.

Thank you,

David Truong
WPI Class of 2010

From: Truong, David
Sent: Wednesday, July 01, 2009 10:37 AM
To: mbrodeur@westboylston-ma.gov
Subject: WPI Project Concerning Roof Failures and Massachusetts Roof Codes

Hello Mr. Brodeur,

My name is David and I had just contacted you today about roof failures in the area of West Boylston. I am currently working on a project that looks at roof failures and was hoping to get some information from you. However during our brief conversation I wasn't able to write down all of the information you had given me. So I was hoping that you may send an email restating the fact that roof the uncommon occurrence of roof failures in West Boylston, why you would like to change the Massachusetts building codes back to the 6th edition, and if possible any other information which you believe would be helpful or relative to roof failures such as statistical data for the Massachusetts area or even just the West Boylston area.

Also, prior to answering this email, I feel that it is necessary to tell you that I am currently working on an IQP for WPI which this is the focus of. So if possible I was wondering if I would be able to incorporate your response to our paper as a reference which would be greatly appreciated.

In addition I know you stated that you wished for a return to the 6th edition of the Massachusetts Building Codes concerning roof loading, but I was wondering if there was also any changes you would like to be done in reference to the International Building/Residential Code created by the ICC (International Code Council) which Massachusetts references.

Finally, I was wondering if you knew of any place where I could get a hold of statistical data of roof collapses in the Massachusetts area, or should I just contact the Massachusetts DPS.

Thank you for your time and have a great summer.

David Truong
WPI Class of 2010

Appendix G: Shrewsbury Building Inspector Interview

Name: Ronald Alarie
Job Title: Inspector of Buildings
Office: 100 Maple Avenue
Shrewsbury, MA 01545
Phone: 508-841-8512
Email: ralarie@th.ci.shrewsbury.ma.us

Date: Thursday, July 09, 2009
Interviewer: Erik

On Thursday July 9, 2009 an interview was conducted by telephone with Mr. Ronald Alarie of Shrewsbury. Mr. Alarie was first brought to attention through the project advisor Professor Labonté who is a resident of the Town of Shrewsbury. Mr. Alarie was given a brief overview of the details of the project and was very willing to help in any way that he could. He was first asked if he knew of any roof failures and what their causes were which prompted him to think of four right away, two which failed during construction and two after completion. The first was from 1969 and was a flat truss roof. Due to rain freeze up, the drains on the roof were plugged which caused ice to build up and eventually become too heavy for the roof, leading to its failure. The second was from the late 1970s. It was a steel frame structure that failed due to omitted structures during construction and harsh elements consisting of snow storms and a cycle of freezing and thaws. The third incident was a church on Rt-140. The church was made using wood trusses. These trusses were never stabilized and eventually the load on the roof became too much for the trusses leading to its collapse. The final incident was a two story house. The house had a truss roof and a beam system supporting the floor of the second story. These beams were never properly supported and the floor collapsed. This added weight pulling on the structure of the house eventually lead to the failure of the roof as well.

After providing Erik with these specific incidents, Mr. Alarie continued to be helpful citing current situations that are being looked into in order to prevent future failures. The first of these concerns are schools, which a lot of times have flat roofs with a large area. These roofs can have a weak spot in the center, and if not properly checked for water and snow buildup, these roofs have the potential for failure. The second concern is a supermarket which has an overhang leading into the building which is not independently supported but rather extends from the building. The concern here is that there could be too much weight on the unsupported section of the overhang which could lead to too much force for the building to support and a collapse of the overhang. The final concern is similar to the second. At many gas stations there are canopies over the pumps which are supported in the center and then branch away at the top. Similar to the second concern, if the load on the outside edge of these canopies becomes too great, the canopies could collapse.

Finally, Mr. Alarie was asked what he felt about the Massachusetts Building Codes. Specifically he was asked if there were any parts of the codes that he felt could lead to problems and needed to be changed. Although Mr. Alarie did not see any problems with the codes, he did make mention that the snow codes involved a lot of equations that could be confusing to someone who was inexperienced with them and also that the snow load and wind load values to protect against were decreased from the 6^{th} to 7^{th} editions without need. Overall Mr. Alarie was very helpful and cooperative in every way asked of him. The information provided by Mr. Alarie, especially in regards to previous roof failures, was very valuable for the group and their attempts to understand exactly what it is that makes roofs fail.

Appendix H: Interview with Joe McEvoy

Joe McEvoy is a Massachusetts State Inspector for the Department of Public Safety (DPS). He was recommended to us by Professor Robert Fitzgerald during our interview with him. He was recommended because he has decades of experience as an inspector for the City of Worcester and the State. We chose to interview him because he can share specific examples of building failures from an engineer's point of view.

The interview was conducted in his office at a construction site on the Worcester State College campus on Monday, July 13, 2009 at 11:00am. The meeting began with Mr. McEvoy recommending the magazine "Engineering News Record" and a lecture given by J. David Rogers to the California Colloquium on Water. This lecture was on dam failures, and detailed the methodology used to investigate the failures.

The rest of our interview was Mr. McEvoy giving us a crash course on civil engineering. He explained the history of building codes in the United States and Massachusetts. He then gave a background of how codes are developed. He said that most new code developments are driven by insurance companies. He showed us Table 503 (appendix J) of the Massachusetts Building Code which defines the allowable height and area of buildings.

He then introduced us to roofs. The important things that define a roof are the shape, covering material, and the structural material. He explained that roof coverings are classified by fire rating. Table 601 (appendix I) of the Massachusetts Building Code contains building use groups and construction types. These are the two basic ways of classifying a building and are what inspector's first look at when they are inspecting a building. Construction types are the material and flammability of the building framing. Use groups are the way the building will be occupied and used.

During the interview Mr. McEvoy also gave us several examples of buildings and roofs that failed, and explained to us what happened. He showed us examples of blueprints that had been signed off by engineers and were later changed without the engineer's knowledge. He also explained the process of making changes to blueprints during construction, and explained that every building design will be changes many times during construction.

Appendix I: Massachusetts Building Code Table 601

The following page is taken from the Massachusetts building code, 7th edition (September 2008), page 135.

603.1.1 Ducts. The use of nonmetallic ducts shall be permitted when installed in accordance with the limitations of the *International Mechanical Code*.

603.1.2 Piping. The use of combustible piping materials shall be permitted when installed in accordance with the limitations of the International Mechanical Code or the Massachusetts Fuel Gas and Plumbing Code (248 CMR), when applicable.

603.1.3 Electrical. The use of electrical wiring methods with combustible insulation, tubing, raceways and related components shall be permitted when installed in accordance with the limitations of the Massachusetts Electrical Code (527 CMR 12).

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Structural frame[a] Including columns, girders, trusses	3[b]	2[b]	1	0	1	0	HT	1	0
Bearing walls Exterior[f] Interior	3 3[b]	2 2[b]	11	0	21	20	2 1/HT	11	0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[e]	0	0	0	0	0	0	See 780 CMR 602.4.6	0	0
Floor construction Including supporting beams and joists	2	2	1	0	1	0	HT	1	0
Roof construction Including supporting beams and joists	1½[c]	1[c]	1[c]	0[c]	1[c]	0	HT	1[c]	0

For SI: 1 foot = 304.8 mm.

a. The structural frame shall be considered to be the columns and the girders, beams, trusses and spandrels having direct connections to the columns and bracing members designed to carry gravity loads. The members of floor or roof panels which have no connection to the columns shall be considered secondary members and not a part of the structural frame.

b. Roof supports: Fire-resistance ratings of structural frame and bearing walls are permitted to be reduced by one hour where supporting a roof only.

c. 1. Except in Factory-Industrial (F-1), Hazardous (H), Mercantile (M) and Moderate-Hazard Storage (S-1) occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.
   2. In all occupancies, heavy timber shall be allowed where a one-hour or less fire-resistance rating is required.
   3. In Type I and II construction, fire-retardant-treated wood shall be al lowed in buildings including girders and trusses as part of the roof construction when the building is:
      i. Two stories or less in height;
      ii. Type II construction over two stories; or
      iii. Type I construction over two stories and the vertical distance from the upper floor to the roof is 20 feet or more.

d. An approved automatic sprinkler system in accordance with 780 CMR 903.3.1.1 shall be allowed to be substituted for one-hour fire-resistance-rated construction, provided such system is not otherwise required by other provisions of 780 CMR or used for an al low able area increase in accordance with 780 CMR 506.3 or an allowable height in crease in accordance with 780 CMR 504.2. The one-hour substitution for the fire resistance of exterior walls shall not be permitted.

e. Not less than the fire-resistance rating required by other sections of 780 CMR.

f. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

Appendix J: Massachusetts Building Code Table 503

The following page is taken from the Massachusetts building code, 7th edition (September 2008), page 126.

503.1.4 Type I Construction. Buildings of Type I construction permitted to be of unlimited tabular heights and areas are not subject to the special requirements that allow unlimited area buildings in 780 CMR 507.0 or unlimited height in 780 CMR 503.1.2 and 504.3 or increased height and areas for other types of construction.

503.2 Party Walls. Any wall located on a lot line between adjacent buildings, which is used or adapted for joint service between the two buildings, shall be constructed as a fire wall in accordance with 780 CMR 705.0, without openings and shall create separate buildings.

TABLE 503 ALLOWABLE HEIGHT AND BUILDING AREAS
Height limitations shown as stories and feet above grade plane.
Area limitations as determined by the definition of "Area, building," per floor.

GROUP		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	Hgt(feet) Hgt(S)	UL	160	65	55	65	55	65	50	40
A-1	S	UL	5	3	2	3	2	3	2	1
	A	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
A-2	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-3	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-4	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-5	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	S	UL	11	5	4	5	4	5	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
E	S	UL	5	3	2	3	2	3	1	1
	A	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
F-1	S	UL	11	4	2	3	2	4	2	1
	A	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
F-2	S	UL	11	5	3	4	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	18,000	50,500	21,000	13,000
H-1	S	1	1	1	1	1	1	1	1	NP
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	NP
H-2	S	UL	3	2	1	2	1	2	1	1
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	3,000
H-3	S	UL	6	4	2	4	2	4	2	1
	A	UL	60,000	26,500	14,000	17,500	13,000	25,500	10,000	5,000
H-4	S	UL	7	5	3	5	3	5	3	2
	A	UL	UL	37,500	17,500	28,500	17,500	36,000	18,000	6,500
H-5	S	3	3	3	3	3	3	3	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
I-1	S	UL	9	4	3	4	3	4	3	2
	A	UL	55,000	19,000	10,000	16,500	10,000	18,000	10,500	4,500
I-2	S	UL	4	2	1	1	NP	1	1	NP
	A	UL	UL	15,000	11,000	12,000	NP	12,000	9,500	NP
I-3	S	UL	4	2	1	2	1	2	2	1
	A	UL	UL	15,000	10,000	10,500	7,500	12,000	7,500	5,000
I-4	S	UL	5	3	2	3	2	3	1	1
	A	UL	60,500	26,500	13,000	23,500	13,000	25,500	18,500	9,000
M	S	UL	11	4	4	4	4	4	3	1
	A	UL	UL	21,500	12,500	18,500	12,500	20,500	14,000	9,000
R-1	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-2[a, d]	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-3[a]	S	UL	11	4	4	4	4	4	3	3
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
R-4	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
S-1	S	UL	11	4	3	3	3	4	3	1
	A	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000
S-2b, [c]	S	UL	11	5	4	4	4	5	4	2
	A	UL	79,000	39,000	26,000	39,000	26,000	38,500	21,000	13,500
U[c]	S	UL	5	4	2	3	2	4	2	1
	A	UL	35,500	19,000	8,500	14,000	8,500	18,000	9,000	5,500

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2 .
UL = Unlimited, NP = Not permitted.
a. As applicable in 780 CMR 101.2.
b. For open parking structures, see 780 CMR 406.3.
c. For private garages, see 780 CMR 406.1.
d. For purposes of allowable height and building area, Town Houses shall be treated as R-2 use.

Appendix K: Massachusetts Building Code Table 5301.2

The following two pages are taken from the Massachusetts building code, 7th edition (September 2008), page 543 and 544. These tables designate snow and wind loads for one and two family residential structures.

TABLE 5301.2(4) MASSACHUSETTS BASIC WIND SPEEDS

<90 MPH	90 MPH		100 MPH		110 MPH
Adams	Acton	New Braintree	Abington	Middleton	Acushnet
Alford	Agawam	New Marlborough	Amesbury	Milford	Aquinnah
Ashfield	Amherst	New Salem	Andover	Millis	Barnstable
Becket	Ashburnham	North Brookfield	Arlington	Millville	Bourne
Bernardston	Ashby	Northampton	Ashland	Milton	Brewster
Buckland	Athol	Northborough	Attleboro	Nahant	Carver
Cheshire	Auburn	Northfield	Avon	Natick	Chatham
Clarksburg	Ayer	Oakham	Bedford	Needham	Chillmark
Colrain	Barre	Orange	Bellingham	Newbury	Dartmouth
Cummington	Belchertown	Otis	Belmont	Newburyport	Dennis
Dalton	Berlin	Palmer	Berkley	Newton	Duxbury
Egremont	Blandford	Paxton	Beverly	Norfolk	Eastham
Florida	Bolton	Pelham	Billerica	North Andover	Edgartown
Great Barrington	Boxborough	Pepperell	Blackstone	North Attleborough	Fairhaven
Greenfield	Boylston	Petersham	Boston	North Reading	Fall River
Hancock	Brimfield	Phillipston	Boxford	Northbridge	Falmouth
Hawley	Brookfield	Princeton	Braintree	Norton	Freetown
Heath	Carlisle	Rolyalston	Bridgewater	Norwell	Gay Head
Hinsdale	Charlton	Russell	Brockton	Norwood	Gosnold
Lanesborough	Chelmsford	Rutland	Brookline	Oxford	Halifax
Lee	Chester	Sandisfield	Burlington	Peabody	Harwich
Lenox	Chesterfield	Shirley	Cambridge	Plainville	Kingston
Leyden	Chicopee	Shrewsbury	Canton	Quincy	Lakeville
Middlefield	Clinton	Shutesbury	Chelsea	Randolph	Marion
Monroe	Conway	South Hadley	Cohasset	Raynham	Marshfield
Monterey	Deerfield	Southampton	Concord	Reading	Mashpee
Mount Washington	Dracut	Southbridge	Danvers	Rehoboth	Mattapoisett
New Ashford	Dunstable	Southwick	Dedham	Revere	Middleborough
North Adams	East Brookfield	Spencer	Dighton	Rockland	Nantucket
Peru	East Longmeadow	Springfield	Douglas	Rockport	New Bedford
Pittsfield	Easthampton	Sterling	Dover	Rowley	Oak Bluffs
Plainfield	Erving	Stow	Dudley	Salem	Orleans
Richmond	Fitchburg	Sturbridge	East Bridgewater	Salisbury	Pembroke
Rowe	Gardner	Sunderland	Easton	Saugus	Plymouth
Savoy	Gill	Templeton	Essex	Seekonk	Provincetown
Sheffield	Goshen	Tolland	Everett	Sharon	Rochester
Shelburne	Granby	Townsend	Foxborough	Sherborn	Sandwich
Stockbridge	Granville	Tyngsborough	Framingham	Somerville	Scituate
Tyringham	Groton	Wales	Franklin	Southborough	Somerset
Washington	Hadley	Ware	Georgetown	Stoneham	Swansea
West Stockbridge	Hampden	Warren	Gloucester	Stoughton	Tisbury
Williamstown	Hardwick	Warwick	Grafton	Sudbury	Truro
Windsor	Harfield	Wendell	Groveland	Sutton	Wareham
Worthington	Harvard	West Boylston	Hamilton	Swampscott	Welfleet
	Holden	West Brookfield	Hanover	Taunton	West Tisbury
	Holland	West Springfield	Hanson	Tewksbury	Westport
	Holyoke	Westfield	Haverhill	Topsfield	Yarmouth
	Hubbardston	Westford	Hingham	Upton	
	Hudson	Westhampton	Holbrook	Uxbridge	
	Huntington	Westminster	Holliston	Wakefield	
	Lancaster	Whately	mm	Walpole	
	Lawrence	Wilbraham	Hopkington	Waltham	
	Leicester	Williamsburg	Hull	Watertown	
	Leominster	Winchendon	Ipswich	Wayland	
	Leverett	Worcester	Lexington	Webster	
	Littleton		Lincoln	Wellesley	
	Longmeadow		Lynn	Wenham	
	Lowell		Lynnfield	West Bridgewater	
	Ludlow		Malden	West Newbury	
	Lunenburg		Manchester	Westborough	
	Maynard		Mansfield	Weston	
	Methuen		Marblehead	Westwood	
	Millbury		Marlborough	Weymouth	
	Monson		Medfield	Whitman	
	Montague		Medford	Wilmington	
	Montgomery		Medway	Winchester	
			Melrose	Winthrop	
			Mendon	Woburn	
			Merrimac	Wrentham	

TABLE 5301.2(5) MASSACHUSETTS GROUND SNOW LOADS

25 PSF	35 PSF	40 PSF	40 PSF	50 PSF		
Brewster	Abington	Alford	Nahant	Acton	Lenox	Topsfield
Carver	Agawam	Arlington	Natick	Adams	Leominster	Townsend
Chatham	Amherst	Ashland	Needham	Amesbury	Leverett	Tyngsborough
Eastham	Avon	Belchertown	New Braintree	Andover	Leyden	Tyringham
Harwich	Braintree	Belmont	New Marlborough	Ashburnham	Littleton	Warwick
Martha's Vineyard	Brockton	Bellingham	New Salem	Ashby	Lowell	Washington
Nantucket	Chicopee	Beverly	Newton	Ashfield	Lunenburg	Wendell
Orleans	Cohasset	Blackstone	Norfolk	Athol	Maynard	Wenham
Plymouth	East Longmeadow	Blandford	Northbridge	Auburn	Merrimac	West Boylston
Provincetown	Easton	Boston	Norwood	Ayer	Methuen	West Newbury
Truro	Foxborough	Brimfield	Peabody	Barre	Middlefield	West Stockbridge
Wareham	Granby	Brookfield	Pelham	Becket	Millbury	Westfield
Wellfleet	Hadley	Brookline	Quincy	Bedford	Monroe	Westford
	Hampden	Cambridge	Revere	Berlin	Montague	Westminster
	Hingham	Canton	Russell	Bernardston	Monterey	Whately
	Holbrook	Charlton	Salem	Billerica	New Ashford	Williamsburg
	Holyoke	Chelsea	Saugus	Bolton	Newbury	Williamstown
30 PSF	Hull	Dedham	Sheffield	Boxborough	Newburyport	Willmington
Acushnet	Longmeadow	Douglas	Sherborn	Boxford	North Adams	Winchendon
Attleboro	Ludlow	Dover	Shutesbury	Boylston	North Andover	Windsor
Barnstable	Mansfield	Dudley	Somerville	Buckland	North Brookfield	Worthington
Berkley	Monson	East Brookfield	Southampton	Burlington	North Reading	
Bourne	North Attleborough	Easthampton	Southborough	Carlisle	Northampton	
Bridgewater	Norwell	Everett	Southbridge	Chelmsford	Northborough	
Dartmouth	Palmer	Framingham	Stoneham	Cheshire	Northfield	
Dennis	Plainville	Franklin	Sturbridge	Chester	Oakham	
Dighton	Randolph	Grafton	Sudbury	Chesterfield	Orange	
Duxbury	Rockland	Granville	Sutton	Clarksburg	Otis	
East Bridgewater	Scituate	Great Barrington	Swampscott	Clinton	Oxford	
Fairhaven	Sharon	Hardwick	Tolland	Colrain	Paxton	
Fall River	South Hadley	Hatfield	Upton	Concord	Pepperell	
Falmouth	Southwick	Holland	Uxbridge	Conway	Peru	
Freetown	Springfield	Holliston	Wakefield	Cummington	Petersham	
Gosnold	Stoughton	Hopkinton	Wales	Dalton	Phillipston	
Halifax	West Springfield	Lexington	Walpole	Danvers	Pittsfield	
Hanover	Weymouth	Lincoln	Waltham	Deerfield	Plainfield	
Hanson	Wilbraham	Lynn	Ware	Dracut	Princeton	
Kingston		Lynnfield	Warren	Dunstable	Reading	
Lakeville		Malden	Washington	Egremont	Richmond	
Marion		Manchester	Watertown	Erving	Rockport	
Marshfield		Marblehead	Wayland	Essex	Rolyalston	
Mashpee		Marlborough	Webster	Fitchburg	Rowe	
Mattapoisett		Medfield	Wellesley	Florida	Rowley	
Middleborough		Medford	West Brookfield	Gardner	Rutland	
New Bedford		Medway	Westborough	Georgetown	Salisbury	
Norton		Melrose	Westhampton	Gill	Sandisfield	
Pembroke		Mendon	Weston	Gloucester	Savoy	
Raynham		Middleton	Westwood	Goshen	Shelburne	
Rehoboth		Milford	Winchester	Greenfield	Shirley	
Rochester		Millis	Winthrop	Groton	Shrewsbury	
Sandwich		Millville	Woburn	Groveland	Spencer	
Seekonk		Milton	Worcester	Hamilton	Sterling	
Somerset		Montgomery	Wrentham	Hancock	Stockbridge	
Swansea		Mount Washington		Harvard	Stow	
Taunton				Haverhill	Sunderland	
West Bridgewater				Hawley	Templeton	
Westport				Heath	Tewksbury	
Whitman				Hinsdale		
Yarmouth				Holden		
				Hubbardston		
				Hudson		
				Huntington		
				Ipswich		
				Lancaster		
				Lanesborough		
				Lawrence		
				Lee		
				Leicester		

Appendix L: Massachusetts Building Code Table 1604.10

The following pages are taken from the Massachusetts building code, 7th edition (September 2008), page 383-389.

TABLE 1604.10 GROUND SNOW LOADS; BASIC WIND SPEEDS; EARTHQUAKE DESIGN FACTORS

(For R-3 of three stories or less one- and two-family stand alone buildings, see 780 CMR 53.00 for snow and wind loads)

City/Town	Ground Snow Load p_g, psf	Basic Wind Speed V, MPH	Earthquake Design Factors	
			Ss	S_1
Abington	45	110	0.26	0.064
Acton	55	100	0.29	0.071
Acushnet	45	110	0.23	0.058
Adams	65	90	0.22	0.068
Agawam	55	100	0.23	0.065
Alford	65	90	0.22	0.066
Amesbury	55	110	0.35	0.077
Amherst	55	100	0.23	0.067
Andover	55	110	0.32	0.075
Aquinnah (see Gay Head)				
Arlington	45	105	0.29	0.069
Ashburnham	65	100	0.27	0.072
Ashby	65	100	0.28	0.072
Ashfield	65	100	0.22	0.068
Ashland	55	100	0.25	0.066
Athol	65	100	0.25	0.070
Attleboro	55	110	0.24	0.062
Auburn	55	100	0.23	0.065
Avon	55	100	0.26	0.064
Ayer	65	100	0.28	0.071
Barnstable	35	120	0.20	0.054
Barre	55	100	0.24	0.068
Becket	65	90	0.22	0.066
Bedford	55	100	0.29	0.071
Belchertown	55	100	0.23	0.066
Bellingham	55	100	0.24	0.064
Belmont	45	105	0.28	0.069
Berkley	55	110	0.24	0.061
Berlin	55	100	0.26	0.068
Bernardston	65	100	0.23	0.070
Beverly	45	110	0.32	0.072
Billerica	55	100	0.30	0.072
Blackstone	65	100	0.24	0.064
Blandford	65	100	0.23	0.066
Bolton	55	100	0.26	0.069
Boston	45	105	0.29	0.068
Bourne	35	120	0.21	0.056
Boxborough	55	100	0.28	0.070
Boxford		110	0.33	0.075
Boylston	55	100	0.25	0.067
Braintree	45	105	0.27	0.066
Brewster	35	120	0.18	0.052
Bridgewater	45	110	0.24	0.062
Brimfield	55	100	0.23	0.065
Brockton	45	110	0.25	0.064
Brookfield	55	100	0.23	0.065
Brookline	45	105	0.28	0.068
Buckland	65	100	0.22	0.068
Burlington	55	105	0.30	0.071

TABLE 1604.10 GROUND SNOW LOADS; BASIC WIND SPEEDS; EARTHQUAKE DESIGN FACTORS
(For R-3 of three stories or less one- and two-family stand alone buildings, see 780 CMR 53.00 for snow and wind loads)

City/Town	Ground Snow Load p_g, psf	Basic Wind Speed V, MPH	Earthquake Design Factors	
			Ss	S_1
Cambridge	45	105	0.28	0.068
Canton	55	100	0.26	0.066
Carlisle	55	100	0.29	0.071
Carver	45	110	0.24	0.060
Charlemont	65	100	0.22	0.068
Charlton	55	100	0.23	0.065
Chatham	35	120	0.17	0.050
Chelmsford	55	100	0.30	0.073
Chelsea	45	105	0.29	0.069
Cheshire	65	90	0.22	0.068
Chester	65	100	0.22	0.066
Chesterfield	65	100	0.22	0.067
Chicopee	55	100	0.23	0.066
Chilmark	35	120	0.18	0.051
Clarksburg	65	90	0.22	0.069
Clinton	55	100	0.26	0.068
Cohasset	45	110	0.27	0.066
Colrain	65	100	0.23	0.069
Concord	55	100	0.29	0.070
Conway	65	100	0.22	0.068
Cummington	65	100	0.22	0.067
Dalton	65	90	0.22	0.067
Danvers	45	110	0.32	0.073
Dartmouth	45	110	0.23	0.058
Dedham	55	100	0.26	0.066
Deerfield	65	100	0.23	0.068
Dennis	35	120	0.19	0.052
Dighton	55	110	0.24	0.061
Douglas	55	100	0.23	0.064
Dover	55	100	0.26	0.066
Dracut	55	100	0.33	0.075
Dudley	55	100	0.23	0.064
Dunstable	65	100	0.31	0.074
Duxbury	45	110	0.25	0.062
East Bridgewater	45	110	0.25	0.063
East Brookfield	55	100	0.23	0.066
East Longmeadow	55	100	0.23	0.065
Eastham	35	120	0.19	0.052
Easthampton	55	100	0.23	0.066
Easton	55	110	0.25	0.064
Edgartown	35	120	0.18	0.050
Egremont	65	90	0.23	0.066
Erving	65	100	0.23	0.069
Essex	45	110	0.33	0.073
Everett	45	105	0.29	0.069
Fairhaven	45	110	0.22	0.057
Fall River	45	110	0.23	0.059
Falmouth	35	120	0.20	0.054
Fitchburg	65	100	0.27	0.071
Florida	65	90	0.22	0.069

TABLE 1604.10 GROUND SNOW LOADS; BASIC WIND SPEEDS; EARTHQUAKE DESIGN FACTORS
(For R-3 of three stories or less one- and two-family stand alone buildings, see 780 CMR 53.00 for snow and wind loads)

City/Town	Ground Snow Load p_g, psf	Basic Wind Speed V, MPH	Earthquake Design Factors	
			Ss	S_1
Foxborough	55	100	0.25	0.064
Framingham	55	100	0.26	0.067
Franklin	55	100	0.24	0.064
Freetown	45	110	0.23	0.060
Gardner	65	100	0.26	0.070
Gay Head (a.k.a Aquinnah)	35	120	0.18	0.051
Georgetown	55	110	0.34	0.075
Gill	65	100	0.23	0.069
Gloucester	45	110	0.33	0.073
Goshen	65	100	0.22	0.067
Gosnold	35	120	0.19	0.053
Grafton	55	100	0.24	0.066
Granby	55	100	0.23	0.066
Granville	65	100	0.23	0.066
Great Barrington	65	90	0.22	0.066
Greenfield	65	100	0.23	0.069
Groton	65	100	0.30	0.073
Groveland	55	110	0.34	0.076
Hadley	55	100	0.23	0.067
Halifax	45	110	0.25	0.062
Hamilton	45	110	0.33	0.074
Hampden	55	100	0.23	0.065
Hancock	65	90	0.22	0.068
Hanover	45	110	0.26	0.064
Hanson	45	110	0.25	0.063
Hardwick	55	100	0.23	0.067
Harvard	55	100	0.28	0.070
Harwich	35	120	0.18	0.051
Hatfield	55	100	0.22	0.067
Haverhill	55	110	0.35	0.077
Hawley	65	100	0.22	0.068
Heath	65	100	0.22	0.069
Hingham	45	110	0.27	0.066
Hinsdale	65	90	0.22	0.067
Holbrook	45	105	0.26	0.065
Holden	55	100	0.25	0.068
Holland	55	100	0.23	0.064
Holliston	55	100	0.25	0.066
Holyoke	55	100	0.23	0.066
Hopedale	55	100	0.24	0.065
Hopkinton	55	100	0.25	0.066
Hubbardston	65	100	0.25	0.069
Hudson	55	100	0.26	0.068
Hull	45	110	0.28	0.067
Huntington	65	100	0.22	0.066
Ipswich	45	110	0.34	0.074
Kingston	45	110	0.24	0.061
Lakeville	45	110	0.24	0.061
Lancaster	55	100	0.27	0.070
Lanesborough	65	90	0.22	0.068

TABLE 1604.10 GROUND SNOW LOADS; BASIC WIND SPEEDS; EARTHQUAKE DESIGN FACTORS
(For R-3 of three stories or less one- and two-family stand alone buildings, see 780 CMR 53.00 for snow and wind loads)

City/Town	Ground Snow Load p_g, psf	Basic Wind Speed V, MPH	Earthquake Design Factors	
			Ss	S_1
Lawrence	55	110	0.33	0.075
Lee	65	90	0.22	0.066
Leicester	55	100	0.24	0.066
Lenox	65	90	0.22	0.067
Leominster	65	100	0.26	0.070
Leverett	65	100	0.23	0.068
Lexington	55	105	0.29	0.070
Leyden	65	100	0.23	0.069
Lincoln	55	100	0.28	0.069
Littleton	55	100	0.29	0.071
Longmeadow	55	100	0.23	0.065
Lowell	55	100	0.31	0.074
Ludlow	55	100	0.23	0.066
Lunenburg	65	100	0.28	0.071
Lynn	45	110	0.31	0.071
Lynnfield	45	110	0.31	0.072
Malden	45	105	0.29	0.069
Manchester	45	110	0.32	0.072
Mansfield	55	110	0.25	0.063
Marblehead	45	110	0.31	0.071
Marion	45	110	0.22	0.057
Marlborough	55	100	0.26	0.068
Marshfield	45	110	0.26	0.064
Mashpee	35	120	0.20	0.054
Mattapoisett	45	110	0.22	0.057
Maynard	55	100	0.27	0.069
Medfield	55	100	0.25	0.065
Medford	45	105	0.29	0.070
Medway	55	100	0.25	0.065
Melrose	45	105	0.30	0.070
Mendon	55	100	0.24	0.064
Merrimac	55	110	0.35	0.077
Methuen	55	110	0.34	0.076
Middleborough	45	110	0.24	0.061
Middlefield	65	100	0.22	0.066
Middleton	45	110	0.32	0.073
Milford	55	100	0.24	0.065
Millbury	55	100	0.24	0.065
Millis	55	100	0.25	0.065
Millville	55	100	0.24	0.064
Milton	45	105	0.27	0.066
Monroe	65	100	0.22	0.069
Monson	55	100	0.23	0.065
Montague	65	100	0.23	0.068
Monterey	65	90	0.22	0.066
Montgomery	65	100	0.23	0.066
Mount Washington	65	90	0.23	0.066
Nahant	45	110	0.30	0.070
Nantucket	35	120	0.15	0.047
Natick	55	100	0.26	0.067

TABLE 1604.10 GROUND SNOW LOADS; BASIC WIND SPEEDS; EARTHQUAKE DESIGN FACTORS

(For R-3 of three stories or less one- and two-family stand alone buildings, see 780 CMR 53.00 for snow and wind loads)

City/Town	Ground Snow Load p_g, psf	Basic Wind Speed V, MPH	Earthquake Design Factors	
			Ss	S_1
Needham	55	100	0.27	0.067
New Ashford	65	90	0.22	0.068
New Bedford	45	110	0.23	0.058
New Braintree	55	100	0.23	0.067
New Marlborough	65	90	0.23	0.066
New Salem	65	100	0.24	0.068
Newbury	55	110	0.35	0.076
Newburyport	55	110	0.35	0.077
Newton	55	105	0.27	0.068
Norfolk	55	100	0.25	0.065
North Adams	65	90	0.22	0.069
North Andover	55	110	0.33	0.075
North Attleborough	55	110	0.24	0.063
North Brookfield	55	100	0.23	0.066
North Reading	55	105	0.32	0.073
Northampton	55	100	0.22	0.066
Northborough	55	100	0.25	0.067
Northbridge	55	100	0.24	0.065
Northfield	65	100	0.24	0.070
Norton	55	110	0.24	0.063
Norwell	45	110	0.26	0.064
Norwood	55	100	0.26	0.065
Oak Bluffs	35	120	0.18	0.051
Oakham	55	100	0.24	0.067
Orange	65	100	0.24	0.070
Orleans	35	120	0.18	0.051
Otis	65	90	0.23	0.066
Oxford	55	100	0.23	0.065
Palmer	55	100	0.23	0.066
Paxton	55	100	0.24	0.067
Peabody	45	110	0.31	0.072
Pelham	55	100	0.23	0.067
Pembroke	45	110	0.25	0.063
Pepperell	65	100	0.30	0.073
Peru	65	90	0.22	0.067
Petersham	65	100	0.24	0.068
Phillipston	65	100	0.24	0.069
Pittsfield	65	90	0.22	0.067
Plainfield	65	100	0.22	0.068
Plainville	55	100	0.24	0.063
Plymouth	45	110	0.24	0.060
Pympton	45	110	0.24	0.061
Princeton	65	100	0.25	0.069
Provincetown	35	120	0.22	0.058
Quincy	45	105	0.27	0.067
Randolph	45	105	0.26	0.065
Raynham	55	110	0.24	0.062
Reading	55	105	0.31	0.072
Rehoboth	55	110	0.24	0.062
Revere	45	105	0.30	0.070
Richmond	65	90	0.22	0.067

TABLE 1604.10 GROUND SNOW LOADS; BASIC WIND SPEEDS; EARTHQUAKE DESIGN FACTORS

(For R-3 of three stories or less one- and two-family stand alone buildings, see 780 CMR 53.00 for snow and wind loads)

City/Town	Ground Snow Load p_g, psf	Basic Wind Speed V, MPH	Earthquake Design Factors	
			Ss	S_1
Rochester	45	110	0.23	0.059
Rockland	45	110	0.26	0.064
Rockport	45	110	0.33	0.073
Rowe	65	100	0.22	0.069
Rowley	55	110	0.34	0.075
Royalston	65	100	0.25	0.070
Russell	65	100	0.23	0.066
Rutland	55	100	0.24	0.068
Salem	45	110	0.31	0.071
Salisbury	55	110	0.35	0.077
Sandisfield	65	90	0.23	0.066
Sandwich	35	120	0.22	0.058
Saugus	45	110	0.30	0.070
Savoy	65	90	0.22	0.068
Scituate	45	110	0.27	0.065
Seekonk	55	110	0.24	0.062
Sharon	55	100	0.25	0.065
Sheffield	65	90	0.23	0.066
Shelburne	65	100	0.23	0.068
Sherborn	55	100	0.26	0.066
Shirley	65	100	0.28	0.072
Shrewsbury	55	100	0.25	0.067
Shutesbury	65	100	0.23	0.068
Somerset	55	110	0.23	0.060
Somerville	45	105	0.28	0.069
South Hadley	55	100	0.23	0.066
Southampton	55	100	0.23	0.066
Southborough	55	100	0.26	0.067
Southbridge	55	100	0.23	0.064
Southwick	55	100	0.23	0.065
Spencer	55	100	0.23	0.066
Springfield	55	100	0.23	0.065
Sterling	55	100	0.26	0.069
Stockbridge	65	90	0.22	0.066
Stoneham	45	105	0.30	0.071
Stoughton	55	100	0.26	0.065
Stow	55	100	0.27	0.069
Sturbridge	55	100	0.23	0.065
Sudbury	55	100	0.27	0.069
Sunderland	65	100	0.23	0.068
Sutton	55	100	0.24	0.065
Swampscott	45	110	0.30	0.070
Swansea	55	110	0.24	0.061
Taunton	55	110	0.24	0.062
Templeton	65	100	0.25	0.070
Tewksbury	55	100	0.31	0.073
Tisbury	35	120	0.18	0.052
Tolland	65	100	0.23	0.066
Topsfield	45	110	0.33	0.074
Townsend	65	100	0.28	0.072
Truro	35	120	0.22	0.057

TABLE 1604.10 GROUND SNOW LOADS; BASIC WIND SPEEDS; EARTHQUAKE DESIGN FACTORS
(For R-3 of three stories or less one- and two-family stand alone buildings, see 780 CMR 53.00 for snow and wind loads)

City/Town	Ground Snow Load p_g, psf	Basic Wind Speed V, MPH	Earthquake Design Factors	
			Ss	S_1
Tyngsborough	55	100	0.31	0.074
Tyringham	65	90	0.22	0.066
Upton	55	100	0.24	0.065
Uxbridge	55	100	0.24	0.064
Wakefield	45	105	0.31	0.071
Wales	55	100	0.23	0.065
Walpole	55	100	0.25	0.065
Waltham	55	105	0.28	0.069
Ware	55	100	0.23	0.066
Wareham	45	110	0.23	0.058
Warren	55	100	0.23	0.066
Warwick	65	100	0.24	0.070
Washington	65	90	0.22	0.067
Watertown	45	105	0.28	0.068
Wayland	55	100	0.27	0.068
Webster	55	100	0.23	0.064
Wellesley	55	100	0.27	0.067
Wellfleet	35	120	0.20	0.054
Wendell	65	100	0.23	0.069
Wenham	45	110	0.32	0.073
West Boylston	55	100	0.25	0.067
West Bridgewater	45	110	0.25	0.063
West Brookfield	55	100	0.23	0.066
West Newbury	55	110	0.35	0.077
West Springfield	55	100	0.23	0.065
West Stockbridge	65	90	0.22	0.066
West Tisbury	35	120	0.18	0.052
Westborough	55	100	0.25	0.067
Westfield	55	100	0.23	0.066
Westford	55	100	0.30	0.073
Westhampton	65	100	0.22	0.066
Westminster	65	100	0.26	0.071
Weston	55	100	0.27	0.068
Westport	45	110	0.23	0.058
Westwood	55	100	0.26	0.066
Weymouth	45	105	0.27	0.066
Whately	65	100	0.22	0.067
Whitman	45	110	0.25	0.063
Wilbraham	55	100	0.23	0.065
Willamsburg	65	100	0.22	0.067
Williamstown	65	90	0.23	0.069
Wilmington	55	105	0.31	0.073
Winchendon	65	100	0.26	0.071
Winchester	55	105	0.29	0.070
Windsor	65	90	0.22	0.067
Winthrop	45	105	0.29	0.068
Woburn	55	105	0.30	0.071
Worcester	55	100	0.24	0.067
Worthington	65	100	0.22	0.067
Wrentham	55	100	0.24	0.064
Yarmouth	35	120	0.19	0.052

Appendix M: Eurocode 1 Part 1-3 Excerpt

The following pages are taken from Eurocode 1 Part1-3, pages 10-12, 17-19, 39, and 55.

1.6. Terms and Definitions

For the purposes of this European standard, a basic list of terms definitions given in EN 1990:2002, 1.5 apply together with the following.

1.6.1
characteristic value of snow load on the ground
snow load on the ground based on an annual probability of exceedence of 0,02, excluding exceptional snow loads.

1.6.2
altitude of the site
height above mean sea level of the site where the structure is to be located, or is already located for an existing structure.

1.6.3
exceptional snow load on the ground
load of the snow layer on the ground resulting from a snow fall which has an exceptionally infrequent likelihood of occurring.

NOTE: See notes to 2(3) and 4.3(1).

1.6.4
characteristic value of snow load on the roof
product of the characteristic snow load on the ground and appropriate coefficients.

NOTE: These coefficients are chosen so that the probability of the calculated snow load on the roof does not exceed the probability of the characteristic value of the snow load on the ground.

1.6.5
undrifted snow load on the roof
load arrangement which describes the uniformly distributed snow load on the roof, affected only by the shape of the roof, before any redistribution of snow due to other climatic actions.

1.6.6
drifted snow load on the roof
load arrangement which describes the snow load distribution resulting from snow having been moved from one location to another location on a roof, e.g. by the action of the wind.

1.6.7
roof snow load shape coefficient
ratio of the snow load on the roof to the undrifted snow load on the ground, without the influence of exposure and thermal effects.

1.6.8
thermal coefficient
coefficient defining the reduction of snow load on roofs as a function of the heat flux through the roof, causing snow melting.

1.6.9
exposure coefficient
coefficient defining the reduction or increase of load on a roof of an unheated building, as a fraction of the characteristic snow load on the ground.

1.6.10
load due to exceptional snow drift
load arrangement which describes the load of the snow layer on the roof resulting from a snow deposition pattern which has an exceptionally infrequent likelihood of occurring.

1.7. Symbols

(1) For the purpose of this European standard, the following symbols apply.

NOTE: The notation used is based on ISO 3898

(2) A basic list of notations is given in EN 1990:2002 1.6, and the additional notations below are specific to this Part.

Latin upper case letters

C_e	Exposure coefficient
C_t	Thermal coefficient
C_{esl}	Coefficient for exceptional snow loads
A	Site altitude above sea level [m]
S_e	Snow load per metre length due to overhang [kN/m]
F_s	Force per metre length exerted by a sliding mass of snow [kN/m]

Latin lower case letters

b	Width of construction work [m]
d	Depth of the snow layer [m]
h	Height of construction work [m]
k	Coefficient to take account of the irregular shape of snow (see also 6.3)
l_s	Length of snow drift or snow loaded area [m]

s Snow load on the roof [kN/m^2]

s_k Characteristic value of snow on the ground at the relevant site [kN/m^2]

s_{Ad} Design value of exceptional snow load on the ground [kN/m^2]

Greek Lower case letters

α Pitch of roof, measured from horizontal [^{o}]

β Angle between the horizontal and the tangent to the curve for a cylindrical roof [^{o}]

γ Weight density of snow [kN/m^3]

μ snow load shape coefficient

ψ_0 Factor for combination value of a variable action

ψ_1 Factor for frequent value of a variable action

ψ_2 Factor for quasi-permanent value of a variable action

NOTE: For the purpose of this standard the units specified in the above list apply.

Table 4.1 Recommended values of coefficients ψ_0, ψ_1 and ψ_2 for different locations for buildings.

Regions	ψ_0	ψ_1	ψ_2
Finland Iceland Norway Sweden	0,70	0,50	0,20
Reminder of other CEN member states, for sites located at altitude H > 1000 m above sea level	0,70	0,50	0,20
Reminder of other CEN member states, for sites located at altitude H ≤ 1000 m above sea level	0,50	0,20	0,00

4.3. Treatment of exceptional snow loads on the ground

(1) For locations where exceptional snow loads on the ground can occur, they may be determined by:

$$s_{Ad} = C_{esl}\, s_k \qquad (4.1)$$

where:

s_{Ad} is the design value of exceptional snow load on the ground for the given location;

C_{esl} is the coefficient for exceptional snow loads;

s_k is the characteristic value of snow load on the ground for a given location.

NOTE: The coefficient C_{esl} may be set by the National Annex. The recommended value for C_{esl} is 2,0 (see also 2(3))

5. Section 5 Snow load on roofs

5.1. Nature of the load

(1)P The design shall recognise that snow can be deposited on a roof in many different patterns.

(2) Properties of a roof or other factors causing different patterns can include:

a) the shape of the roof;
b) its thermal properties;

c) the roughness of its surface;
d) the amount of heat generated under the roof;
e) the proximity of nearby buildings;
f) the surrounding terrain;
g) the local meteorological climate, in particular its windiness, temperature variations, and likelihood of precipitation (either as rain or as snow).

5.2. Load arrangements

(1)P The following two primary load arrangements shall be taken into account:

- undrifted snow load on roofs (see 1.6.5);
- drifted snow load on roofs (see 1.6.6).

(2) The load arrangements should be determined using 5.3; and Annex B, where specified in accordance with 3.3.

NOTE: The National Annex may specify the use of Annex B for the roof shapes described in 5.3.4, 5.3.6 and 6.2, and will normally apply to specific locations where all the snow usually melts and clears between the individual weather systems and where moderate to high wind speeds occur during the individual weather system.

(3)P Snow loads on roofs shall be determined as follows:

a) for the persistent / transient design situations

$$s = \mu_i \, C_e \, C_t \, s_k \qquad (5.1)$$

b) for the accidental design situations where exceptional snow load is the accidental action (except for the cases covered in 5.2 (3) P c)

$$s = \mu_i \, C_e \, C_t \, s_{Ad} \qquad (5.2)$$

Note: See 2(3).

c) for the accidental design situations where exceptional snow drift is the accidental action and where Annex B applies

$$s = \mu_i \, s_k \qquad (5.3)$$

NOTE: See 2(4).

where:

μ_i is the snow load shape coefficient (see Section 5.3 and Annex B)

s_k is the characteristic value of snow load on the ground

s_{Ad} is the design value of exceptional snow load on the ground for a given location (see 4.3)

C_e is the exposure coefficient

C_t is the thermal coefficient

(4) The load should be assumed to act vertically and refer to a horizontal projection of the roof area.

(5) When artificial removal or redistribution of snow on a roof is anticipated the roof should be designed for suitable load arrangements.

NOTE 1: Load arrangements according to this Section have been derived for natural deposition patterns only.

NOTE 2: Further guidance may be given in the National Annex.

(6) In regions with possible rainfalls on the snow and consecutive melting and freezing, snow loads on roofs should be increased, especially in cases where snow and ice can block the drainage system of the roof.

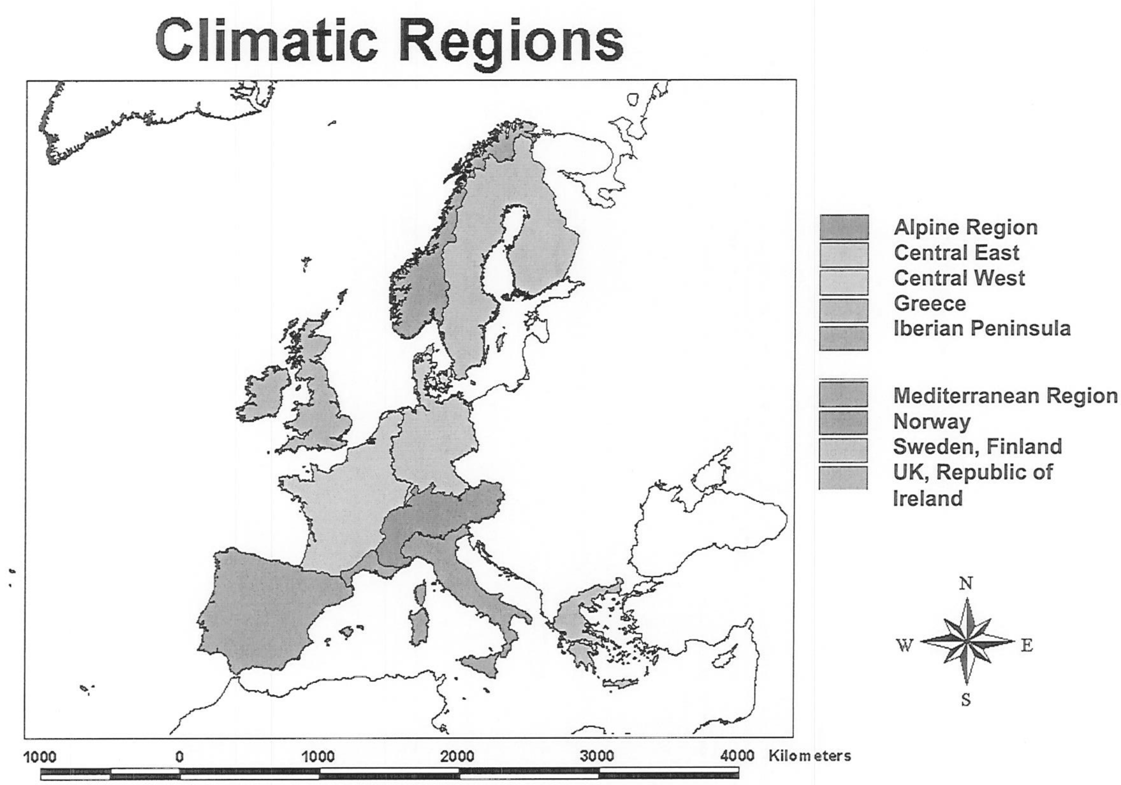
NOTE: Further complementary guidance may be given in the National Annex.

(7) The exposure coefficient C_e should be used for determining the snow load on the roof. The choice for C_e should consider the future development around the site. C_e should be taken as 1,0 unless otherwise specified for different topographies.

NOTE: The National Annex may give the values of C_e for different topographies. The recommended values are given in Table 5.1 below.

(7) Figure C.13 shows the map supplied by the Polish National Authority.

Figure C.1. European Climatic regions



ANNEX E
(informative)

Bulk weight density of snow

(1) The bulk weight density of snow varies. In general it increases with the duration of the snow cover and depends on the site location, climate and altitude.

(2) Except where specified in Sections 1 to 6 indicative values for the mean bulk weight density of snow on the ground given in Table E.1 may be used.

Table E.1: Mean bulk weight density of snow

Type of snow	Bulk weight density [kN/m^3]
Fresh	1,0
Settled (several hours or days after its fall)	2,0
Old (several weeks or months after its fall)	2,5 - 3,5
Wet	4,0

Appendix N: I-Codes Adoption by State

The following is the I-Code State Adoption Chart provided by the ICC Website

International Codes-Adoption by State

ICC makes every effort to provide current, accurate code adoption information. Not all jurisdictions notify ICC of code adoptions. To obtain more detailed information on amendments and changes to adopted codes, please contact the jurisdiction. To submit code adoption information: http://www.iccsafe.org/government/adoption-form.html

X = Effective Statewide A = Adopted, but may not yet be effective L = Adopted by Local Governments
S = Supplement 06 = 2006 Edition 04 = 2004 Edition 03 = 2003 Edition 00 = 2000 Edition

* The title of the 2000 and 2003 IUWIC Code was changed to IWUIC in the 2006 version.

ST	JURISDICTION	IBC	IRC	IFC	IMC	IPC	IPSDC	IFGC	IECC	IPMC	IEBC	ICCPC	IUWIC	IZC	ICCEC	Chart Comments
AL	Alabama	X06	L	X06	X06,L	X06,L	L	X06,L	L	L	L	L		L	L	IBC, IFC, IMC, IPC, IFGC - AL Building Commission: state owned, schools, hotels, movie theaters
AK	Alaska	X06	L06	X06	X06			X06	L06							
AZ	Arizona	X06	L	X06	X06	X06	X06	X06	X06	X06	L	L	L	L	X00	AZ-Dept of Health Services, health care institutions
AR	Arkansas	X06	X06	X06	X06	X06	L	X06	X03	L	L				L	
CA	California	X06		X06												CA currently adopts the 2006 IBC & IFC as the base model codes for the CA 2007 Building Standards Code. CA also adopts a portion of the IEBC, Apx A, Chapter 1 which is published in Volume II of the 2007 CA Building Code.
CO	Colorado	X06	L	X06	X06	X06	L	X06	X06	L	L	L	L	L	L	All State Buildings & Facilities: IBC, IMC, IPC, IFGC, IECC. All Public Schools & Junior Colleges: IBC, IFC, IMC, IPC, IFGC
CT	Connecticut	X03	X03	X03	X03	X03			X03	L	X03					IFC: Portions used in the CT State Fire Code; ICC/ANSI A117.1
DE	Delaware	L	L	L	L	X03		L	L	L	L				L	
DC	District of Columbia	X06	X06	X06	X06	X06		X06	X06	X06	X06					
FL	Florida	X03	X03		X06	X06		X06	X06	L06	X06					
GA	Georgia	X06	X06	X06	X06	X06		X06	X06	L	L					
HI	Hawaii	X06, L03	L03													
ID	Idaho	X03, L06	X03, L06	X03, L06	X03, L06			X03, L06	X06, L06		L					
IL	Illinois	X06	L	X06	X06	L	L	X06	X06	X06	X06	L	L	L	L	2000 IECC, modified by the 2001 Supplement for commercial structures statewide. IBC, IFC, IMC, IFGC, IPMC, IECC, IEBC for IL Board of Edu Facilities (other than vehicular), but do not apply to Chicago. IBC adopted by Dept of Health for hospitals where local codes do not apply.
IN	Indiana	X06	X03	X06	X06			X06								
IA	Iowa	X06	X06	X06	X06	L	L	L	X06	L	X06			L	L	IBC, IRC, IMC, IEBC, IECC: State owned and rented structures
KS	Kansas	X03	X03	X03	L03	L03	L	L03	X06	L	L				L	Applies to state owned facilities
KY	Kentucky	X06	X06	X06	X06			X06	X06	L						Kentucky, with amendments, has adopted the 2006 editions of IBC and IRC statewide. In the KBC (Kentucky Building Code) the state has adopted by reference the 2006 editions of the IMC and IECC. The 2006 IFC is utilized for new construction projects. While the Kentucky codes are applicable statewide, enforcement is only mandatory statewide for commercial buildings.IECC: bldgs other than 1&2 family regulated by the KRC.
LA	Louisiana	X06	X06	L	X06			X06	X06, L	L	X06				L	
ME	Maine	X03,L	X03	L	L	L	L	L	X03	L	X03			L	L	
MD	Maryland	X06	X06		X06	X06,L	L	L	X06	L	X06				L	IPC: Industrialized housing. Other codes: edition shown may not be in use locally; check with local jurisdiction.
MA	Massachusetts	A03	X03		A03				X06							

ST	JURISDICTION	IBC	IRC	IFC	IMC	IPC	IPSDC	IFGC	IECC	IPMC	IEBC	ICCPC	IUWIC	IZC	ICCEC	Chart Comments
MI	Michigan	X06	X06	L	X06	X06	L	X06	X03	L	X06	L			L	The State of Michigan has, with amendments, adopted for enforcement statewide the 2006 editions of IBC, IRC, IMC, IPC and IEBC. The state has adopted by reference with amendments the 2006 editions of the ICC Electrical Code, IFGC, IPMC, IUWIC, ICC/ANSI A117.1-98 and the 2003 IECC. Enforcement of the Michigan codes is mandatory statewide for all buildings including 1 and 2 family dwellings.
MN	Minnesota	X06	X06	X06	X00			X06		L						
MS	Mississippi	X06	X06	X06	X06	X06	L	X06	L	L	L	L			L	MSBCC adopted the '06 IBC, IRC, IFC, IMC, IPC, and IFGC in 2008. Effective immediately; jurisdictions adopting codes for the first time or jurisdictions who are updating their adoptions must adopt these codes. Jurisdictions that have codes adopted must update to these codes by July 2010.
MO	Missouri	X00	X00	L	X00	X00, X03	L	X00	L	L	L	L	L	L	L	State Office Space - 03 IPC; Modular Construction - 00 IBC, IRC, IMC, IPC, IFGC
MT	Montana	X06	X06	L	X06			X06	X03		X06					
NE	Nebraska	X00	X00	L	L	L	L	L	X03	L	L		L	L	L	
NV	Nevada	X06	X06	X03	L	L	L	L	X06	L	X06	L			L	IBC, IFC: SFM, schools, health care, state bldgs, commercial bldgs for counties over 100k. IBC, IRC, IFC, IECC, IEBC NV Public Works Board, state buildings
NH	New Hampshire	X06	X06	L	X06	X06		L	X06	L						
NJ	New Jersey	X06	X06	X06	X06			X06	X06	L						
NM	New Mexico	X06	X06	X03		L			X06		X06					06 IBC, IRC, IECC & IEBC adopted statewide by NM Const Ind Div. 03 IFC adopted statewide by the State Fire Marshal's Office.
NY	New York	X03	X03	X03	X03	X03		X03	X03	X03	X03					
NC	North Carolina	X06	X06	X06	X06	X06		X06	X06							All codes contain NC specific amendments
ND	North Dakota	X	X	L	X	L		X		L	L					
OH	Ohio	X06	X06	X06	X06	X06		X06	X06	L				L	L	For commercial buildings the State of Ohio has, with amendments, adopted statewide the 2006 editions of IBC, IMC, IPC and IFC, and by reference, the ICC/ANSI A117.1-2004 and the 2006 edition of the IFGC. The 2006 IECC for commercial buildings has been adopted with a prescriptive package. The 2006 IRC with amendments has been adopted statewide for 1, 2 and 3 family dwellings. Enforcement of the Ohio Building Codes is mandatory statewide for all buildings except 1, 2 and three family dwellings. The Residential Code of Ohio (RCO) is required statewide for jurisdictions that enforce a building code for 1, 2 and/or 3 family dwellings.
OK	Oklahoma	X06	X06	X06	X06	X06	L	X06	X03	X06	X06	X06	L	L	L	IRC - Mechanical, Plumbing and Fuel Gas provisions only
OR	Oregon	X06	X06	X06	X06			X06								
PA	Pennsylvania	X06	X06	X06	X06	X06		X06	X06	L	X06	X06	X06		X06	
RI	Rhode Island	X06	X06		X06	X06		X06	X06							
SC	South Carolina	X06	X03	X06	X06	X06		X06	X06	L06	L06	L06				The IRC will be effective July 1, 2009
SD	South Dakota	X00	L	X00	X00		L	L	L	L	L	L	L		L	IBC, IFC: Approved for local adoption; IMC for state school construction
TN	Tennessee	X06	L	X06	L	L		L	L	L	L	L		L	L	
TX	Texas	X03	X00	L	L	L	L	L	X00	L	L	L	L	L	L	Jurisdictions authorized by state law to adopt later editions of IBC, IRC, IPC, IMC, IFGC, and IECC. See Jurisdiction Chart for specific edition adopted.
UT	Utah	X06	X06	X03	X06	X06		X06	X06							
VT	Vermont	X06	L03			X03			X04							2006 IBC will be effective June 15, 2009
VA	Virginia	X06	X06	X06	X06	X06		X06	X06	X06	X06					
WA	Washington	X06	X06	X06	X06			X06	L	L	L	L	L			
WV	West Virginia	X03	X03	L	X03	X03		X03	X03	L00	X03					West Virginia, through the WV Fire Commission, has the regulatory authority to adopt the state's building and fire codes. The Commission has adopted statewide the 2003 editions of IBC, IRC, IMC, IFGC, IPC, IEBC and IECC for any jurisdiction that chooses to enforce building codes. The 2006 I-codes are recognized, but have not been officially adopted. The State Fire Commission passed a resolution in April of 2008 to encourage all counties and municipalities to utilize the 2006 I-Codes. The IPMC also has been adopted statewide but enforcement is optional. As the Fire Code, the Fire Commission has adopted the entire collection of the NFPA codes and standards excepting NFPA 5000 and NFPA 900 and NFPA 101A. The WV Fire code applies to both new and existing construction and whenever there is a conflict between the State Building Code (Title 87 Series 5b) and the State Fire Code (Title 87 Series1), the fire code takes precedence.
WI	Wisconsin	X06		L	X06			X06	X06		X06					
WY	Wyoming	X	L	X	X	L	L	X	L	L	L	L			L	
TY	**US TERRITORIES**	**IBC**	**IRC**	**IFC**	**IMC**	**IPC**	**IPSDC**	**IFGC**	**IECC**	**IPMC**	**IEBC**	**ICCPC**	**IUWIC**	**IZC**	**ICCEC**	**Chart Comments**
PR	Puerto Rico					X										
VI	U.S. Virgin Islands	X03	X03		X03				X03							

Appendix O: CABO Code vs. International Residential Code (Roof)

The following table is an excerpt from SBCII's *A Comparison of the Technical Requirements in the 1995 CABO One- and Two-Family Dwelling Code and the 2000 International Residential Code*

—	R703.9	The 2000 IRC includes provisions for Exterior Insulation Finish Systems (EIFS). EIFS must be installed in accordance with the manufacturer's installation instructions. Decorative trim shall not be face nailed through the EIFS and the EIFS shall terminate not less than 6 inches above the ground.
—	R703.9.1	The 2000 IRC requires that EIFS have a weather-resistive barrier applied between water-sensitive building components and the EIFS.
—	R703.9.2	The 2000 IRC addresses flashing on EIFS.
CHAPTER 8- CEILING CONSTRUCTION		
Ch 8 Rafter Span Tables for Wood Roofs	Ch 8 Rafter Span Tables for Wood Roofs	Rafter span tables have been expanded in the 2000 IRC to include 70 psf and 50 psf of ground snow load.
Ch 8 Rafter Span Tables for Steel Roofs	Ch 8 Rafter Span Tables for Steel Roofs	The steel roof framing span tables inthe 2000 IRC are limited to sites subjected to a maximum design wind speed of 130 m.p.h., Exposure A, B, or C and a maximum ground snow load of 70 psf.
CHAPTER 9 - ROOF ASSEMBLIES		
Ch 9	Ch 9	Chapter 9 of the 2000 IRC has been re-organized for ease of use.
Sec. 905	Sec. R905	The 2000 IRC includes a Table R905.10.3 which addresses application standards for different types of metal roof coverings.
—	R905.2.6	Provisions for 6 fasteners per asphalt strip shingle are provided in the 2000 IRC where: 1. The basic wind speed is 110 m.p.h. or greater and the eave is 20 feet or higher above grade. 2. The basic wind speed is 120 m.p.h. or greater. 3. Special wind zones.
—	R905.11	The 2000 IRC addresses the installation of modified bitumen roofing.
—	R905.12	The 2000 IRC addresses the installation of thermoset single-ply roofing.
—	R905.13	The 2000 IRC addresses the installation of thermoplastic single-ply roofing.
—	R905.14	The 2000 IRC addresses the installation of sprayed polyurethane foam roofing.
—	R906.1	The 2000 IRC requires that roof insulation used above deck be covered with an approved roof covering and passes FM 4450 or UL 1256.

910	R907.3	The criteria has changed in the 2000 IRC for when existing roof coverings must be removed. (Item 1 & 2 are the same as 1998, Item 3 has been revised and Item 4 is new in the 2000 IRC). 1. Where the existing roof or roof covering is water soaked or has deteriorated to the point that the existing roof or roof covering is not adequate as a base for additional roofing. 2. Where the existing roof covering is wood shake, slate, clay, cement or asbestos-cement tile. 3. Where the existing roof has two or more applications of any type of roof covering (Changed from 3 to 2 applications). 4. For asphalt shingles, when the building is located in an area subject to severe hail damage.
—	R907.4	The 2000 IRC will allow metal panel, metal shingle, and clay tile roof coverings to be installed over wood shingle or shake roofs when the entire existing surface is covered with gypsum board, mineral fiber, glass fiber, or other approved materials securely fastened in place.
—	Figure R907.3	The 2000 IRC includes a new hail risk map.
CHAPTER 10 - CHIMNEYS AND FIREPLACES		
1001.1	R1001.1	The IRC changed Seismic Zones 3 and 4 to Seismic Design Categories D_1 and D_2. Seismic Zones 0, 1 or 2 has been changed to Seismic Design Categories A, B or C.
1001.2	R1001.2	This section has been revised to change the maximum amount of corbeling from 6" to one-half of the chimney's wall thickness.
—	R1001.4	The IRC provides a new section to address offsets.
1001.7	R1001.8	The IRC does not prescribe a 5/8" minimum fireclay liner. The IRC requires all masonry chimneys to be lined.This section has been expanded to cover other liner materials in addition to the fireclay liner. Flue linings for specific appliances has been added.
1001.8	R1001.9	The IRC does not specify a ½" wide air space between the flue liner and the chimney. The IRC requires flue liners to be installed in accordance with ASTM C 1283. The maximum slope of the liner can be no greater than 30 degrees.
—	R1001.9.2	The IRC addresses the use of the space around the liner.
1001.11	R1001.12	The IRC has changed the criteria and method for sizing the flue area for masonry fireplaces.
1001.13	R1001.14	The IRC addresses additional requirements for the location of masonry chimney cleanout openings.
1001.14	R1001.15	The IRC provides for two additional exceptions to the 2" clearance of a masonry chimney to combustibles.
1002	R1002	The IRC has expanded the factory-built chimney section to include prescriptive requirements for decorative shrouds, solid fuel appliances, and medium-heat appliances.

Appendix P: Building Code Excerpt from the Code of Hammurabi

229. If a builder has built a house for a man, and has not made his work sound, and the house he built has fallen, and caused the death of its owner, that builder shall be put to death.

230. If it is the owner's son that is killed, the builder's son shall be put to death.

231. If it is the slave of the owner that is killed, the builder shall give slave for slave to the owner of the house.

232. If he has caused the loss of goods, he shall render back whatever he has destroyed. Moreover, because he did not make sound the house he built, and it fell, at his own cost he shall rebuild the house that fell.

233. If a builder has built a house for a man, and has not keyed his work, and the wall has fallen, that builder shall make that wall firm at his own expense.

Appendix Q: Week 1 report

For the previous week and by the end of this week our main objective was/is as follows: Ben would look into the building codes of Massachusetts, David would look into the building codes of the United States, and Erik would look into the building codes of other developed countries such as Canada and those of Europe. The purpose of this research was to conclude whether or not there were similarities between the building codes, specifically codes pertaining to a building's roof and weather concerns, of the various researched locations. Having discerned the similarities and differences between the states and countries we would use our research findings to determine possible questions for the interview and possible candidates to interview.

As of right now we have completed most of the research pertaining to the building codes of the Massachusetts area, the United States, Canada, and Europe concerning weather concerns and building roofs. Currently we are still brainstorming topics of discussion and possible interviewees although we do have some ideas. From our previous meeting it was determined that we would try and contact town inspectors from towns that were severely affected by the ice storm this previous winter. The purpose of this interview is to find out whether or not any roofs had collapsed during that period and if so what was the underlying cause for these collapses. Other possible candidates for interviews that we determined to be insightful would be people who take part in making these building codes, architects, and construction workers.

We are currently on schedule and should be done with our research, if all goes well, by Saturday, June 13. However, there is still work to be done and that would be the following: finalize the specific codes that apply to our area of concern, research on a country that doesn't receive snow fall (i.e. Mexico), and brainstorm more possible questions and people to interview.

There were two main problems faced during our research, the first one was the cost to obtain the necessary information and the second was the amount of information obtained concerning our area of research. While trying to obtain information for our research it seemed as though all the books containing the information had to be purchased from one vendor or another at exorbitant prices and since we only needed one or two sections for our research it seemed unnecessary. Luckily, we were able to find these books at the WPI Library which had several sources of information pertaining to what we needed.

Appendix R: Week 2 report

Our goals for the past week were to complete the reading of building codes and begin the identification of subjects to be interviewed. For the first goal, Ben was assigned the task of researching building codes in the state of New Hampshire. Erik was assigned the task of researching building codes in warmer developed countries. Both of these tasks were accomplished. Erik did locate one issue that defined building codes do not exist in Mexico and South America.

To complete our second task of locating interview subjects, Erik and David gathered contact information for municipal building inspectors from the areas surrounding their hometowns. Both also began brainstorming some questions to ask in an interview. David also compiled a short list of WPi civil engineering professors who may be interested in building construction. We did have the problem that none of us have any contacts in the civil engineering department, so we read professors web pages to create a list of those that may be able to assist us.

After this research had been completed, we had a group meeting to discuss our findings. It was decided that the first interviews conducted will be with WPI professors, followed by at least one municipal building inspector. Timelines were set for meetings, with immediate email contact with WPI professors and a possible interview to be scheduled on Wednesday the 17th or Thursday the 18th. Monday and Tuesday of the next week were selected as possible dates for an interview with a municipal building inspector. Ben was assigned the task of making initial contact with WPI professors. After our meeting, none of the selected professors were able to be located in their offices, so emails were sent to each of them.

After doing this work, we believe we are still on schedule, provided we complete reaching out to possible interviewees by the end of this calendar week.

Appendix S: Week 3 report

For this past week, David, Ben, and I all had the same objectives; to check our research on building codes and formulate questions for interviews as well as finding people to interview. The upcoming week, or longer if necessary, will involve contacting these people and setting up potential interview times. Our approach is to interview with professors first in the hopes that they will give us some insight into what types of questions we should be asking. Then with the revised questions we will interview with town building inspectors in and around the city of Worcester.

So far we have completed an introductory list of questions and have drawn a few names of professors and inspectors to interview with. Ben has emailed all of the professors and has only heard back from a few; most are either unavailable and referred us to other professors or just haven't responded at all. David and I have found names of some town inspectors as well as their numbers and will be getting in touch with them as soon as a final set of questions is made.

We have met with one professor so far with the help of Professor Labonte, who is Professor Fitzgerald. The meeting was held on Tuesday June 23 in Kaven Hall. Professor Fitzgerald was very helpful and knowledgeable in the field of structural design as well as the use of standards and codes. We asked him a few basic questions about his knowledge of roof collapses and found that other than following the codes and standards it isn't a large concern among professionals in the civil engineering field. However, Professor Fitzgerald gave us much useful information on the use of standards and codes with respect to building design. In the end he also referred us to two men, Joe Mcavoy and Norton Remmer, who would be knowledgeable people in the same field and could be possible interviewees. He also mentioned that the people who would be likeliest to have statistics would be insurance companies and mentioned Factory Mutual as a possible candidate for questioning.

As far as the scheduling is concerned, we are still on schedule but depending on how long the rest of the interviews go, we may fall off schedule in the remaining weeks. The schedule right now is to have all of the interviews completed by next week but due to unforeseeable obstacles in scheduling the interviews, we may have to conduct interviews later than anticipated. After the interviews we plan on starting our research on collapsed roof statistics. We can remain on schedule by researching these statistics while still conducting interviews. In essence we will be going on schedule with the research we will just have to add in more work with the interviews. Overall the project is progressing well and at the present rate we will be able to meet our intended deadline of August 1.

Appendix T: Week 4 report

As mentioned in the previous weekly report, the past week and most of this week's goal was to get in contact and if possible interview specific people whom we believed to have knowledgeable insight or statistical data on roof failures. Ben's task was to do some investigation into Factory Mutual in hopes of finding specific employees whom he believed could help us in obtaining statistical data on roof failures in the Massachusetts and New Hampshire area and get in contact with them. Erik's first task was to obtain contact information concerning Joe McEvoy, Norton Remmer, possible contacts in Factory Mutual, and a professor who teaches classes concerning engineering failures from Professor Fitzgerald. Erik's other task was to contact Professor Labonte's Shrewsbury contact and Haverill's Building Inspector. As for David, his task was to contact and interview the town inspectors of Worcester, Holden, West Boylston, and Boston, as well as the state inspector for Massachusetts.

From the above mentioned tasks, only a few have been successfully completed whereas most of the other tasks are either not completed or partially completed. Of the tasks, the only ones to be completed are the following: Erik was able to obtain contact information from Professor Fitzgerald concerning the people he mentioned; and David was able to contact the Boston Town Inspector, however, the town inspector was only there for emergencies so no information was obtained. The tasks that have only been partial completed are the following: Ben was able to find contact information concerning Dick Davis, the Factory Mutual lead given by Professor Fitzgerald, but has yet to get a response; Erik has contacted Professor Roberto Pietroforte, the colleague Professor Fitzgerald told us to look into, but no response has been received; and David was able to speak with, Dennis Lipka, the building inspectors of Holden and was able to get some information, however, after emailing Mr. Lipka for further information no response was received. Finally, the following are tasks that have yet to be completed: Erik has yet to contact the Shrewsbury or Haverill Building Inspectors but will be doing so within this week; and David has yet to contact the West Boylston Building Inspector and has been unable to contact the Worcester Building Inspector.

Several problems occurred throughout the week which can be noticed in the above paragraph. First, Ben was unable to find the exact contact information for Dick Davis; however, after extensive searching he was able to find the email address and has contacted Dick Davis but has yet to receive a response. Second, as mentioned earlier, Erik has yet to receive a response from Professor Pietroforte; however, being a professor at WPI we will surely be able to obtain his contact information from the WPI directory. Third, David has yet to receive a response from Dennis Lipka, though he could still be formulating a reply to the email. However, if David doesn't receive a response after a reasonable amount of time from Mr. Lipka, David will send him another email and if necessary contact him by phone again. Fourth, David was unable to obtain any information from the Boston Building Inspector but was told to contact the Massachusetts Department of Public Safety which he did. However, after having tried calling the DPS, he was told to use the DPS emailing address instead, so as to find a suitable person to speak with, but no response has yet to be received. Luckily, David found the names of the Commissioner, Chief of Inspections – Buildings, and Building Code Development Manager while browsing through the DPS website and will be contacting them shortly. Finally, David has had no luck contacting the Worcester Town Inspector by phone because of problems with their automated answering system. In order to solve this problem, David will first try and email the town inspector to see if he can answer questions, and if he can contact him either by phone or in person.

As of right now we are definitely behind schedule in terms of where we had hoped to originally be. In order to compensate for this, we will start working on statistical data research, which was originally schedule for this week, as well as continuing our interviews. Nonetheless, if we keep up with this pace we should be done within our new deadline of in the middle of August if no other major obstacles impede our way.

Appendix U: Week 5 report

At the beginning of this week, we realized that we were behind schedule on our interviews and information gathering. Because of this, we rewrote our schedule, using the extra time that had previously been unallocated and reserved for situations where we got behind schedule. We now feel that we are on schedule, but we plan to finish at the end of the summer so there it will be very inconvenient if we fall behind our new schedule. The new schedule we created is as follows:

Finish Interviewing: July 1 - July 14

Gather Statistics: July 8 - July 22

Research Roof Failures (Cause and Effect): July 22 - July 31

Solutions/Recommendations: August 1 - Finish

Report: July 1 - Finish

Based on this schedule, we hope to complete our interviews with engineers next week. Gathering of statistics will include internet research and hopefully interviews with an insurance company. We also decided that it would be best to start the report as soon as possible.

The goals for this week were to continue to make contacts and attempt to schedule interviews. David was assigned the tasks of contacting the MA State Department of Public Safety (DPS), specifically their general information line and Joe McEvoy. He also remains in contact with the Holden, West Boylston, and Worcester building inspectors.

Erik was assigned the task of attending to open office hours of the Haverhill building inspector. He also contacted the Shrewsbury town building inspector. He also began internet research on the causes of roof collapses.

Ben was given the task of contacting the head of the DPS building code division and the building inspection division. He also continued to attempt to make contacts in the Factory Mutual insurance company.

We encountered several issues this week. The largest issue is that due to the holiday, it was difficult to reach many of our contacts. We did receive information via email from the Holden building inspector. We also spoke with Joe McEvoy and will be interviewing him in the next week. The head of the DPS codes division replied and was happy to help, but suggested other people who would be more knowledgeable. We still plan on contacting him for further information. At this time we still have not been able to make contact with anyone form the Factory Mutual insurance company, a company that we believe will be able to provide us with statistics on roof failures. Joe McEvoy is still the only engineer that we have been able to make contact with. We have not yet started writing the report, but we have gathered several informational materials that we will be citing and including as appendixes.

At this time we believe we are on schedule. Goals for the next week are to complete background interviews and move towards interviewing engineers that can provide statistics.

Appendix V: Week 6 report

The last meeting of this group it was determined that our next meeting would take place when the group felt they had enough to report. It has been two weeks since that meeting. In that time the group has completed the interview process, started researching roof failure causes and effects, and started writing the final report.

In the past two weeks we have finished our interviews completing two more in that time. The first was completed by Erik and was a telephone interview with the town building inspector of Shrewsbury, Ron Alarie. This interview was very successful and Mr. Alarie was very helpful, citing specific examples of roof failures as well as providing suggestions for solutions and even mentioning specific worries with structures that the inspectors are currently looking into.

The second interview was with a contact of Professor Fitzgerald, Massachusetts Building Inspector and Department of Public Safety worker Joe McEvoy. The interview with Mr. McEvoy was conducted on the Worcester State College campus and was an in person interview with the entire group. Mr. McEvoy was able to talk for multiple hours on everything from how buildings are made and how their plans are looked at before being built to what to research and how to find information. Specifically, we were given multiple books, one on the formation of codes and another on building failures with specific sections pointed out for research. Also we were given a quick lesson on the different classifications of buildings and how the type of building can play a role when inspecting its failure. With the completion of these interviews we have decided that we have interviewed and gathered information from as many outside sources as we can and are focusing on moving past the interview stage; we will complete one more interview with Factory Mutual in the hopes that we can gather some statistics from them if we are able to contact them in a timely fashion.

Also in the last few weeks the group has started writing the final report. Ben has written sections on the Massachusetts Building Code as well as the Abstract section describing the purpose of the project. David has written sections on the history of US Building Codes as well as the current US Building Code and its importance towards the project. He is also scheduled to begin writing the Acknowledgement section thanking those involved with helping the project. Erik has written a section on the group interview with Professor Fitzgerald and is scheduled to write sections on the history of International Building Codes in Canada and Europe as well as their importance to the project. All writing is in the rough draft stage and is not finalized.

Based on the rescheduling of the project, we are currently on schedule and with the completion of interviews feel that the project is coming together nicely and will be completed on time. The only sections left to complete are research on roof failure causes and effects, solutions and recommendations, and writing the report. Time has been allotted to gather statistics but due to the rare nature of roof failures, these statistics are hard to find. We will continue to search and are hoping that contact with Factory Mutual will help complete this. We still see an overall completion date to be somewhere in the middle of August but before the start of A term.

Appendix W: Week 7 report

Since last week's meeting, we have chosen to focus our main efforts in writing a rough draft of the final report and focusing some minor efforts in additional research as well as in possible interviews. Our main goals for this week, as stated in last week's report, was to have finished a rough draft of the Acknowledgements section and a rough draft of the history of the Canadian and European Building Codes. If possible, we would also have liked to start writing the rough draft of our interview with Joe McEvoy, the current Canadian and European Building Codes, and portions of the Methodology section. In addition to the goals set above, we were also hoping that we could come in contact with individuals from Factory Mutual (FM Global).

Of the goals we set for ourselves, the ones to have been completed are the rough draft for the Acknowledgements section, the history of the Canadian and European Building Codes, and the current Canadian Building Codes which were completed by David and Erik respectively. However, we have only completed an outline for the rough drafts concerning the interview with Joe McEvoy and the Methodology section. We have also contacted Maria Mike-Meyer, who works at WPI's Office of Alumni Relations, who helped us come in contact with individuals at FM Global.

The only problem that we faced during this week, besides the fact that we didn't get a substantial amount of writing done, was the fact that we weren't able to come in contact with Dr. Hosam Ali, an employee of FM Global who was referred to us by another employee of FM global. Ben had tried to contact Dr. Hosam Ali by email after having been given Dr. Hosam Ali's email address; however, all Ben received was an automated vacation response. David had also tried contacting Dr. Hosam Ali a few days after Ben had received the automated response; however David has yet to receive a response from Dr. Hosam Ali.

Based on what was and wasn't accomplished during this week, we are still roughly on schedule and are in good shape to finish by the designated deadline. As for next week, we hope to have at least completed a rough draft of the interview with Joe McEvoy and sections of the Methodology as well as contact with Dr. Hosam Ali if possible.

Appendix X: Week 8 report

Our goals for this week focused mostly on writing. We broke the Methodology section into three parts. David is assigned the writing about causes of roof failures, which may also require him to do some research. Erik was assigned writing of the conduction of interviews. Ben was assigned writing of our code research. Other sections that were assigned this week are the project introduction, which was written by Erik and the interview with Joe McEvoy, which was written by Ben.

Most of the assigned writing has been completed or started. We believe that we are on track to complete our writing in the next week. Sections left to assign are the results, conclusion, and executive summary.

We have still been unable to make any contacts for interviews within the FM Global insurance company. The group has decided that we can continue our project without this interview, however if we do have any response from FM Global we will work with them and possibly schedule an interview.

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