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State Building Codes and Structural Safety Provisions for Unreinforced Masonry (URM) Buildings in the Northeast States
Disclaimer

This report was compiled in collaboration between the Northeast States Emergency Consortium (NESEC) and Scott Civjan P.E., Ph.D. at the University of Massachusetts, Amherst. Conclusions and recommendations contained herein are based upon a review of published data, interviews with design and code professionals and the expertise of the researchers, and are not necessarily to be construed as official views or policy. The University of Massachusetts and the Northeast States Emergency Consortium assume no liability for its contents or the use thereof.

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I. Introduction

What is a building code?

Building codes have been in existence since antiquity as a means of protecting the public health, safety and welfare of citizens. These are legal documents containing standardized regulations and technical requirements for the design and construction of most types of buildings. In general, modern building codes contain regulations for use and occupancy classifications, height and area limitations, fire resistance and protection, evacuation, disability access, lighting, HVAC, plumbing systems, elevators, energy provisions, building renovations, encroachment outside property lines and structural components. They also include design load requirements for wind, snow, and earthquake provisions. Building codes are necessary in a developed society as a way to ensure integrity in both the design and construction of buildings, shelters, and other physical structures. In the United States, state and local governments have jurisdiction over the adoption and enforcement of local building codes. For structural design, building codes specify the loads that a building must withstand and methods to design the building to resist these loads. The purpose of building codes is “life safety”, meaning that the codes are meant to limit collapses of structures, but that damage would be expected in an extreme event. Designing to a higher performance level, such as limiting damage in an extreme event, can be achieved, but is not the intent of building codes. Building codes are applicable to structures at the time that they are built, with a building being “code compliant” even if the codes become more restrictive after the structure is constructed. Building codes can apply to existing structures if the building changes use or if a significant alteration is made to the structure. The requirement for invoking these provisions to existing buildings is not always consistent. Rarely, a mandatory retrofit to existing structures can be implemented in cases where safety of the general public is perceived to be at a very high risk.

What is a URM building?

URM stands for unreinforced masonry. These types of buildings are typically constructed from masonry (brick or block) and mortar and have no steel reinforcement or ties or connections required by modern building codes for most structures. The critical structural aspects of URMs are the poor performance of walls when loaded out of plane (transverse to the wall), unsupported members such as chimneys, parapets and gable walls when loaded laterally as in an earthquake, and large openings in walls such as storefronts. Failures typically include the loss of chimneys, wall sections, or entire wall units. Wall performance can be improved dramatically through proper attachment to the floors and roof, but this was not done in older structures or in many residential buildings in the Northeast. Instead, it is typical in URM construction for roof or floor systems to rest directly on masonry sections through blockouts, pockets or corbels. Throughout the Northeast states, URM non-residential structures can be classified in three general categories.

First are URM buildings built prior to 1950. These are the classic brick structures that are prevalent in the Northeast states. They comprise many historic downtown sections, older housing stock, mill buildings, churches and some of the older schools and essential facilities such as schools, fire stations, police stations and hospitals. Examples are shown in Figure 1.
A second group of URM buildings were constructed from approximately 1950 to 1990. Construction during this time varied widely due to the advent of new masonry construction materials such as cinder block and concrete block, either used solely or in combination with brick. In addition, some designers began to include some steel reinforcement in the masonry design. Any reinforcement included was typically prescriptive rather than designed and often included only joint reinforcement along the horizontal wall joints. More importantly, existing reinforcement was not designed for any significant lateral forces applied to the structure until the latter years of this time period and even then only in some regions of the Northeast states. Through most of the time period seismic load was not included in design codes and wind load design was inconsistent and low for moderate height structures. These URM structures comprise many strip malls, office buildings, big-box stores, and critical and essential facilities such as schools, fire stations, police stations and hospitals. Examples are shown in Figure 2.

Figure 1. Typical Pre-1950 Structures
Finally, the term URM can be applied to some post 1990 structures. These buildings are typically situated in locations of very low earthquake hazard and/or may apply to a design method where steel reinforcement is ignored in the design calculations as a means of a simplified and conservative design method. Generally, post 1990 structures are designed for modern design code loads and if constructed properly should perform similarly to other modern structures. There is no external feature to distinguish these URM from reinforced buildings constructed during the same time period. Codes adopted in the late 1980’s and early 1990’s were the first to include seismic design requirements for most of the Northeast states and initiated the current restrictions on URM construction. This provides a benchmark year of 1990 for most URM structures in the Northeast, with structures constructed prior to this year expected to sustain significantly more damage in an earthquake or hurricane load.

Of particular concern in this study is the regulation of existing URM buildings in the Northeast states. This would include most pre-1990 masonry construction. Multiple family homes and multi-story residences would have similar concerns as non-residential URM buildings, while the greatest hazard to single family homes is chimney damage.
What loads act on a building?

Buildings are designed to account for all of the possible loads that they will be subjected to over their lifetime and ensure life safety. Loads can be broadly categorized as predominantly gravity (acting vertically) or lateral (acting horizontally). Gravity loads include dead loads due to the permanent self-weight of the structure, live loads resulting from the occupancy and use of the structure and snow load. The two most common examples of lateral loads are from seismic and wind. Seismic loads are the additional loads imposed on a building during an earthquake due to the movement of the earth beneath it. Wind loads are the forces experienced by a structure due to the natural motion of the air during extreme storms. Other loads are less important to the URM portion of a structure but can include earth and water pressures, construction loads, differential temperature, blast, etc.

Wind and earthquake loads are based on an expected extreme event in the region for which the building is designed. The selection of the return period of the event such as a “100 year storm” or “2,500 year earthquake” impacts the load for which it is designed. Building codes attempt to provide a similar life-safety risk for structures. As more data is collected on the potential impact and probability of extreme storms and seismicity in the Northeast states, the loads to be applied to structures are revised in the codes, resulting in ever-evolving code design forces. Snow loads are calculated not as a result of a single storm, but as the total accumulation of snow and drifting that could occur on a building.

The careful appraisal of all of these loads is important because overestimation can unnecessarily increase the cost of construction, while underestimation can result in structural failure, high maintenance costs, resource damage, and life-safety issues.
II. Northeast Building Codes Overview

What model codes are used in the Northeast states?

Across the United States, a version of the International Building Code (IBC), written by the International Code Council (ICC), is currently used as a base code at either the state or jurisdictional level. The ICC is a private, non-profit organization that has been developing widely accepted building codes since 2000. The ICC also develops the International Existing Building Code (IEBC), the International Fire Code (IFC), and the International Residential Code (IRC), that many states have elected to adopt. The IBC applies to almost all types of new buildings. The IRC applies to new one and two family dwellings and townhomes of not more than three stories in height. The IEBC applies specifically to the alteration, repair, addition, or change in occupancy of existing structures. Existing buildings are also included in Chapter 34 of the IBC through the 2012 edition. However, the requirements are different from the IEBC with some states adopting one over the other and other states allowing either to be used where typically the least restrictive is chosen.

Beyond these, the ICC develops publications regarding issues such as plumbing, energy conservation, green construction, and more. All of these model codes rely heavily on referenced standards published by other organizations such as the American National Standards Institute (ANSI), the American Society of Civil Engineers (ASCE), the American Society for Testing and Materials (ASTM), and the National Fire Protection Agency (NFPA). The ICC publishes new editions of the International Codes every three years.

The Northeast states have generally adopted the ICC model codes as the basis for their state codes. However, the adoption process, amendments to the codes, and differences in provisions for existing buildings (which applies directly to URM structures) varies widely. Table 1 outlines the edition of the base codes on which each Northeast state currently bases their state code (for more information, visit www.iccsafe.org and state specific links found in Section VIII). The codes listed in the table are either adopted directly, are subject to state specific amendments, or are published as a state specific version of the ICC code. Most of the Northeast states have their own state documents amending the standards of the ICC.

Three exceptions to adoption of ICC codes related to existing URM buildings are the New Jersey, New York City and Rhode Island Rehabilitation/Existing Building Codes. The New Jersey and New York City versions are completely independent from the ICC codes (pre-dating them as well) while Rhode Island allows either the state code or ICC to be followed. Overall, these are much less restrictive than IEBC existing building requirements.

State building codes are adopted state wide with the exceptions of New York and Maine. New York City and New York State historically developed independent building codes. They were seen as having very different building inventories, construction methods, safety issues and development to address and have therefore maintained separate codes. New York State has adopted ICC codes similar to other states and New York City maintains their own independent codes. In Maine there is an exception that the State Building Code does not apply to any community of 4,000 people or less. This accounts for approximately 1/3 of the state population residing in communities where the State Building Code is not legally required. Individual towns are therefore allowed to independently adopt the State Building Code, ICC or other codes,
or forego building codes altogether. Maine State Building Code committees are currently in the process of documenting the resulting practice throughout the state.

While it may appear from Table 1 that some states are behind others in adopting ICC codes, this is not the case. Most states do not adopt the ICC codes each time that they are updated on a three year cycle. Each state has committees to review changes in the codes, evaluate against their existing codes, propose amendments which are subject to public meetings and voting, and finally submit to the legislature for approval of code adoptions and amendments. This is a time consuming process and is not taken lightly. States currently adopting the 2009 or earlier versions are on track to adopt the 2015 ICC codes, whereas those adopting the 2012 version are expected to adopt the 2018 version. States using pre-2009 versions should generally work toward shortening their adoption schedules.

It is noted that the existence of state wide building codes is relatively new in the Northeast states, with most being adopted post 1975, as recently as 2005.

<table>
<thead>
<tr>
<th>State</th>
<th>Version of International Code Adopted</th>
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<tbody>
<tr>
<td>Massachusetts</td>
<td>IBC 2009</td>
</tr>
<tr>
<td>New York City</td>
<td>IBC 2009</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>IBC 2012</td>
</tr>
<tr>
<td>Vermont</td>
<td>IBC 2012</td>
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Table 1. Northeast States and versions of each section of International code adopted

How are the codes enforced?

Regardless of the codes that are adopted, the provisions are only meaningful if properly enforced. Code enforcement is generally the responsibility of the local government's building official(s) who review design plans, inspect construction work, and issue building and occupancy permits. The most effective codes are those that are both up to date and widely adopted and enforced. Problems with enforcement generally stem from recurring issues: staffing, understanding of the codes, historical practice, perceived responsibility, and varying levels of inspection.

Staffing can be a major issue in rural areas, where there often is no local building official. The responsibility can then fall to a state official who cannot realistically inspect structures throughout the remote portions of the state. The Maine building code exception for communities of 4000 persons or less is a realization of this limitation and does not necessarily indicate any difference in code adherence to other rural locations.
throughout the Northeast states. It is also a significant problem that building code officials are responsible for a wide scope of work and cannot be expected to be an expert in every area. Some states have adopted Construction Control documents in which the Engineer of Record needs to approve that the structure was constructed (new or work on an existing building) in accordance with their intent. This is very advantageous in theory by providing inspection by those with expertise but has its own potential problems. In this method the engineer needs to accept the responsibility for inspection, a fee structure needs to be in place to account for the added workload and a clear authority must be delegated to the inspector to stop construction and require changes in accordance with the design. The long history of typical practice in a region can be difficult to overcome, especially with regard to seismic design which was not even considered in most Northeast states pre-1990 and has seen changing requirements since then. The fact that structures constructed in the past 50 years are still standing does not indicate that they are safe in a rare, but possible, event that has not occurred in this time (seismic or wind). However, past performance can lead to regional resistance to these design provisions. Inconsistent interpretation of code provisions in a region can also lead to pressure on building officials to adhere to the least restrictive interpretations. The perceived responsibility of the building official can make a large difference, with many anecdotal references to higher quality construction in specific areas of a state due to enforcement policies by the local building officials. Varying levels of inspection and penalties for non-compliance can lead to varying levels of building safety. Anecdotal discussions of work on post-1990 existing masonry structures that uncovered missing reinforcement or improperly grouted cells indicates that in some areas the standard practice of masonry structures may not be fully compliant with the code. This may be more prevalent in residential construction using prescriptive designs where an engineer and architect are not involved.

What other considerations are there for existing buildings?

Code committees have struggled with the requirements for work on existing buildings. It is the intention that any building that is constructed according to the code in place at the time construction is code-compliant. The opportunities for updating these structures are generally only considered when a major alteration, repair, addition, or change in occupancy occurs. The need for upgrading the structure is invoked by specific “triggers” depending on the code and these have varied historically. The triggers and requirements vary by code (IBC Chapter 34, IEBC and State Rehabilitation/Existing Building codes) with the IEBC having three “Alterations Levels”, each with increasing compliance requirements. The triggers can be due to a higher occupancy category (higher risk to human life), amount of square footage affected by the work (as a percentage of the total structure), cost of the work (as a percentage of the total cost of the structure), or additional forces imposed on structural members. When invoked, existing building provisions may require upgrading the existing structure to new construction standards (IBC Ch. 34), require design of the existing structure to a reduced seismic load (IEBC), or require some general prescriptive provisions (such as tying back parapets and walls to the floors and roof).

URM buildings constructed prior to 1990 would not meet current code. It is generally cost prohibitive to upgrade them to existing code provisions, meaning that it would be more cost effective to replace the building but the owner would often not have funds to do either. Therefore, most URM building stock is not modified, or modified within a scope of work to not invoke the seismic design provisions, such as by isolating an addition or minimizing the limits of an alteration.

There are many other factors at play when existing buildings are considered. For example, the IEBC has a provision where re-roofing a URM structure would invoke bracing of the parapets. It is seen by the IEBC
that this is the most cost-effective time to include this upgrade. However, some Northeast states have over-
ridden this provision, from the perspective that owners would then find it too expensive to re-roof and
subsequent moisture related roof deterioration could lead to the potential for roof collapses under snow
load. Other local code committees have decided that IEBC provisions were too restrictive and would stall
development of existing URM inventory so have avoided adoption of the IEBC.

These economic and practical issues must also be balanced with the potential economic and life safety
losses associated with a possible seismic event. In an area where the downtown is predominantly URM
construction the effects of a seismic event could include the loss of historical infrastructure, high cost to the
local economy, impacted function of essential facilities and life safety issues. These factors could
overshadow short term economic impacts of retrofit and strengthening of URM buildings. Overall, finding a
balance between the safety of new construction, promoting economic vitality and development,
encouraging upgrading of vulnerable structures and understanding the risk of extreme events and potential
for collapse in these events is something that all Northeast states have addressed through their own paths
and explain some of the code differences throughout the region.

Existing URM structures pose a much higher risk to both human life and economic loss than new structures
under extreme load events. However, it is difficult to balance these risks against the political and economic
considerations due to a very low perceived risk by the public.
III. Loads in the Northeast states: snow, wind and seismic

There is historical data of extreme events related to snow, wind and seismic throughout the Northeast states. Each state has amended the IBC (which references ASCE-7) to provide local snow, wind and seismic loads. Although provided through amendment, these loads are generally direct values obtained from the IBC requirements in tabular format with the exception of snow load as noted. For each of the Northeast states, wind, snow and seismic load data was compiled in Figures 3 through 6. This data was either given by each individual state’s amendments to the building code or by ASCE’s national database (as referenced in the International Building Code). ArcGIS was used to display the data.

High accumulation snow events can result in roof collapses which are often common in severe winters throughout the region. Despite the fact that most of these collapses are due to deteriorated materials and poor design or detailing, the relatively frequent occurrence of these failures keeps the risk high in the minds of designers and the public. To prevent these failures, many of the Northeast states have adopted higher minimum snow loads than required by the IBC. In addition, over several of the northern parts of the Northeast states (ME, NH, NY, VT) the local extremes of snow load and variation regionally require case studies per the IBC. Data from these case studies are available from local Building Officials and are typically included in state amendments, though in Maine values can be found by contacting the local official as indicated in Figure 3. As shown in Figure 3, the white spaces in Maine indicate case study regions, areas where site-specific data is required to establish ground snow loads not provided in state amendments. Extreme local variations in ground snow loads in these areas preclude mapping at this scale. There appear to be some discrepancies in snow load along the borders between Vermont and neighboring states. Also, Massachusetts’ snow load standards look to be higher than those in surrounding areas. These discrepancies appear to be attributable to state adoption of minimum snow load requirements and the consideration of site specific data that was adopted.

In general, there have been hurricanes and Nor’easters in the region within the memory of most designers and the general public. Major events in the Northeast states have included hurricane and storm damage include the 1938 Hurricane “Long Island Express”, 1954 Hurricanes Carol and Edna, 1985 Hurricane Gloria, 1991 Hurricane Bob, 2011 Hurricane Irene and 2012 Superstorm Sandy. The recurrence of these events has maintained a dialogue and awareness of wind damage (especially along coastal regions) and flood damage throughout the region. Wind load provisions shown in Figure 4 are generally a direct adoption of IBC provisions, resulting in wind loads that are consistent across state borders, with higher results for wind loading in coastal areas. While Rhode Island values appear significantly higher, this is due to a change in the way that wind speeds are reported in the 2012 IBC that Rhode Island and Vermont have adopted. In the 2010 version of ASCE-7, the design concept was changed for wind, where the extreme event is considered, rather than a more common event that was factored up in the design provisions to the equivalent of an extreme event. Therefore, all mapped values from 2012 IBC into the future will be approximately 1.6 times the previous values, but the resulting design wind forces will be unchanged (load factor has changed from 1.6 to 1.0). It does appear that Long Island’s wind loads are slightly lower than surrounding regions.
Figure 3. Snow Loads for Northeast States

Figure 4. Wind Loads for Northeast States
Earthquakes occur much less frequently than extreme snowfall or storms in the Northeast states, but still have a historical and geological basis for design considerations. Significant Earthquakes in the region have included events in 1638 (M6.5 Central New Hampshire), 1663 (M7.0 Charlevoix, Quebec), 1727 (M5.6 Newbury MA), 1737 (M5.2 NYC), 1755 (M6.0 Cape Ann MA), 1884 (M5.2, NYC), 1887 (M unknown Northeastern NY), 1912 (M unknown ME), 1925 (M7.0 (estimated) St. Lawrence River Valley Canada), 1927 (M unknown, NJ), 1929 (M unknown Attica NY), 1940 (M5.8 Lake Ossipee NH), 1944 (M unknown Northern NY), 1983 (M5.3 Blue MT Lake, NY), 1994 (M5.9 Eastern ME), 2002 (M5.1 Au Sable Forks, NY). All magnitude values (M) from historic events are approximate based on reported damage. Magnitudes of several of these are unknown due to lack of measurements and accurate accounts, but were noted to have caused damage in the area. A more recent example of a similar scale earthquake would be the 2011 Virginia earthquake (M 5.8) which caused some damage locally and over a very wide area, including significant damage to the National Monument in Washington DC, which is the tallest URM structure in the world.

Load on a building due to the earthquake ground shaking has many factors. The basic concept is that Force=Mass x Acceleration. Therefore, more force develops in a heavier structure with significant mass and in one that shakes at a higher acceleration. However, the acceleration in a building is not the acceleration of the rock at the site, but instead is a combination of effects including the characteristics of ground shaking, the soil properties, and the characteristics of the building. Figures 5 and 6 show 0.2 second spectral response acceleration and 1.0 second spectral response acceleration for the Northeast states, which are values used in design calculations. These values are used to analytically predict the expected structural acceleration experienced under the risk adjusted maximum considered earthquake in the region. Mapped accelerations are based on a rock site (Soil Classification B), while increasingly softer soil conditions (C, D, E or F) amplify these values. Figure 7 shows approximate soil designations for the Northeast states based on topographic slope data (which may de-emphasize very soft and hard soils). It can be seen that many densely populated areas have soil Classification D which would see significantly higher ground shaking than a rock site. Specifically, many older urban areas such as Boston, New York City and Portland Maine have significant areas of non-engineered fill land that further amplifies the ground shaking and may require site specific evaluation. URM Buildings founded over this type of historic filled land would be expected to sustain significant damage from a large earthquake. Another issue in the Northeast states is that, while expected earthquakes are much lower magnitude than in a high seismic zone, they are felt over a much wider region.

Figures 5 and 6 display minor discrepancies among states when it comes to spectral response acceleration at 0.2 seconds (RI has slightly lower values) and 1.0 second (CT values appear higher). The 0.2 second map nicely displays the epicenters of some earthquakes that have occurred in the Northeast states as were previously noted. There are some differences from IBC provision adopted by states that have caused discrepancies. Updated data and analysis resulted in a decrease in mapped ground motions in the 2010 ASCE-7 maps (USGS maps) compared to the previous version. This means that states who have adopted the 2012 IBC have this included in their maps. Several other states, though not yet using the 2012 IBC, have adopted these new ground motions in the state amendments to the IBC code that they are using. This means that all states are using the 2012, or slightly more conservative previous ground accelerations for design. The newest USGS Seismic Hazard Maps, released in 2014, suggest a slight increase in seismic hazards in parts of the northeast. It is unclear at this time if this increase will result in changes to seismic design loads when ASCE releases its updated maps in 2016.
Figure 5. Maximum Considered Earthquake Ground Motion for Northeast States, of 0.2 second Spectral Response Acceleration (5% of Critical Damping)

Figure 6. Maximum Considered Earthquake Ground Motion for Northeast States, of 1.0 second
Spectral Response Acceleration (5% of Critical Damping)

**Figure 7.** Soil Type in Northeastern States Determined from Topographic Slope Data
IV. URM Hazards

URM buildings are the most likely structure to be damaged in an earthquake, but can also experience significant damage in severe storms. URM is designed for vertical load, but does not have connection to the floor and roof systems which can lead to failures of areas of brick or entire wall sections. Masonry is a material that is very strong in compression, but has very little resistance to tensile load which occurs in the case of a significant lateral load or uplift in an earthquake. Reinforcing these buildings with steel, which is very strong in tension, adds strength and stability to the building (reinforced masonry design). The hazard posed by URM buildings can be greatly reduced by retrofits to the structure.

Common failures of URM include collapses of chimneys and parapets and walls peeling away from the structure, often initiated at parapet or gable failures. These can lead to collapses of the building, but are also a life safety hazard as the heavy masonry materials fall onto the adjacent sidewalk and street.

Hurricanes are rated on the Saffir Simpson Scale, ranging from Category 1 (weakest) to Category 5 (strongest). Significant storms making landfall in the Northeastern states have been Category 2 or 3, with several listed in Section III. This intensity scale is often published with expected damage. Specific to masonry the following are noted

Related to masonry the MMI states:

VII: “Damage... considerable in poorly built... buildings”, “cracked chimneys to considerable extent, walls to some extent.” “dislodged bricks”

VIII: “Damage slight in structures (brick) built especially to withstand earthquakes, Considerable in ordinary, fall of chimneys”

IX: “Damage considerable in (masonry) structures built especially to withstand earthquakes, great in substantial (masonry) buildings, some collapse in large part”

X: “Destroyed most masonry structures”

XI: “…few, if any (masonry) structures remain standing”
XII: "...practically all works of construction damaged greatly or destroyed"

The Northeast states have experienced M5.8 to M5.9 in the last century with events between M6.0 and M7.0 in the past 400 years (MMI rankings from VII to VIII). Several of these were noted in Section III. Reports from these historical earthquakes consistently noted damage to URM structures, including damaged and toppled chimneys (over 1600 collapsed in the 1755 Cape Ann MA earthquake), falling bricks, and some isolated URM wall failures. However, the larger historic earthquakes often occurred in rural areas that were sparsely populated at the time. The extent of damage is expected to be considerably greater in populated areas with the current infrastructure. A more recent example of a relatively frequent earthquake is the 2011 Virginia earthquake (M 5.8) which caused some damage over a very wide area. In this earthquake the majority of collapsed buildings and damage was noted in older URM structures in Virginia, Maryland, Delaware and Washington D.C. Note that the magnitudes of earthquakes experienced in the Northeast are comparable to those that led to complete re-defining of earthquake risk in California (1925 Santa Barbara M6.2, 1933 Long Beach M6.3 and 1971 San Fernando M6.6). These specific earthquakes led to the first modern building code on seismic design, the “Field Act” and “Riley Act” (these included specific design requirements for school buildings) and the development of masonry design provisions for earthquake load. The 2014 South Napa Earthquake (M6.0), though in California, showed significant differences in performance between URM structures that were retrofit and those that were not. Severe structural damage was generally concentrated in URM and other older structures.
V. Provisions for URM buildings in the Building Codes

For new building construction northeast, states are using versions of the IBC codes. For these, URM is only allowed in circumstances of very low seismic load on very good soils. For these cases, wind loads will likely control a design and the designer would only allow URM for very low material stresses. These new codes would still require continuity to floors and roof so would be considered to be designs that would perform well for expected loads. Residential construction has fewer masonry reinforcement requirements, but is still considered adequate under new construction. The main concern in these buildings would be chimneys and inspection to ensure that masonry is indeed reinforced as intended.

URM hazards are of concern in existing buildings throughout the region. The combination of deteriorating materials (mortar) and original designs that often only considered gravity loads leave these structures vulnerable to wind and earthquake loads that have historical and calculated basis for future occurrence. Most Northeast states did not have mandatory building codes until 1975 through 2005, with most states not considering earthquake loads in design until around 1990. Code requirements for existing buildings are not consistent, requiring either Chapter 34 of the IBC, the IEBC, or state and city specific Rehabilitation codes. Where the IEBC has been adopted, it is often subject to specific state amendments reducing URM structure requirements. Amendments can include exemptions for historic structures and exemptions for some triggers for parapet bracing.

Within the IEBC and general practice, it is accepted that additions to existing structures should meet new code requirements, but that alterations must be significant to invoke any upgrades to the building. Justification of this policy is based on balancing the economic realities of promoting development while not requiring closure of existing buildings due to expensive retrofit costs, when the structure met the code requirements at the time of construction. Current code triggers for upgrading an existing structure are based on alteration as a percentage of total floor area or increased forces within structural members. In the past triggers have also been based on alteration cost as a percentage of total assessed value of the property. The IEBC includes three levels of alterations, with increasing URM requirements from Level 1 to Level 3 which correspond to increasing amounts of work on the building. Appendix A of the IEBC is focused on seismic URM upgrades while Appendix C focuses on roof connections in strong wind areas, both of which are very good overviews of retrofit measures. IEBC requirements are in general more specific with regard to URM and focus on continuity of the structure, but are designed to resist reduced seismic forces from the IBC. However, the wide variation in state existing building requirements and amendments results in wide variations in URM upgrade requirements.

Unless an alteration or addition project is substantial the IBC, IEBC or state codes require no changes to existing URM buildings. The stepped cost of triggering an IEBC alteration Level 3 is typically avoided when possible by limiting alterations to below the respective triggers, as would also be the case in other codes. This is effective in limiting additional risk from URM structures, but does not decrease existing risk posed by existing URM buildings. It is generally acknowledged that the intent of these codes is to address new construction of a substantial nature, not to retroactively upgrade existing infrastructure.
VI. Mitigation Strategies

Beyond the enforcement of building codes, there are other ways to mitigate the hazards posed by the environment on our structures in order to increase their safety and avoid destructive and or fatal collapses. These can include structural and non-structural mitigation strategies. By taking active steps to lessen the impact of disasters before they occur, mitigation reduces the loss of life and property endured by affected communities. Links to reports or web pages that describe some general mitigation strategies for primary hazards outlined in this report include:

a. Snow
   i. FEMA Snow Load Safety Guide – http://www.fema.gov/media-library-data/7d8c55d1c4f815edf3d7e7d1c120383f/FEMA957_Snowload_508.pdf

b. Wind

c. Seismic

d. General
VII. Conclusions and Recommendations

The proper development, use and enforcement of building codes are crucial for the safety of society and sustainability of the nation's infrastructure. The Northeast states all have an ongoing cycle of evaluation and adoption of IBC provisions for new buildings. Masonry buildings built prior to 1950 are URM and include designs that would not be acceptable per current codes. Masonry buildings built between 1950 and 1990 are expected to have a significant variation in detailing, but in general will include a large percentage of URM structures which are expected to perform only marginally better than earlier structures. Masonry buildings that included reinforcement during this period may still not have the critical vertical reinforcement or proper grouting to ensure performance significantly better than URM structures. Modern, post 1990 structures have been designed to modern building codes with lateral load and reinforced masonry design provisions. However, code enforcement is critical to ensure that these structures perform as intended.

URM hazards are predominantly within the existing building infrastructure. Building codes do not focus on reducing the existing building inventory risk unless major re-use or alterations are done to these structures. Reduction of the risk to existing structures in the Northeast states is voluntary and rarely invoked due to economic constraints.

Ensuring that masonry construction standards are met is essential. Education of building code officials, architects, engineers, contractors, elected officials, owners and the general public is critical to ensure that new designs and significant alterations of existing structures meet the intent of building codes. Understanding the purpose of tying masonry elements, such as chimneys and walls, to floor systems, the critical need of properly placed and grouted reinforcement to ensure reinforced masonry performance, proper workmanship and the potential for hurricane and seismic load in the Northeast states are all essential for avoiding hazards posed by URM buildings.

State and local governments should consider identifying, inventorying and inspecting existing URM buildings within their jurisdictions and developing programs and strategies to retrofit them to current standards. While it is unrealistic to expect that all structures would be retrofit, a prioritized list of critical and essential structures such as fire stations, police stations, emergency operations centers, hospitals and schools should be developed. Regional discussion of hazards related to the URM infrastructure throughout the Northeast states should be promoted. The Northeast states should work to develop consistent regional policies, a focused message and expand their influence on international code development committees.
VIII. Additional Resources

For more information or to learn more, please look at the following links to the text of the international building codes referenced in the report, specific state building code information and amendments, and other information on URM and loads including some of FEMA’s (Federal Emergency Management Agency) resources about URM Buildings and building codes.

Building Codes and information
- ICC pages and bookstore - http://www.iccsafe.org/

Northeast state code adoption and amendments
- Rhode Island State Building Code - http://sos.ri.gov/library/buildingcodes/

URM hazards
- FEMA 396 Incremental Seismic Rehabilitation of Hospital Buildings - https://www.fema.gov/media-library/assets/documents/5167
• FEMA Guidebook for State Earthquake and Mitigation Managers - https://www.fema.gov/media-library/assets/documents/564?id=1421

Load information
• Structural Collapse from Snow Loads - http://www.structuremag.org/?p=5301
• National Snow Load Information - http://www.fs.fed.us/t-d/snow_load/
• USGS Earthquake Hazards Program - http://earthquake.usgs.gov/