ZALLEN ENGINEERING

COMMENTARY ON THE STRUCTURAL PROVISIONS FOR EXISTING BUILDINGS IN THE 7TH EDITION OF THE MASSACHUSETTS STATE BUILDING CODE

by Rubin M. Zallen, P.E.[1]

June 29, 2009

The structural provisions for alterations, repairs, or additions to existing buildings or for their change of use is contained in Section 3408 of Chapter 34 of the Massachusetts State Building Code. These provisions were devised by The Joint Loads and Seismic Advisory Committee on Existing Buildings of the Massachusetts State Board of Building Regulations and Standards (the Joint Committee), and adopted by the Board for the 7th Edition of the State Building Code. These provisions apply to all building construction, except one or two-family detached houses, which are governed by a separate code. The following is an explanation of the major aspects of the provisions.

Current State of Existing Buildings

A substantial portion of the building stock in Massachusetts was constructed since the late1800s, prior to the inception of modern building codes starting around 1945. Most of these buildings were not engineered and many of them have little or no lateral load resistance. These buildings will probably collapse in a significant earthquake (strong shaking of the ground) causing extensive loss of life. Many of these buildings have masonry walls and parapets that could fall from the buildings if they did not collapse, which would also cause extensive loss of life.

Since 1945 but prior to the inception of the State Building Code in 1975, many modern local building codes were promulgated, notably in the Cities of Boston, Cambridge, and Worcester; however most municipalities in the Commonwealth did not have a modern building code until the inception of the State Building Code in 1975. Many of the buildings built between 1945 and 1975 were not engineered and many have little or no lateral load resistance. The same as for pre 1945 buildings, many of these buildings will also collapse in a significant earthquake.

Basic Principles for Section 3408

It is universally accepted in the construction industry that an existing building cannot be treated the same as a new building when the existing building is being altered. It is not

[1]Principal, Zallen Engineering, 1101 Worcester Rd, Framingham, MA 01701; Chairman, Joint Loads and Seismic Advisory Committee for the Structural Provisions for Existing Buildings, Massachusetts Board of Building Regulations and Standards; Tel: 508-875-1360; email: rmzallen@zallenengineering.com.

generally practical to require the existing building to meet all the structural code requirements for new buildings, particularly those for seismic design. Thus a philosophy on addressing the structural issues of existing buildings was devised for the 6th Edition of the Code and has been carried forward for the current 7th Edition of the Code. The philosophy is embodied in a set of basic principles, as follows:

1. Many old buildings do not have complete load paths to the foundations for lateral load, meaning that they have little or no lateral load resistance.

2. Old buildings have deteriorated over time and many lateral load resisting elements in these buildings have been removed or modified.

3. Allowing a rehabilitation or renovation to these buildings (i.e. allowing a continuation of their use) without a structural upgrade is a danger to the public safety.

4. All buildings should have a minimum lateral load resistance to protect the public safety.

5. To the extent reasonably possible, buildings should have structural systems and details that provide good structural behavior during an earthquake, to increase their survivability.

6. Masonry walls and parapets need to be adequately tied to floors and roofs to prevent them from falling from the structure during an earthquake, and those with inadequate proportions need to be braced or reinforced.

7. The greater the changes to a building, the greater should be the lateral load resistance required and provided.

The implementation of these principles in Section 3408 are discussed below.

Minimum Lateral Load Resistance

The minimum lateral load that buildings need to resist is 2/3 of the wind load required for new buildings, and, nonconcurrently, a lateral load equal to 1% of the sum of the building dead load and ½ of the snow load required for new buildings.

The Joint Committee believes that most good buildings have the ability to resist, or can be readily and economically reinforced to resist, the just described minimum lateral load. This minimum lateral load resistance is no guarantee that buildings closest to large ground shaking will not collapse; however, other buildings nearby with the minimum lateral load resistance will have a chance to survive without collapse, although they may not be reusable.

Classification of Existing Buildings

The inception date of the state-wide Massachusetts State Building Code was January 1, 1975. All structures in Massachusetts since January 1, 1975 have been required to have robust wind and seismic resistance. However, as described above, buildings built prior to this date were built under various local codes or no code at all; many of these codes have no lateral load resistance requirements or have requirements that are inferior to modern day codes. Thus existing buildings in Section 3408 are classified for structural purposes as *Pre-1975* and *Post-1975*.

Since it is expected that all Post-1975 buildings will have robust lateral load resistance, Post-1975 buildings are assumed to meet minimum lateral load requirements if the lateral load resisting systems are unchanged during alterations or repairs. Thus certain criteria for Pre-1975 buildings do not apply to Post-1975 buildings, making it easier for the structural engineer, architect, and owner to deal with the structural requirements when making alterations to Post-1975 buildings.

Levels of Work

All structural work on existing buildings is assigned a level of work in relationship to the extent of the work performed, consistent with Basic Principle No. 7, stated above. The levels of work and a generalized description of each are given in Table 1.

TABLE 1 - LEVELS OF WORK

Level 1	Work that is not classified as Level 2 or above. Mostly minor structural work. No lateral load requirements. In Post-1975 buildings, extensive work can be classified as Level 1 if it does not affect the lateral load resisting system.
Level 2	Work involving a significant amount of rehabilitation or remodeling, or alterations or repairs that involve low to moderate amounts of structural work. Additions comprising a low percentage of existing total framed floor and roof area, or weight, are permitted. Minimum lateral load resistance must exist or be provided.
Level 3	Alterations or repairs that involve extensive structural work.
Level 4	Structurally attached additions.
Level 5	Extensive changes or additions: removal or reconstruction of a major percentage of the existing building, or structurally attached additions that increase the size or weight by more than 100%.

Level 2 Work

The psychological barrier for developers and owners is going from Level 1 Work to Level 2 Work, since the latter in many cases requires structural reinforcement of some kind, and creates fear that the resulting expense will make their project unprofitable. The Joint Committee spent much time and effort in devising the triggers for Level 2 Work to

mitigate these fears but to also provide a reasonable minimum lateral load resistance to protect the public safety.

The most important trigger for Level 2 Work is the requirement for alterations to Pre-1975 buildings to be classified as Level 2 Work "when rehabilitation or remodeling is accumulated over a floor area of 20,000 sf or 50% of the total floor area of the building, whichever is less, starting from July 1, 2008." The trigger is intended to have as broad an effect as is reasonably possible. The 20,000 sf threshold is for large buildings and represents a significant financial investment in what could be a structurally unsafe building; the 50% threshold is for small buildings and represents a significant investment relative to building size. If owners want to continue the use of such buildings, then they are required (and should be required) to perform Level 2 structural work to protect the public safety.

For Post-1975 buildings, the just mentioned trigger does not apply. As long as there is no significant alteration to the structural system of these buildings, extensive interior architectural work can be performed under Level 1. An example of this situation is the cutting of openings for communicating stairs between floors of a high rise building.

Level 2 Work is required if there is a change in use for more than 35% of the total existing floor area.

Level 2 Work is required if there is an increase in total framed floor and roof area; however this increase is limited to 10 %, beyond which Level 4 Work is required. Level 2 Work is also required if there is an increase in the weight of the building of more than 2% for one-story buildings and more than 1% for multi-story buildings; however this increase is limited to 10 %; beyond which Level 4 Work is also required. These small increases allow for the construction of loading docks, stairway entrances, and mechanical penthouses, while keeping the necessary structural work within Level 2 requirements.

There are a number of structural triggers for Level 2 Work, but these involve substantial changes to the structure. Examples are structural work involving more than 25% or 20,000 sf, whichever is less, of the area of any existing framed floor or roof; changes to shear walls that reduce their in-plane shear resistance by more than 15%; and removal or reconfiguration of lateral load resisting frames, or foundations supporting them.

Most well designed Pre-1975 buildings will not require more structural work than the tying of masonry walls to floors and roofs to meet the minimum lateral load resistance. However, in some cases additional shear walls or braced frames may be required. An example of the latter is a long narrow mill building which may need new intermediate shear walls or braced frames to resist lateral load in the transverse direction.

Of interest in this discussion are masonry wall buildings that were constructed with wide openings at the 1st story for store fronts. Where there are wide piers between the openings in the planes of the walls, they, in many cases, will be able to resist the in-plane shear of the minimum required lateral loads; the resisting mechanism is sufficient gravity load on the piers to keep the line of action of the gravity loads within the width of the piers.

Level 3 Work

Level 3 Work is triggered when there are extensive structural alterations, usually required when there are substantial changes to the interior of the existing building. This level of work is triggered when 15% to 40% of the total framed floor and roof area is removed or reconstructed, or where new shear walls and braced frames are required and provide more than 35% of the required lateral load resistance.

Although more structural work may be required for Level 3 than for Level 2, there is usually no cost penalty, since there is usually extensive demolition and the structure is opened up and much more accessible than for Level 2 Work.

Level 4 Work

There are two types of additions to existing buildings: structurally separate additions and structurally attached additions. Structurally separate additions are treated as separate buildings for structural purposes and must meet the code requirements for new construction. This simple requirement poses no practical burden on designers, contractors, or owners.

The requirements for structurally attached additions are addressed in Section 3408, and these requirements apply to the structure-as-whole, the existing building and the addition acting as a single structure. In the past, many engineers viewed code requirements for additions as applying to the addition only, ignoring the effects of the attached existing building. This is illogical structurally; the existing building and the addition must be treated as a whole for lateral load analysis and design.

Section 3408 contains special provisions for buildings designed for additional stories in the future. If the additional stories are added within 15 years of the original date of permit, the edition of the State Building Code in effect for the original building (the 5th or 6th Edition) can be used for the design of the additional stories and their effect on the building as-a-whole. If designed according to the 5th Edition of the Code, additional requirements may apply.

Lateral Load Requirements

The minimum lateral load for Level 2 Work was described above. In addition, for Level 2 Work, and also for Level 3 Work and Level 4 Work, the building must resist the code wind load (if any) at the time the building was originally built, and for Post-1975 buildings, must resist the code seismic loads at the time the building was originally built.

Level 3 Work requires a minimum lateral load resistance equal to the full code wind load required for new buildings and 35% of the seismic load required for new buildings. Seismic design must comply with the code requirements for new construction, but Section 3408 contains modified criteria for seismic resisting systems not permitted for new construction (3408.10). Generally, the order of magnitude of the required load will be similar to that required for Level 2; however, the invoking of the seismic design criteria for new buildings will lead to an arrangement of lateral force resisting elements that will efficiently resist earthquakes, increasing the survivability of the buildings when subjected to seismic load.

The requirements for Level 4 Work are similar to those of Level 3, except that the percentage of full code seismic load that must be resisted ranges linearly from 50% to 100% for 10% to 60% increase in total framed floor and roof area, or 10% to 60% increase in building weight, respectively. As stated above, these loads are applied to the structure as-a-whole: the original existing building and the structurally attached addition, acting together.

Level 5 structural work requires wind and seismic resistance which are in full compliance with the code requirements for new construction.

Structural Engineering

Although many owners speculate as to the extent of the required structural work for existing buildings and its costs, they cannot realistically know what the extent of the work and its costs may be until they engage a structural engineer to determine what structural work is required. Every existing building is unique; the structural work that needs to be done and its cost will be different for each building. For most buildings, the structural engineer can make a preliminary study to give the owner an approximate scope of work that may be required to meet the minimum lateral load requirements for Level 2 Work

Section 3408 provides specific requirements for structural investigation of existing buildings. For Level 1 Work, the only investigation required is in the areas where there will be structural work.

For Level 2 Work, the entire building needs to be evaluated for deterioration, for existing lateral load resistance, and for the structural work that is required to provide the minimum lateral load resistance. No geotechnical or foundation investigation is required if there is no indication of settlement or lateral movement of the foundation, there are no new shear walls or vertical frames, and any added gravity load does not increase the load on any foundation element by more than 10%.

The requirements for structural investigation for Levels 3, 4, and 5 Work are more comprehensive.

Restricted Uses

A building is generally considered hazardous based on a combination of two factors: the hazard of the use itself, and the hazard created by the number of people who will occupy the building at any one time. For the purposes of structural work on existing buildings, the uses and occupant load in Table 2 are considered hazardous. The classification of the uses is defined in Chapter 3 of the Code (except for Seismic Use Group III, which is defined in Chapter 16, Section 1614). Level 2 Work is permitted for restricted uses, but all work beyond Level 2 must comply with the requirements of Level 5; i.e., the building must be designed and retrofitted so that it can resist full code wind and seismic loads.

A change of use of an existing building to a restricted use is not permitted unless the structure complies with the requirements for Level 5 Work.

Seismic Resistance

Underlying much of the thinking of the Joint Committee was the concept of improving the seismic behavior of existing buildings to the

TABLE 2 Restricted Uses		
Classification	**Abbreviated Description**	**Occupant Load Greater Than:**
Assembly A-1 and A-2	Theaters, concert halls, motion picture theaters, banquet halls, restaurants	600
Assembly A-3	Lecture and assembly halls, gymnasiums, libraries, and all other assembly uses not classified as A-1, A-2, A-4, or A-5	1200
Assembly A-4 and A-5	Arenas and Stadiums	600
Hazardous H	All hazardous classifications	0
Institutional I-2	Hospitals and nursing homes	400
Institutional I-3	Prisons and detention centers	0
Seismic Use Group III	Buildings which must remain operational after an earthquake	0

extent that it is practical, although the required lateral load capacity in many cases will be less than what is required for new buildings.

Some of the requirements in Section 3408, intended to improve seismic behavior are:

- For buildings with wood floors or roofs or similar flexible diaphragms, requiring in each direction a minimum of two lines of shear walls or vertical steel frames, one on each side of the building located as remote as practical from the other, to reduce torsion of the building about a vertical axis during an earthquake.

- For Levels 3, 4, and 5 Work, requiring an arrangement of structural elements, and seismic details, in conformance with the seismic requirements for new construction, (as discussed above), so that buildings will efficiently resist earthquakes, increasing their survivability.

- Providing lateral drift control due to seismic load on Pre-1975 masonry walls and reinforced concrete moment frames, so that the masonry walls and moment frames can safely support the gravity loads imposed on them during and after an earthquake.

- Requiring masonry walls to be connected to floors and roofs to provide a path of resistance for the transverse seismic loads imposed on the walls due to their own weight.

Unreinforced Masonry Walls

Unreinforced masonry (URM) walls represent a substantial part of the value of many Pre-1975 buildings and their use is permitted to continue in Section 3408 regardless of the level of work, but with certain conditions. Requirements for maximum height-width ratio have been discussed above; other conditions are discussed below.

In order for most existing buildings with URM walls to meet the seismic lateral force requirements of Section 3408 for Levels 4 and 5 Work, they will have to be reinforced with a new lateral load resisting system composed of ductile shear walls or vertical steel frames. When applying the design seismic load, there will be many cases of URM walls that will not crack, which affects the distribution of the lateral forces to the planes of the shear walls and vertical steel frames. This condition is recognized in Section 3408 and criteria are provided to determine when the uncracked condition is assumed to occur. Shear walls that are determined to be cracked are assumed to have zero in-plane shear strength and stiffness.

Existing URM walls may be preserved in-place and reused for a new building. These walls must be laterally supported by the new building in such a manner that no seismic loads are transferred from the new building to the planes of the URM walls. Further, the URM walls themselves must be able to resist seismic in-plane forces due to their own weight.

Row Buildings

For the first time in any code, the characteristics of buildings with party walls in a row along a street are addressed in Section 3408. Recognition is given to the fact that a lateral load parallel to the street is resisted by all the buildings in the row, and that removal or substantial alteration to one of the buildings affects this lateral resistance.

Experience in many earthquakes have shown that rows of buildings are generally undamaged, except for the last building in the row, where the end wall has collapsed outwardly because it was not anchored to the floors and roof. (The front and rear walls of the buildings may also fail outwardly, if not adequately anchored).

Criteria are given in Section 3408 for maintaining the lateral resistance parallel to the street of the entire row when one of the buildings is demolished, altered, or replaced.