Seismic Evaluation and Retrofit Manual
MTPTC Training, April & May 2011

Build Change
&
Degenkolb Engineers

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A. INTRODUCTION

1. Background

The earthquake of January 12th 2010 killed tens of thousands of people and left over one million people homeless with many more finding refuge in unaffected surrounding areas. The location, mechanism, magnitude, and ground motion characteristics of every earthquake are different, as is the response of individual buildings to varying ground motions. Consequently buildings that survived the January 2010 earthquake may still be at risk of collapse in future earthquakes.

The MTPTC has conducted surveys of hundreds of thousands of buildings and has classified the damage state relative to its pre-earthquake condition. Green-tagged buildings have mostly been reoccupied. Repairs of yellow and some red-tagged buildings are ongoing, however, there is uncertainty regarding whether the repaired buildings will meet a recognized engineering standard for life-safety performance in future earthquakes.

2. Objective

This manual provides criteria for undamaged or repaired buildings to evaluate their capacity to resist future earthquakes. Existing earthquake damage is identified as a deficiency in the evaluation procedure and must be repaired as part of the retrofit scheme. This may be accomplished using the MTPTC publication for earthquake damage repair, The Practical Guide to Repair of Small Buildings in Haiti (Guide Pratique de Réparation de Petits Bâtiments en Haïti). Other seismic deficiencies are identified through the procedure, and specific retrofit techniques are provided in order to strengthen the building structure to a life-safety level performance level.

By performing damage repair and retrofit simultaneously the goal is to facilitate the rapid repair and rebuilding of existing damaged or unsafe houses so that displaced people can return to their homes. Information is also provided on strengthening and construction methods to improve the resistance of these houses to resist hurricane wind loading, although not to a specific performance level.
3. **Applicability**

This guideline is appropriate for application to existing, low-rise, typical Haitian masonry construction. Elevated floor and roof systems consist of reinforced concrete slabs and joists with masonry void-forms. Roof systems may also be constructed of lightweight metal and wood systems. These buildings utilize unreinforced concrete masonry bearing walls for vertical support with or without reinforced concrete columns and other confining reinforcement. Foundations are also assumed to be typical Haitian construction, with rock/concrete or masonry footings and reinforced or unreinforced concrete slabs-on-grade.

A variety of restrictions of building dimensions, aspect ratios, etc., are incorporated into the checklist-based evaluation process. In general, this guideline applies to buildings that meet the following requirements:

- Infill Masonry (IM) and Confined Masonry (CM) buildings up to three (3) stories, with additional restrictions on Unreinforced Masonry (URM) buildings in areas of high seismicity
- Buildings located on sites that do not meet the MTPTC requirements for new confined masonry construction (refer MTPTC Guideline for Confined Masonry Construction (Guide de Bonnes Practiques pour La Construction de Petits Batiments en Maconnerie Chaninee en Haiti). This includes sloping sites (>10%) or those located close to bodies of water, or on potentially liquefiable or unstable ground.
- Buildings that are supported on tall retaining walls constructed of unreinforced rock/concrete.

Buildings that do not meet these requirements are referred for a more detailed engineering review that is beyond the scope of this manual. Procedures for more detailed engineering review are included in the reference standards used in the development of this Guideline.

The guideline provides information on solutions and retrofit techniques which can be implemented with locally available labor, materials and equipment. It does not provide any guidance on suitable construction techniques to implement these solutions. It is assumed that construction will be performed by a suitably qualified local contractor or homeowner.
4. **Manual Basis and Performance Criteria**

This manual is based on rational engineering principles and the two US standards, ASCE-31 Seismic Evaluation of Existing Buildings and ASCE-41 Seismic Rehabilitation of Existing Buildings. These standards are referenced by the International Building Code (IBC) as an alternate method of evaluating and strengthening existing buildings. The IBC is one of several acceptable standards adopted by the MTPTC for construction in Haiti until an official Haitian Building Code document is completed.

Seismic evaluation is defined as an approved process or methodology of evaluating deficiencies in a building, which prevent the building from achieving a selected performance goal. Seismic rehabilitation is defined as improving the seismic performance of structural and/or nonstructural components of a building by correcting deficiencies identified in a seismic evaluation. The seismic performance goals used in ASCE 31 and ASCE-41 are shown in the figure below. The performance goal adopted in this Guideline is structural life-safety, defined as follows.

**LIFE SAFETY PERFORMANCE LEVEL:** *Building performance that includes damage to the structural components during the design earthquake, such that: (a) at least some margin against either partial or total structural collapse remains, and (b) injuries may occur, but the overall risk of life-threatening injury as a result of structural damage is expected to be low.*

This is a technically a reduced level of performance because this Guideline does not specifically address nonstructural hazards such as seismic anchorage of building contents and systems. These items are assumed to be the responsibility of the owner.

Seismic evaluation of existing buildings performed using ASCE 31 is specifically intended to accept somewhat greater levels of damage within each performance level than permitted in both new construction, and buildings retrofitted in accordance with ACSE-41. We have incorporated this aspect of ASCE 31 in this Guideline with the use of a 0.75 factor on demands when performing an existing building evaluation, as opposed to a 1.0 factor when validating a proposed strengthening scheme.

This is consistent with the historic practice of evaluating existing buildings for slightly lower criteria than those used for design of new buildings. This essentially lowers the reliability of achieving the selected performance level from about 90% to about 60%. This practice minimizes the need to rehabilitate structures with relatively modest deficiencies relative to the desired performance level.
ASCE-31 and ASCE-41 do not specifically address typical Haitian confined masonry construction and so additional references have been used to extend the information available in these standards to develop this manual. A complete set of references is provided at the back of this manual. The guideline is also informed by the observed experiences of the January 12, 2010 earthquake, and intended to address the common causes of building damage and collapse.

Some of the requirements of ASCE-31 and ASCE-41, particularly those related to required site investigation, material testing and design documentation have not been included in this Guideline because they are not consistent with typical Haitian practice. A more complete discussion on these omissions and adjustments is provided in Appendix F.

It is expected that most buildings rehabilitated in accordance with this standard would perform within the desired levels when subjected to the design earthquakes. However, compliance with this standard does not guarantee such performance; rather it represents the current standard of practice in designing to attain this performance. The practice of earthquake engineering is rapidly evolving, and both our understanding of the behavior of buildings subjected to strong earthquakes and our ability to predict this behavior are advancing. In the future, new knowledge and technology will improve the reliability of accomplishing these goals.

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**Seismic Performance Levels**

- **Backup utility services maintain functions. Very little damage.**
- **The building remains safe to occupy; any repairs are minor.**
- **Structure remains stable and has significant reserve capacity; hazardous nonstructural damage is controlled.**
- **The building remains standing, but only barely; any other damage or loss is acceptable.**

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5. **How to use the Manual**

The evaluation and retrofit process is summarized in the following flowchart. The seismic evaluation procedure is centered on a checklist used to identify critical seismic deficiencies. When deficiencies are identified, retrofit measures can be proposed, and the evaluation repeated until all deficiencies have been addressed.

The checklist procedure is used to identify critical site and building configuration issues that have been observed to contribute to collapse in past earthquakes, including the January 2010 event. A common issue for this type of building is insufficient wall area or wall density. This results in excessive in-plane cracking damage to the masonry bearing walls, which then collapse, usually out-of-plane, resulting in partial or complete collapse of the building at that level.

One of the checklist items addresses this issue by requiring that the engineer evaluate the Wall Area Percentage at each level and direction in order to determine sufficient wall for the type of construction present (URM or CM/IM). If the actual shear wall density is LESS than the required shear wall density, the building needs to be retrofitted.

The engineer can choose from a list of alternatives that either increase the actual wall area percentage, or reduce the required shear wall percentage. Techniques that increase the wall area percentage include measures such as adding new masonry walls, filling in windows, or adding a reinforced concrete overlay to an existing wall. Techniques that decrease the required wall area include measures such as introducing confining reinforced concrete elements to make the structure more ductile, improving the masonry quality/workmanship, removing an upper level or converting to a lightweight roof system.

Once the engineer selects the retrofit option or options, they perform the evaluation again to confirm that the checklist deficiencies have all been addressed, including the Wall Area Percentage requirement.
Identify Building
- Locate on Map
- Determine Hazard Parameters

Visit Site
- Draw Plan
- Identify Building Type (CM, IM, or URM)
- Identify Lateral Walls

Complete Deficiency Identification Checklist
- Includes Wall Area Percentage Check

Do Deficiencies Exist?
- Yes
  - Retrofit Possible Using Manual?
    - Yes
      - Retrofit Specific deficiencies
    - No
      - Perform additional evaluation or suggest building replacement
- No
  - Building is Life-Safe. Repair if necessary
Once the retrofit scheme has been designed, the engineer is responsible for developing the necessary plans, details, and specifications necessary for the contractor or owner to execute the construction. The engineer is responsible for adapting these to their particular condition and care should be taken in this regard to ensure that the strengthening approach can be effectively integrated into the overall lateral system for the building.

Retrofit considerations should be discussed with the homeowner. Options such as adding filling in a door or window, or demolish the upper story may not be very appealing, but tend to be lower in cost. Adding new masonry walls or reinforced concrete confining elements may be more attractive but higher cost. This manual attempts to provide the necessary tools for engineers to develop strengthening schemes to accommodate the individual situations and needs of the homeowner.

This guideline does not address requirements for conducting this work. New construction should comply with the relevant MTPTC documents, the Guideline for Confined Masonry Construction (Guide de Bonnes Pratiques pour La Construction de Petits Batiments en Maconnerie Chaninee en Haiti) and The Practical Guide to Repair of Small Buildings in Haiti (Guide Pratique de Réparation de Petits Bâtiments en Haïti).
B. SITE VISIT

An essential part of the seismic evaluation and retrofit process is the site visit. To be most efficient with the time required on site it is recommended that site visits be performed with teams of two. Some information can also be gathered in advance of the site visit, such as mapped local seismicity, soil type, and slope stability information.

1. **What to Bring**
   - This Manual
   - Deficiency Identification Checklist
   - Clipboard, notepaper and pens or pencils
   - Camera
   - Tape measure or tape
   - Hardhat
   - Sturdy footwear or boots
   - GPS receiver (if available)

2. **Draw Plans**

   **For Existing Floor Plans:**
   
   1. Start with a grid and an approximate scale (i.e. 2cm = 1m). The plan doesn’t have to be drawn exactly to scale, but use it as a guide.
   2. Fill in the title block with the following:
      a. Title (describing floor plan and level)
      b. Name and phone number of homeowner
      c. Sheet number (E for existing, R for retrofit)
      d. Project number (eg CVM000X)
      e. Date
      f. GPS coordinates
Section B: Site Visit

3. Draw the existing floor plan – remember that walls have width, they aren’t just lines.
4. Use the correct symbols from the legend to represent the elements of the structure.
5. Add gridlines along the walls
6. Label the front of the house
7. Draw the dimensions of the following on the plan:
   a. lengths of walls (note which side of wall dimensions are to)
   b. length and locations of window and door openings
   c. positions and sizes of columns
   d. thickness of walls
   e. lengths of overhangs and/or balconies
   f. Distance to adjacent buildings
   g. Wall height
   h. Parapet height
8. Note any other important information, such as the slope, about building or site next to plan

For Retrofit Floor Plans:

1. Start following steps 1-6 on drawing an existing floor plan
2. Draw retrofit elements.
3. Add dimensions to the new elements.
4. Call out the corresponding details on the plan with the correct page number.
5. Note any other important information about retrofits (i.e. rafter spacing) next to plan
3. Define Construction Type

This manual applies to typical Haitian masonry construction, one to three stories in height, with floor systems of typical concrete and masonry construction. Roof systems may be either the same as the floors, or made of light-weight timber and metal systems. Within this construction type, for seismic evaluation purposes, there are three structural systems: Unreinforced Masonry (URM), Infill Masonry (IM), and Confined Masonry (CM). CM and IM systems have vertical confining reinforced concrete elements at the corners of the building, wall intersections, and around door and window openings, whereas URM has only unreinforced masonry walls supporting the floors and roof.

In IM construction the concrete frame is built first and the masonry “infills” the frame. In CM construction the masonry walls are typically built first, working around the vertical reinforcement and the concrete elements are poured second. The differences are illustrated in the photos and figure below.

Provided CM and IM buildings are well-constructed and the masonry is in close contact with the beams and columns, the seismic behavior of CM and IM systems is similar, within the precision of the evaluation method used in this manual. Consequently they are typically referred to together as CM/IM.

The seismic performance of CM/IM buildings is preferred over that of URM because the reinforced concrete elements help to control the damage to the masonry so that it does not collapse during earthquake shaking. For two otherwise identical buildings this makes a URM building more likely to collapse than a CM or IM building. In many seismically active countries URM construction is not permitted for new construction for this reason. For evaluation, this guideline applies only to one-story URM buildings in areas of high seismicity (Sds > 1.1g) and two-story buildings elsewhere. CM/IM buildings may be evaluated up to three stories in height. Conversion of URM buildings CM/IM is encouraged, especially when more than one-story and in areas of high seismicity.

The building structural system (CM/IM or URM) shall be classified at each level and horizontal direction (transverse and longitudinal) and noted on the plan. Section E, Item 4.1 provides guidance on how to identify the required reinforced concrete confining elements necessary for a given wall to be classified as CM/IM. All of the walls in a given direction must be CM//IM to meet the classification, otherwise URM shall be assumed. It is possible, and common, for a building to have a mixture of different systems in each direction and at each level.
Unreinforced Masonry (URM) construction (left) and Confined Masonry construction (right)
**Unreinforced Masonry**
- Use as default if other Building Types cannot be confirmed

<table>
<thead>
<tr>
<th>Infill Masonry</th>
<th>Confined Masonry</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Concrete frame built first</td>
<td></td>
</tr>
<tr>
<td>• Masonry infill built within frame</td>
<td></td>
</tr>
<tr>
<td>• Masonry should fit tightly against frame at all horizontal and vertical faces</td>
<td></td>
</tr>
<tr>
<td>• Concrete walls built first</td>
<td></td>
</tr>
<tr>
<td>• Tie-columns and tie-beams built around wall</td>
<td></td>
</tr>
<tr>
<td>• Lateral walls must be located between tie columns</td>
<td></td>
</tr>
</tbody>
</table>

Credit: Confined Masonry Design Manual: April 2010 Draft

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C. DEFICIENCY IDENTIFICATION CHECKLIST

The Deficiency Identification Checklist is the most important part of the evaluation process. A copy of the checklist is provided in Appendix F. It provides a list of potential seismic deficiencies that have been known to cause building collapse. Read each statement carefully and provide comments in the notes column for each item:

- **C** Compliant – Make this selection when your observations agree with the statement in the checklist.
- **NC** Non-Compliant – Make this selection when your observations disagree with the statement in the checklist. Non-compliant items must be corrected through retrofit.
- **N/A** Not Applicable – Make this selection when the statement in the checklist does not apply to the building being evaluated. Not Applicable items are not considered in evaluating the seismic safety of the building.

Once the evaluation is completed and the deficiencies are known, the engineer determines an appropriate retrofit scheme to convert all of the Non-Compliant items to Compliant. For the building to meet the target structural Life-Safety performance goal all of the items must be Compliant in the final condition.

The engineer always has the option to perform a more detailed evaluation to attempt to convert a Non-Compliant item to Compliant. This is mitigation through additional evaluation. The engineer would perform this evaluation using reference standards accepted by the MTPTC.

Suitable retrofit techniques are provided for some but not all checklist items. Some Non-Compliant items will automatically require either a more detailed engineering review or additional input from MTPTC, for example houses located on steeply sloping sites.

Unless the retrofits are being mandated by the local jurisdiction to meet all the requirements for the Life-Safety performance level, then they are technically Voluntary Seismic Upgrades. Consequently it may be possible to simply inform the owner of the deficiency, the possible consequences of the deficiency, and that retrofit of the building is not practical or cost effective in this case. The owner can then make an informed decision to relocate, rebuild, or accept the increased risk.
Geologic Site Hazards

1.1: Liquefaction:

Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 feet under the building. To determine if the building is compliant, identify ONE of the following items below.

Credit: Guide de bonnes pratiques pour la construction de petits bâtiments en maçonnerie chaînée en Haïti, MTPTC, Septembre 2010
<table>
<thead>
<tr>
<th><strong>COMPLIANT</strong></th>
<th><strong>NON-COMPLIANT</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Site is located outside of known Liquefaction hazard zones. Consult maps in Appendix B. OR Check the water table location by looking in a well or asking homeowners or residents how deep is the groundwater. If it is deeper than 50 feet, circle compliant OR Assess the soil condition by excavating the soil to the depth of the bottom of the foundation. Push a 12mm diameter bar in to the ground. If it cannot be pushed more than 6 inches, circle compliant.</td>
<td>Site is located in an area that experienced settlement during or before the earthquake. If evidence of building settlement exists, check neighboring buildings and interview residents to determine the cause of the settlement and associated cracking.</td>
</tr>
</tbody>
</table>

A NON-COMPLIANT result for this checklist item cannot be mitigated using this manual and a more detailed evaluation is required.
### 1.2: Slope Failure

House siting meets the requirements described here according to the MTPTC Construction Guidelines for Confined Masonry Construction, pp 8, 9, 12 and 13.

<table>
<thead>
<tr>
<th>COMPLIANT</th>
<th>NON-COMPLIANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope is less than 10%</td>
<td>Slope is between 10% and 35% and a more detailed evaluation has not been performed.</td>
</tr>
<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td>Slope is between 10% and 35% and a more detailed evaluation is performed</td>
<td>Slope is greater than 35%.</td>
</tr>
</tbody>
</table>

If the slope is greater than 10% and less than 35%, then a more detailed evaluation is required in order to determine what retrofit measures may be required at the site. If the site slope is greater than 35%, then the item is Non-Compliant.
Houses should be set back 10m from a slope greater than 35% above or below.

Circle COMPLIANT if any of the following are true
- No slope is present
- Setback from slope is greater than 10m

Circle NON-COMPLIANT if any of the following are true
- Setback from adjacent slope is less than 10m

A NON-COMPLIANT result for this checklist item cannot be mitigated using this manual and a more detailed evaluation is required.

Prevoir un dégagement de 10 mètres au minimum entre le bâtiment et une pente abrupte.
1.3: Site Retaining Walls

Unreinforced rock retaining walls which directly support the structure shall be no greater than 1.0m tall without supplemental reinforcement. Weep holes shall be present in solid wall systems for drainage.

Circle COMPLIANT if any of the following are true
- No retaining walls are needed or present.
- Unreinforced or rock retaining walls supporting the structure are less than 1m tall
- Reinforced retaining walls have weepholes for drainage

Circle NON-COMPLIANT if any of the following are true
- Unreinforced or rock retaining walls supporting the structure are greater than 1m tall
- Retaining walls do not have weepholes

A NON-COMPLIANT result for this checklist item cannot be mitigated using this manual and a more detailed evaluation is required.
1. **Foundations**

2.1: **Wall Foundations**

**COMPLIANT:** All of the following are true:

- The foundation is made of rock or concrete
- The foundation is continuous under all walls and around the whole perimeter
- There is a plinth beam at the base of all walls
- All columns are doweled into the foundation AND
- The footings are embedded at least 50cm below grade

**Structures identified as NON-COMPLIANT for this deficiency will require attention.** Consider the following solutions:

- Thicken existing foundation by adding concrete
- Fill in foundation where necessary to complete the perimeter
- Remove column cover and provide spliced rebar into foundation
2.2: Foundation Performance

1. Does the foundation appear to have settled or lifted significantly?

A NON-COMPLIANT result for this checklist item cannot be mitigated using this manual and a more detailed evaluation is required.

2.3: Overturning

COMPLIANT:
The total building height is less than three times the narrowest lateral system dimension.

Structures identified as NON-COMPLIANT for this deficiency may be modified by adding walls or removing stories to make the item COMPLIANT.
2.4: Ties between Foundation Elements

For all sloped sites (>10% grade) or for soft sites, the foundation elements shall be interconnected by a reinforced concrete slab, and footings and reinforced concrete plinth beams shall be continuous underneath all walls.

COMPLIANT:

For flat sites or stiff soils: All independent foundation elements are embedded at least 50cm below grade on all sides (per Item 2.1)
For soft soils or steep sites (>10%): All foundation elements are interconnected by a reinforced concrete slabs, and the wall footings shall have plinth beams and be continuous underneath all walls.

- Structures identified as NON-COMPLIANT for this deficiency shall be evaluated by a retrofitted by adding new slab or plinth beams.

2.5: Deterioration

There shall not be evidence that foundation elements have deteriorated excessively due to corrosion, sulfate attack, material breakdown, or other reasons in a manner that would affect the integrity or strength of the structure.

COMPLIANT:

There is no evidence that foundation elements have deteriorated excessively due to corrosion, sulfate attack, or material breakdown

- Structures identified as NON-COMPLIANT for this deficiency shall be repaired or reconstructed to address the deterioration.
3 Building System

3.1: Materials

Materials used for the gravity and lateral load resisting systems shall consist of reinforced concrete and concrete masonry. A lightweight wood and metal roof system may be present but is not required to resist seismic forces.

This manual does not apply to structures not constructed of reinforced concrete and concrete masonry. NON-COMPLIANT structures require a more detailed evaluation be performed using MTPTC approved reference standards.

Where repairs are made, always use good quality materials in accordance with MTPTC requirements for new construction.

3.2: Load Path

A minimum of two separate lines of wall is required in each direction; an additional line of walls is required for each additional 4.5 m of building dimension over 4.5 m. Walls considered for lateral resistance shall be at least 1.0m long. Parallel walls are located no greater than 4.5 m apart. Walls shall be connected to the diaphragm at the top and bottom by a continuous reinforced concrete floor or plinth beam that is centered on the wall and contiguous with the floor slab.

If Load Path is NON-COMPLIANT, then structure may be retrofit with new walls to provide adequate load path.
3.3: Number of Stories

The maximum number of stories is three, except for URM buildings which are limited to two for $Sds < 1.1g$, and one for $Sds \geq 1.1g$.

Stories may be removed in order to comply with evaluation procedure, otherwise a more detailed evaluation is required.

3.4: Story Heights

Structures shall be considered compliant where the maximum story height of the first story is 3.0 m from the ground floor slab and the floor to floor height of the upper levels is no more than 2.75m.

A more detailed evaluation is required for structures identified as NON-COMPLIANT for this deficiency.
3.5: Mass
The average weight \((1.0xD)\) of each level, including the tributary weight of walls and contents shall not exceed 7.2kPa (150 psf).

A more detailed evaluation is required for structures identified as NON-COMPLIANT for this deficiency. It is recommended that the evaluating engineer ratio up the seismic demands proportionally to the increased weight.

3.6: Floor and Roof System
Elevated floor and roof systems shall be of typical Haitian construction (approximately 15cm thick, with 5cm of reinforced concrete over reinforced concrete joists and masonry void-forms. Roofs may be constructed of lightweight materials, such as wood and metal sheeting.

A more detailed evaluation is required for structures identified as NON-COMPLIANT for this deficiency.

3.7: Walls
Walls shall consist of at least 15cm thick concrete masonry units with sand cement mortar, with no less than 50% net solid area.

See Appendix B for a method of accounting for different wall thicknesses and net areas. Structures with walls less than 15cm and 40% net solid area require a more detailed evaluation.
3.8: Cantilever Upper Levels

Perimeter walls at the upper levels shall not be supported on cantilevers or eaves that extend beyond the lower level building envelope greater than 50% of wall thickness. This statement does not apply to single story buildings.

3.9: Damage

Structures have no earthquake or weather related damage to the masonry walls or roof system. Damaged buildings are NON-COMPLIANT but may be repaired per the MTPTC guidelines to become COMPLIANT.
4 Masonry Walls

4.1: Masonry Confinement
Walls shall be tightly installed to the soffits of the ring beam or slab and to the columns where present. Formwork shall not be present between the top of the masonry and underside of the beam/slab.

Masonry walls identified as NON-COMPLIANT for this deficiency may be repaired using techniques in the MTPTC Repair Manual.

4.2: Openings
Doors, windows and other openings wider than 0.6m shall extend to the beam above, or shall be provided with a reinforced concrete lintel beam. Lintel beams shall extend a minimum of 15cm into the adjacent masonry or shall be connected to an adjacent concrete boundary column or trim reinforcement. Maximum opening width shall be 1.5m.

Openings identified as NON-COMPLIANT for this deficiency may be infilled to remove the opening, modified to comply, or retrofitted to add lintels as required.

4.3: Top Ring Beam
Buildings constructed with light-weight wood/metal roofs shall have a continuous reinforced concrete ring beam at the top of the walls to transfer out-of-plane forces to cross walls. Ring beams shall span over door openings where present. Roof systems shall be positively anchored to ring beams.

Structures identified as NON-COMPLIANT for this deficiency shall have ring beams added, or a more detailed evaluation shall be performed.

URM building cutaway section with continuous ring beam at the top of the wall.
4.4: Wall Area Percentage

The provided Wall Area Percentage shall be greater than the required Wall Area Percentage (see table below) at each level and in each direction. The following is a general description of the approach. Appendices A and B provide more detailed information if required. The companion manual to this document includes a detailed and tabulated procedure if required.

**Identify Construction Type, Wall Locations and Lengths**

Each level and horizontal direction in the building shall be assigned a construction type of Unreinforced Masonry (URM) or Confined Masonry / Infill Masonry (CM/IM). For a given level and direction all of the walls must meet the requirements for CM/IM in order for that level/direction to be defined CM/IM.

The masonry walls in the building shall be defined in plan as extending from Wall Edge to the next adjacent Wall Edge. A Wall Edge occurs at the corners of the building, the sides of a door or other full height opening, or the intersection of two walls. The sides of windows and other openings larger than 0.6m long or 0.6m high shall be designated a Wall Edge.

If all of the walls in a given level and direction meet the following CM/IM requirements then that level/direction may be considered CM/IM, otherwise it shall be considered URM:

- The minimum wall length for lateral resistance is 1.0m. Shorter lengths are permitted but cannot be included in the Wall Area Percent calculation.

- Each Wall Edge location shall be reinforced. A four bar column is required at building corners and wall intersections, and at least a single bar is required at door and window openings.

- Isolated segments of wall with only one boundary column are permitted provided the maximum length does not exceed 0.6m. These wall segments shall not be considered in the Wall Area Percentage check.
ACTUAL Wall Area Percentage

Once the type of construction and the wall lengths have been identified in each direction the ACTUAL or available shear wall density (percentage) shall be determined. This information is gained during the site visit by recording the area of the supported slab or roof, and the area of wall in each primary direction of the building. Dividing the area of the wall by the area of the supported slab provides the ACTUAL wall area percentage (WAP). Masonry walls that do not meet the minimum requirements above shall not be included in the WAP Check. See Appendix A.

Existing cement plaster shall not be considered as contributing to the lateral capacity without confirmation of the average thickness and bond to the underlying masonry. The contribution of existing plaster shall be considered by increasing the existing masonry wall thickness, and/or net area, not in the same way as new retrofit plaster.

REQUIRED Wall Area Percentage

Next determine the REQUIRED wall area density (percentage) for each storey in the building, and in each horizontal direction (transverse and longitudinal). This is based on the tabulated value below, adjusted according to the following assumptions:

<table>
<thead>
<tr>
<th>Level</th>
<th>1-Story</th>
<th>2-Story</th>
<th>3-Story</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>4.7</td>
<td>For buildings with heavy floors and roofs having concrete slabs, concrete joists, and masonry void forms.</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>4.6</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4.0</td>
<td>6.9</td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3.0</td>
<td>For buildings with light roofs made of sheet metal and wood framing.</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>3.0</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3.0</td>
<td>4.0</td>
<td>6.9</td>
<td></td>
</tr>
</tbody>
</table>
Assumptions and Adjustments:

- Table applies for Sds = 1.05g, for other design ground motion values ratio accordingly.
- Tabulated values are for URM construction. For compliant CM or IM construction use 50% of these value, 1.5% minimum.
- Tabulated values are for “Average” quality construction. For poor quality construction increase by 50%. See photo guide in Appendix B.
- The assumed concrete block strength is 4.8MPa. See Appendix A for adjustment to other strengths if required.
- These values are for Building Evaluation, increase by one third for evaluation of a proposed Retrofit Design.
- Block is typical 15cm, between 50% to 60% solid, and not plastered. For other thicknesses and net solid area ratios adjust the required WAP using the information in Appendices A and B.

**Wall Area Percentage Check**

The provided Wall Area Percentage shall be greater than the required Wall Area Percentage (see table below) at each level and in each direction.

If the actual wall area percentage is GREATER than the required shear wall area percentage for each level and direction, then that potential deficiency may be marked ‘C’ for Compliant. Report the Wall Area percent values in the checklist for reference.

If the actual shear wall density is LESS than the required shear wall density, the building needs to be retrofitted. The engineer can choose from a list of alternatives in Section D that would either increase the actual wall area percentage, or reduce the required shear wall percentage.

If the actual shear wall density is LESS than the required shear wall density, the building needs retrofit. Choose from the list of alternatives in Section D to either increase the actual WAP, or reduce the required WAP.
The following table can be used to determine the length of 15cm wall for provide a target Wall Area Percentage (%) for a given Building Area (m²):

<table>
<thead>
<tr>
<th>Area (m²)</th>
<th>2%</th>
<th>3%</th>
<th>4%</th>
<th>6%</th>
<th>8%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.3</td>
<td>2.0</td>
<td>2.7</td>
<td>4.0</td>
<td>5.3</td>
<td>6.7</td>
</tr>
<tr>
<td>20</td>
<td>2.7</td>
<td>4.0</td>
<td>5.3</td>
<td>8.0</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>30</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>12</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>5.3</td>
<td>8.0</td>
<td>11</td>
<td>16</td>
<td>21</td>
<td>27</td>
</tr>
<tr>
<td>60</td>
<td>8.0</td>
<td>12</td>
<td>16</td>
<td>24</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>80</td>
<td>11</td>
<td>16</td>
<td>21</td>
<td>32</td>
<td>43</td>
<td>53</td>
</tr>
<tr>
<td>100</td>
<td>13</td>
<td>20</td>
<td>27</td>
<td>40</td>
<td>53</td>
<td>67</td>
</tr>
</tbody>
</table>
5 Building Configuration

5.1: Torsion

Walls are located on all exterior sides of the building, or within 25% of the plan dimension at the wall location, including L-shaped and T-shaped plans.

Alternatively, the estimated distance between the center of mass and the center of rigidity shall be less than 20% of the maximum building width in either plan dimension.

COMPLIANT:

There are walls close to all exterior sides of the building (within 25% of the plan dimension) OR The distance between the center of mass and center of rigidity is less than 20% of the building width in either plan dimension.

If the building does not satisfy the first criteria then a more detailed evaluation may be performed to demonstrate compliance with the second item. Structures identified as NON-COMPLIANT for this deficiency will require attention. Recommend adding new walls to the building to mitigate the condition. See Section D.
5.2: Adjacent Buildings

If floor and roof slabs of adjacent buildings are not vertically aligned, then the contact distance shall be greater than 3 cm for single story structures, 6 cm for two-story structures, and 9 cm for 3-story structures. If floors and roof slabs are aligned the item is compliant.

COMPLIANT:

Structures identified as NON-COMPLIANT for this deficiency require additional evaluation. Recommend either increasing the clearance where possible. Alternately the item may be made compliant by demonstrating the potential impact will not result in partial or total collapse of the building.
5.3: **Vertical Discontinuities**

Second story walls are generally located on top of lower story walls. Second story walls that do not align with lower story walls are supported on both ends by any of the following, and do not span more than 3.0m unsupported:

- Complying freestanding columns, see separate checklist item for requirements.
- Perpendicular walls that extend at least 60cm each side of the wall above.
- Parallel walls with at least ¼ length (30cm minimum) of the upper wall overlapping with the lower wall.

This statement does not apply to single story buildings.

Examples of compliant and noncompliant conditions are shown below.

NC - Second floor walls not aligned  
C – Provided free-standing column is compliant, see Item 6.1
C - There are perpendicular walls that extend at least 60cm (30cm minimum) on each side of the wall above.

C - There are parallel walls with at least ¼ length upper wall overlapping with the lower wall.

Structures identified as NON-COMPLIANT for this deficiency may be retrofitted by removing upper story wall, adding supporting walls and foundations below, or installing Compliant free standing column, See Section D for adding retrofit requirements.
6 Building Components

6.1: Freestanding/Discontinuous Concrete Columns

Free-standing columns supporting concrete floor/roof slabs or discontinuous masonry walls shall meet the following minimum requirements:

- Columns shall be reinforced concrete in good condition, with a minimum clear height of 1.5m.
- Column bases shall be connected to the remainder of the building by a continuous foundation or reinforced concrete slab.
- Columns shall have a minimum dimension of 6” when supporting a concrete roof or patio, 8” when supporting a one-story discontinuous wall, and 12” when supporting a two-story discontinuous wall above.

Columns identified as NON-COMPLIANT for this deficiency may be addressed in the following ways:

- The column may be strengthened in-situ using the technique indicated in the retrofit detail set.
- The Noncompliant column may be removed and replaced with a Compliant one.
- Supporting walls and foundations may be added adjacent to the column in each horizontal direction.
6.2: Slab Openings at Shear Walls

Slab openings adjacent to shear walls shall meet the following requirements:

- Openings immediately adjacent to the shear walls shall be less than 25% of the wall length.
- Slab openings at exterior masonry walls shall be less than 2.5m in length, and a reinforced concrete beam shall extend the length of the wall adjacent to the opening.

Structures identified as NON-COMPLIANT for this deficiency will require attention. Consider the following solutions:

- Fill in some or all of the opening with slab diaphragm of similar stiffness to the rest of the floor
- Add a reinforcing beam along the side of the opening

6.3: Parapets

There shall be no laterally unsupported unreinforced masonry parapets or cornices with height-to-thickness ratios greater than 1.5. Masonry parapets must be in good condition with masonry units bonded to the supporting roof slab.
NON-COMPLIANT:

Structures identified as NON-COMPLIANT for this deficiency will require attention. Consider the following solutions:
- Remove or reduce the height of the building parapet or cornice
- Add bracing or reinforced concrete elements to provide lateral support for the parapet or cornice

6.4: Stairs and Landings

Stairs shall meet all of the following requirements:
- Stairs shall be connected at each elevated level to the building slab or roof by a continuous reinforced concrete landing. Stairs shall not depend on the building walls for vertical support.
- Vertical support for stairs or landings shall be provided by compliant freestanding columns, or by masonry walls at least 0.6m long.
- Stair foundation components shall be constructed of rock base or concrete footing that is embedded a minimum of 30cm below grade. On sloped sites (>7%) or soft sites the stair foundation shall be continuous with the remainder of the building.
COMPLIANT:

Structures identified as NON-COMPLIANT for this deficiency will require attention. Consider the following solutions:

- Connecting stairs to floor slabs
- Vertically supporting stairs using columns or walls
- Extending and interconnecting foundations if required.
D. RETROFIT INFORMATION

Once the deficiencies have been identified and the structure is understood a suitable retrofit scheme or schemes may be developed. The required retrofit scheme emerges from the checklist evaluation process. Deficiencies such as parapets and stairs can be simply corrected by removal and replacement or by supplemental support or reinforcement.

The Wall Area Percentage evaluation also indicates potential retrofit solutions. If the actual shear wall density is LESS than the required shear wall density, the building needs to be retrofitted. The engineer can choose from a list of alternatives that would either increase the actual wall area percentage, or reduce the required shear wall percentage.

To increase the actual shear wall percentage, the engineer can recommend to

- Add additional shear walls, or increase the length of walls that are less than 1m long. See Detail Series D1.
- Double the thickness of existing shear walls, See Detail Series D2.
- Increase the effective area of the existing walls by coating them in plaster, see Detail Series D3.
- Increase the effective area of the existing walls by coating them in reinforced concrete, see Detail Series D4.
- Infill doors and/or windows, See Detail Series D6.
- Improve the quality of existing walls by repairing them, or if the block is low strength, replacing them with new walls. See Detail Series D1.
- Add support below a discontinuous wall so that it can be included in the WAP. See Detail Series D1 and D8.

To reduce the required shear wall density, the engineer can recommend to

- Make the system more ductile (introduce reinforced concrete confining elements). See Detail Series D5.
- Decrease the seismic loading on the building (remove mass – i.e. demolish an upper storey, replace a concrete roof with a lightweight one).
• Justify better masonry compressive strength through testing.

• Repair masonry that has been installed with poor workmanship, see MTPTC repair manual.

Sample details for these retrofit techniques are shown in Appendix D. The engineer is responsible for confirming that these are suitable for the actual application. A separate set of plans and elevations should be prepared indicating where each retrofit detail is to be applied.

Once the engineer selects the option or options, he/she must do the Checklist and the Wall Area Percentage calculation again to confirm that the proposed scheme meets the requirements of this Guideline.

Retrofit consideration should be discussed with the homeowner. They may not want to add a new wall, fill in a door, or demolish the second story. The flexible approach accommodates different situations and different needs of the homeowners. If the retrofit is voluntary then the owner may elect only to do certain portions of the work, and accept certain risks, for example siting or liquifaction. The engineer should inform the owner of these risks, and if necessary prioritize the retrofit items so that the owner can make an informed decision on the work to be performed.

Responses to Frequently Asked Questions and General Retrofit Advice

• If your retrofit converts to confined masonry, the m-factor increases x2, and the required PSM is lowered significantly. This can be a good way to retrofit.

• Diagonal Walls. If the angle is very slight (say less 15 degrees) we usually assume that it acts entirely along one of the axes. If the angle is greater, we take the x and y components of the length into the calculation.

• Countable wall length. Walls less than 1m long do not count.

• In the case that a window is infilled, Km=1.0 because the lower portion of the wall still contains old masonry.

• Plaster should not be counted along openings
Before writing anything else, write the house number on the paper you are filling out. Keep in mind overall organization and documentation. There are a lot of papers flying around, if they are not labeled or put in the right place, they’ll probably be lost forever.

Frequently there are inconsistencies from the checklist to the drawings, to the calculation sheet, and to the bill of quantities, etc. The engineer should produce a package that is consistent within itself.

Make sure that your drawings and evaluation procedure documents are clear and concise. Somebody who is not familiar with the building should be able to follow your work and understand what you have observed and what you are proposing as a retrofit.

Keep in mind the actual site conditions when planning your retrofit. For example: don’t specify plaster over a wall that already has it, or on a wall that is inaccessible.

Keep cost in mind. If your retrofit has much more wall area than required then you may be wasting money. Thriftiness on the part of the engineer is important. The more wisely your design uses money and materials, the more houses can be retrofit.

Remember to consider torsion and any other issues of the checklist that are not specifically addressed by the WAP calculation.

Keep in mind constructability and the order of construction when designing your retrofit. Before selecting any of the typical details, make sure that is in fact correct for your particular condition.

Mixing of CM and URM systems. Even when retrofitting a building that is considered to be unreinforced masonry, there is a tendency for engineers to add new columns to existing walls and an aversion to adding walls without columns. Engineers should understand the difference between URM and CM/IM and how this ensures sufficient shear wall density, such that confining elements are not needed.

Ensure that you understand the construction process for each of the details before applying them in your retrofit design.
E. References


ASCE-31 Seismic Evaluation of Existing Buildings, ASCE-41 Seismic Rehabilitation of Existing Buildings

Haïti Demain présentation, CIAT, Mars 2010
Haïti Demain résumé, CIAT, Mars 2010
Haïti Demain, CIAT, Mars 2010.

Guide pratique de Réparation de Petits Bâtiments à Haïti, MTPTC, Octobre 2010


Construire Parasismique et Paracyclonique, Ministère de l’Equipe ment, 2000


Compliance Catalogue Guidelines for the Construction of Compliant Rural Houses, ERRA, Mars 2008

MI1007226 Build Change Seismic Retrofit Narrative 01, USAID ECAP, Miyamoto, Build Change, Mai 2011.
Experience in Repair and Retrofitting in the Housing Sector after the Kashmir Earthquake, Pakistan 2005, UN-HABITAT, 6 pages.

Diagnostic et Renforcement du Bâti existant vis-à-vis du sisme. AFPS-CSTB. MEEDDM. Février 2011.
APPENDIX A: WALL AREA PERCENTAGE PROVIDED

Structural Evaluation Section 4.2 requires the calculation of the actual Wall Area Percentage (WAP) of the existing building and the effective Wall Area Percentage if retrofit is required.

**Existing Building Evaluation**

The actual Wall Area Percentage is calculated as the area of wall in each direction divided by the total roof or floor area at the level above the walls. The WAP must be calculated separately for the longitudinal and transverse directions of the building.

\[
WAP_{Actual} = \frac{t_{w1} \times l_{w1} + t_{w2} \times l_{w2} + \ldots + t_{wn} \times l_{wn}}{A_r}
\]

Where:

- \(t_{w1}\) = thickness of wall #1 (repeat for all walls in the same direction)
- \(l_{w1}\) = length of wall #1 (repeat for all walls in the same direction). Refer to Section 2.0 for recommendations for usable wall lengths
- \(A_r\) = Area of roof or floor above the walls being considered

Typical wall areas are in the range of 2% to 8% of the area of the roof or floor above the walls. The value calculated in each direction shall be compared against the required wall areas from Appendix B.
Appendix A: Wall Area Percentage Provided

Retrofit Evaluation

If the actual Wall Area Percent is less than the required Wall Area Percent, then the building requires retrofit. Options are provided in Section D. Some of these increase the Wall Area Percent provided, and so this must be recalculated to account for the retrofit components. Applicable techniques include:

1. Conversion from URM to CM by providing required CM details.
2. Adding Effective Wall Area by
   - Adding new masonry walls
   - Doubling the thickness of existing masonry walls
   - Infilling doors or windows with new masonry walls
   - Providing 2.5 cm of concrete plaster overlay (1.25 cm on each side of wall)
   - Providing new 7.5 cm reinforced concrete overlay

Addition of new masonry, plaster, or concrete provides an increase to the wall area that was calculated in the Existing Building Evaluation. The strength provided by the new materials is normalized to the strength of a typical 15 cm block. ‘K’ factors are provided in order to relate the strength of the new material to the strength of the typical material therefore the effective wall. Below is a summary of the K factors, followed by a more detailed explanation.
**New Masonry Wall Area Adjustment Factor, $K_m$**

New masonry block will likely be stronger than the existing block; therefore a credit is given to using new block in a retrofit. Adding a new masonry wall with a $K_m$ factor of 1.5 can be considered the same as adding 1.5 times the length of the existing masonry wall.

<table>
<thead>
<tr>
<th>New Masonry</th>
<th>Existing Masonry</th>
<th>$f'_m$ MPa (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2.8 (400)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.8 (700)</td>
</tr>
<tr>
<td>4.8 (700)</td>
<td></td>
<td>1.3</td>
</tr>
<tr>
<td>6.9 (1000)</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>10 (1450)</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>12 (1740)</td>
<td></td>
<td>1.5</td>
</tr>
</tbody>
</table>

If $K_m = 1.5$:

\[
1.5 \times L = \text{New Masonry Wall} + \text{Additional Existing Masonry Wall}
\]

**New Plaster Area Adjustment Factor, $K_p$**

$K_p = 0.5$ when adding 2.5 cm of plaster to a 15 cm wall (1.25 cm each side).

$K_p = 0.25$ when adding 2.5 cm of plaster to a 30 cm wall (1.25 cm each side).

Adding plaster to a masonry wall with a $K_p$ factor of 0.5 can be considered the same as adding 0.5 times the length of the existing masonry wall. For calculation purposes, the designer can consider addition of 2.5 cm of plaster as increasing the existing length of a wall by 50%.

\[
L = \text{Existing Masonry Wall With 2.5 cm New Plaster} = 1.5L = L + 0.5 \times L
\]
**New Reinforced Concrete Overlay Area Adjustment Factor, \( K_e \)**

\( K_e = 1.5 \) when adding 7.5 cm of reinforced concrete overlay to a 15 cm wall (one side only).

Adding reinforced concrete overlay to a masonry wall with a \( K_c \) factor of 1.5 can be considered the same as adding 1.5 times the length of the existing masonry wall. For calculation purposes, the designer can consider addition of 7.5 cm of reinforced concrete overlay as increasing the existing length of a wall by 150%.

\[
\begin{align*}
\text{Existing Masonry Wall} & \quad \text{With 7.5 cm New Reinforced Concrete Overlay} \\
L & \quad 2.5L = L + 1.5 \times L \\
\text{Existing Masonry Wall} & \quad \text{Existing Masonry Wall}
\end{align*}
\]

**Calculate Effective Wall Area Percentage After Retrofit**

\[
WAP_{\text{effective}} = \frac{A_{\text{existingwall}}}{A_r} + \frac{0.15 \times (K_m L_m + 0.5 L_p + 1.5 L_e)}{A_r}
\]

Calculate \( WAP_{\text{effective}} \) in each primary direction and compare against required area for retrofit from Appendix B.
APPENDIX B: WALL AREA PERCENTAGE REFERENCE MATERIAL

This Appendix contains reference material for performing the Wall Area Percentage calculation.

For more information see the companion manual, which provides three methods for calculating the required wall area. Method 1 is the detailed procedure. Methods 2 is the tabulated method summarized in Section C and in the checklist. Method 3 use tables generated for the most common cases, but can by extrapolated to other cases by a number of factors.

Reference Information

Seismicity

\[ S_{DS} \] = Short Period Spectral Acceleration Response Parameter from map.

Block Strength

\[ C_B = \text{Block Strength Factor}. \] Block strength may quantified through testing or appropriate field tests calibrated to tests. A value of 4.8 MPa (700 psi) may be assumed if no information is available. \[ C_B = 1.0 \] for \( f_m = 4.8 \) MPa (700 psi)

\[ C_B = \sqrt{\left(\frac{555}{51.2 + 0.724 f_m}\right)} \] for other block strengths, \( f_m \) in psi

The factor may be used to adjust the required Wall Area Percentage for different strengths, and is also used to for retrofit design to adjust the length of new walls when the block has a different strength than the existing block.
Appendix B: Wall Area Percentage Reference Material

C_Q = Construction Quality Factor, intended to capture poor construction details in URM, IM, or CM construction. Not intended to capture weak masonry (See C_B factor)

\[ C_Q = 1.0 \text{ for average quality} \]

\[ C_Q = 1.5 \text{ for poor quality} \]

Intermediate values may be used based on extent and severity of construction quality problems. Selective demolition may be required to confirm reinforcement detailing in some cases. Rebar “trees” or other visible exposed conditions can be used as guidance as to the probable detailing and reinforcement present elsewhere in the building.

Photo examples of poor quality are shown:

Factor may be reduced by applying similar techniques to those included in the MPTPC Repair Manual.
Examples of Poor Quality:

Incomplete mortar infill or no mortar in head joists, loose window infill.

Top row of masonry not in full contact with slab or ring beam

Visible rebar tree is very short

Ongoing construction reveals poor detailing

26 June, 2012
$C_N =$ **Net Area Factor.** $C_N = 1.0$ for 15 cm block with 50% to 60% net solid area, including both webs and flanges.

$$C_N = 0.55 \times \frac{\text{Gross Area}}{\text{Solid Area}}$$

Example: If block were solid, then $C_N = 0.55$, therefore less wall is required.
### SHEET LIST

**D0 - REPAIR OF EXISTING WALLS**
- D0.1 - REPAIR OF WEATHERED MASONRY
- D0.2 - REPAIR OF WALL TO ROOF CONNECTION

**D1 - NEW WALL DETAILS**
- D1.1 - NEW WALL PARALLEL WITH JOIST
- D1.2 - NEW WALL PERPENDICULAR TO JOIST
- D1.3 - NEW WALL TO NEW FOUNDATION CONNECTION
- D1.4 - NEW WALL TO EXISTING FOUNDATION CONNECTION
- D1.5 - NEW WALL TO EXISTING WALL CONNECTION
- D1.6 - NEW WALL TO NEW FOUNDATION CONNECTION WITHOUT PLINTH BEAM
- D1.7 - (N) AND (E) WALL CONNECTION AT CORNER
- D1.8 - (N) AND (E) WALL CONNECTION

**D2 - DOUBLE WALL DETAILS**
- D2.1 - DOUBLE WALL PARALLEL WITH JOIST
- D2.2 - DOUBLE WALL PERPENDICULAR TO JOIST
- D2.3 - DOUBLE WALL FOUNDATION

**D3 - PLASTER OVERLAY**
- D3.1 - PLASTER OVERLAY

**D4 - REINFORCED CONCRETE OVERLAY**
- D4.1 - CONNECTION TO ROOF
- D4.2 - CONNECTION TO COLUMN
- D4.3 - CONNECTION TO FOUNDATION
- D4.4 - CONNECTION TO FOUNDATION FROM ABOVE AND BELOW

**D5 - CONFINED MASONRY CONVERSION**
- D5.1 - CORNER TIE COLUMN
- D5.2 - "T" TIE COLUMN
- D5.3 - FLOOR CONNECTION
- D5.4 - FOUNDATION CONNECTION
- D5.5 - TYPICAL ELEVATIONS
- D5.6 - COLUMN TO EXISTING FOUNDATION CONNECTION
- D5.7 - END WALL TIE COLUMN
- D5.8 - DOOR TIE COLUMN
- D5.9 - WINDOW TIE COLUMN
- D5.10 - WINDOW TIE COLUMN

**D6 - WINDOW INFILL**
- D6.1 - WINDOW INFILL ELEVATION

**D7 - OVERHANG RETROFIT**
- D7.1 - OVERHANG PLAN
- D7.2 - OVERHANG PLAN AT CORNER
- D7.3 - OVERHANG SECTION

**D8 - PORCH ROOF**
- D8.1 - PORCH COLUMN RETROFIT

**D9 - CAP BEAM**
- D9.1 - TYPICAL CAP BEAM SECTION
- D9.2 - CAP BEAM WITH HURRICANE STRAP
- D9.3 - STEPPED CAP BEAM
- D9.4 - THICKENED CAP BEAM

---

**REPAIR OF WEATHERED MASONRY**

**SUPPORT (E) CONC. JOIST UNTIL JOINT HAS SET**
- CLEAN OUT JOINT, THEN DRY-PATCH
- ROUGHEN JOINT BEFORE PATCHING

**TEMPORARY FORMWORK**

**SMOOTH, EVEN LAYER OF CEMENT PLASTER OVER WEATHERED MASONRY**
NOTE: DETAIL SHOWN FOR (N) URM WALL. FOR (N) CMU/M WALL, ADD CONFINING BEAM SIMILAR TO D1.2 IMMEDIATELY BELOW SLAB

(N) CMU WALL
REMOVE AND REPLACE (E) SLAB, CUT AND PRESERVE (E) REINFORCEMENT

(E) CMU WALL

(N) PDM BEAM, PRESERVE (E) SLAB REINF.
MIN. 4 - #3 BARS W/ #2 TIES @ 150mm O.C.

(E) FLOOR BEAM

(E) FOUNDATION TO REMAIN

SMOOTH: EVEN LAYER OF CEMENT PLASTER EACH SIDE OF WALL, MIN. COMP. STRENGTH = 14 MPa

- NOTE: SEE MTPC GUIDELINES FOR MIX PROPORTION AND APPLICATION OF CEMENT PLASTER
**Shear Wall Connection to Roof**

- **Details:**
  - **Break Out Slab Above:** At each dowel location.
  - **Minimum Lap:** 40 cm.
  - **Reinforcement:** @ 30 cm O.C., horizontal & vertical, centered.

**Build Change**

---

**Shear Wall Connection to Column**

- **Details:**
  - **Break Out Face Shell of Masonry:** & Place #2 Tie into Block & Pack w/ Concrete = 1 m.
  - **Minimum Lap:** 40 cm.
  - **Reinforcement:** Centered.

**Build Change**

---

**Shear Wall Connection to Foundation**

- **Details:**
  - **Break Out Slab to Pass Through Lap:** As Required.
  - **Minimum Lap:** 75 mm.
  - **Reinforcement:** Horizontal & Vertical, Centered.

**Build Change**

---

**Shear Wall Connection to Floor From Above & Below**

- **Details:**
  - **Break Out Slab:** To Remain.
  - **Minimum Lap:** 75 mm.
  - **Reinforcement:** Horizontal & Vertical, Centered.

**Build Change**
TYPICAL ELEVATIONS

COLUMN TO EXISTING FOUNDATION

END WALL TIE COLUMN

DOOR TIE COLUMN
STEPPED LAP BEAM

- REMOVE & REPLACE (E) CMU; REPLACE IF DAMAGED OR UNUSABLE
- CAP BEAM, TYP

MINIMUM 40cm EMBEDDED INTO WALL

THICKENED LAP BEAM

- 2 #3 TYP.
- 2 #2 TYP.
- #2 TIES @ 15cm O.C.
- DEPTH AS REQ'D
- DOOR OR WINDOW OPENING

MINIMUM 15cm MIN.

D9.3
D9.4
APPENDIX D: DEFICIENCY IDENTIFICATION CHECKLISTS

Two retrofit checklists are provided, one applies only to single story buildings with lightweight roofs. The second applied to buildings up to three stories in height (with restrictions), and with concrete or lightweight roofs. The first checklist is a subset and simplification of the second.

The same numbering scheme is used in both checklists so that the manual references are consistent. This means that the numbering in the first checklist is not sequential.
# Seismic Evaluation Checklist: Single-Story Light-weight Roof Haitian Masonry Construction
Unreinforced, Confined, or Infill Masonry

## GEOLOGIC SITE HAZARDS

<p>| | | | | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building’s seismic performance shall not exist in the foundation soils at depths within 50 feet under the building.</td>
</tr>
<tr>
<td>1.2</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>SLOPE FAILURE: House siting meets the requirements of the MTPTC Construction Guidelines for Confined Masonry Construction p 8, 9, 12 and 13. Alternatively, in the judgment of the evaluating engineer, the building site shall be sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or shall be capable of accommodating any predicted movements without failure.</td>
</tr>
<tr>
<td>1.3</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>SITE RETAINING WALLS: Unreinforced rock retaining walls which directly support the structure shall be no greater than 1.0m tall without supplemental reinforcement. Weep holes shall be present in solid wall systems for drainage.</td>
</tr>
<tr>
<td>1.4</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site is not anticipated.</td>
</tr>
</tbody>
</table>

## FOUNDATIONS

<p>| | | | | |</p>
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</thead>
<tbody>
<tr>
<td>2.1</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>WALL FOUNDATIONS: Foundations are constructed of rock base or concrete and are continuous under walls and around the perimeter of the building. There is a continuous plinth beam at the base of all walls and the columns are dowelled into the foundation where present. Footings are embedded a minimum of 50cm below grade.</td>
</tr>
<tr>
<td>2.2</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>FOUNDATION PERFORMANCE: There shall be no evidence of excessive foundation movement such as settlement or lift that would affect the integrity or strength of the structure.</td>
</tr>
<tr>
<td>2.3</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>OVERTURNING: The total height above the base of the foundation level is no more than three times the narrowest dimension of the lateral system.</td>
</tr>
<tr>
<td>2.4</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>TIES BETWEEN FOUNDATION ELEMENTS: For all sloped sites (&gt;10% grade) or for soft sites, the foundation elements shall be interconnected by reinforced concrete slab, and footings and reinforced concrete plinth beams shall be continuous underneath all walls.</td>
</tr>
<tr>
<td>2.5</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>DETERIORATION: There shall not be evidence that foundation elements have deteriorated excessively due to corrosion, sulfate attack, material breakdown, or other reasons in a manner that would affect the integrity or strength of the structure.</td>
</tr>
</tbody>
</table>

## BUILDING SYSTEM

<p>| | | | | |</p>
<table>
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<tbody>
<tr>
<td>3.1</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>MATERIALS: Materials used for the gravity and lateral load resisting systems shall consist of reinforced concrete and concrete masonry for the floor and walls, and a lightweight wood and metal roof system.</td>
</tr>
<tr>
<td>3.2</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
<td>LOAD PATH: A minimum of two separate lines of wall is required in each direction; an additional line of walls is required for each additional 4.5 m of building dimension over 4.5 m. Walls considered for lateral resistance shall be at least 1.0m long. Parallel walls are located no greater than 4.5 m apart. Walls shall be connected to the diaphragm at the top and bottom by a continuous reinforced concrete floor or plinth beam that is centered on the wall and contiguous with the floor slab.</td>
</tr>
</tbody>
</table>
3.0 **BUILDING SYSTEM**

<table>
<thead>
<tr>
<th>3.4</th>
<th>C</th>
<th>NC</th>
<th>N/A</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STORY HEIGHTS:</strong> The maximum story height is 3.0 m from the ground floor slab.</td>
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<thead>
<tr>
<th>3.7</th>
<th>C</th>
<th>NC</th>
<th>N/A</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WALLS:</strong> Walls shall consist of at least 15cm thick concrete masonry units with sand cement mortar with no less than 50% net solid area.</td>
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<thead>
<tr>
<th>3.9</th>
<th>C</th>
<th>NC</th>
<th>N/A</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DAMAGE:</strong> Structures have no earthquake or excessive weather related damage to the masonry walls or roof system. Damaged buildings are NON-COMPLIANT but may be repaired per the MTPTC guidelines to become COMPLIANT.</td>
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</table>

3.0 **BUILDING SYSTEM**

<table>
<thead>
<tr>
<th>4.0</th>
<th><strong>MASONRY WALLS</strong></th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>C</td>
<td>NC</td>
</tr>
<tr>
<td><strong>MASONRY CONFINEMENT:</strong> Walls shall be tightly installed to the soffits of the ring beam and to the columns where present. Formwork shall not be present between the top of the masonry and underside of the roof beam.</td>
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<table>
<thead>
<tr>
<th>4.2</th>
<th>C</th>
<th>NC</th>
<th>N/A</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPENINGS:</strong> Doors, windows and other openings wider than 0.6m shall extend to the ring beam above, or shall be provided with a reinforced concrete lintel beam. Lintel beams shall extend a minimum of 15cm into the adjacent masonry or shall be connected to an adjacent concrete boundary column or trim reinforcement.</td>
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<table>
<thead>
<tr>
<th>4.3</th>
<th>C</th>
<th>NC</th>
<th>N/A</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOP RING BEAM:</strong> Buildings constructed with light-weight wood/metal roofs shall have a continuous reinforced concrete ring beam at the top of the walls to transfer out-of-plane forces to cross walls. Ring beams shall span over door openings where present. Roof systems shall be positively anchored to ring beams.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>4.4</th>
<th>Transverse</th>
<th>C</th>
<th>NC</th>
<th>N/A</th>
<th>Longitudinal</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WALL AREA PERCENTAGE:</strong> For existing building evaluation the provided Wall Area Percentage in each direction shall be 3% for URM and 1.5% for CM/IM construction in average condition, and 4.5% for URM and 2% for CM/IM in poor condition. Increase these values by one third for evaluation of a proposed Retrofit Design.</td>
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<thead>
<tr>
<th>5.0</th>
<th><strong>BUILDING CONFIGURATION</strong></th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2</td>
<td>C</td>
<td>NC</td>
</tr>
<tr>
<td><strong>ADJACENT BUILDINGS:</strong> If floor and roof slabs of adjacent buildings are not vertically aligned, then the contact distance shall be greater than 3 cm for single story structures, 6 cm for two-story structures, and 9 cm for 3-story structures. If floors and roof slabs are aligned the item is compliant.</td>
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</tbody>
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<table>
<thead>
<tr>
<th>6.0</th>
<th><strong>BUILDING COMPONENTS</strong></th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>C</td>
<td>NC</td>
</tr>
<tr>
<td><strong>FREESTANDING/DISCONTINUOUS CONCRETE COLUMNS:</strong> Free-standing columns shall be reinforced concrete in good condition, with a minimum clear height of 1.5m, and a minimum dimension of 6”. Column bases shall be connected to the remainder of the building by a continuous foundation or reinforced concrete slab.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>6.3</th>
<th>C</th>
<th>NC</th>
<th>N/A</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PARAPETS:</strong> There shall be no laterally unsupported unreinforced masonry parapets or cornices with height-to-thickness ratios greater than 1.5. Masonry parapets must be in good condition with masonry units bonded to each other and to the supporting roof slab.</td>
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</table>

Refer Evaluation and Retrofit Manual for a more detailed explanation of each item. Numbering is not intended to be continuous.
### GEOLOGIC SITE HAZARDS

<table>
<thead>
<tr>
<th></th>
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<th>NOTES</th>
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<tbody>
<tr>
<td>1.1</td>
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<td>1.2</td>
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<tr>
<td>1.3</td>
<td>C</td>
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<tr>
<td>1.4</td>
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### FOUNDATIONS

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<thead>
<tr>
<th></th>
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<th>NOTES</th>
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<tbody>
<tr>
<td>2.1</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
</tr>
<tr>
<td>2.2</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
</tr>
<tr>
<td>2.3</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
</tr>
<tr>
<td>2.4</td>
<td>C</td>
<td>NC</td>
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<tr>
<td>2.5</td>
<td>C</td>
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### BUILDING SYSTEM

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<tbody>
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<td>3.1</td>
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<td>N/A</td>
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<tr>
<td>3.2</td>
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<td>NC</td>
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### BUILDING SYSTEM

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<th>NOTES</th>
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<tbody>
<tr>
<td>3.3</td>
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<td>NC</td>
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<tr>
<td>3.4</td>
<td>C</td>
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</tr>
<tr>
<td>3.5</td>
<td>C</td>
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<td>3.6</td>
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<tr>
<td>3.7</td>
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<td>NC</td>
<td>N/A</td>
</tr>
<tr>
<td>3.8</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
</tr>
<tr>
<td>3.9</td>
<td>C</td>
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<td>N/A</td>
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### MASONRY WALLS

<table>
<thead>
<tr>
<th></th>
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<th>NOTES</th>
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<tbody>
<tr>
<td>4.1</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
</tr>
<tr>
<td>4.2</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
</tr>
<tr>
<td>4.3</td>
<td>C</td>
<td>NC</td>
<td>N/A</td>
</tr>
</tbody>
</table>
## MASONRY WALLS

### WALL AREA PERCENTAGE

The provided Wall Area Percentage shall be greater than the required Wall Area Percentage at each level and in each direction. Note the Wall Area Percentage provided and required on the right, and C, NC, or N/A in the column to the left.

<table>
<thead>
<tr>
<th>Story</th>
<th>Transverse</th>
<th>Longitudinal</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>C-NC-N/A</td>
<td>C-NC-N/A</td>
</tr>
<tr>
<td>2</td>
<td></td>
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<tr>
<td>1</td>
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</tbody>
</table>

#### Assumptions:

- Sds = 1.05g, for other design ground motion values ratio accordingly.
- URM construction. For compliant CM or IM construction use 50% of these values, 1.5% minimum.
- "Average" quality construction. For poor quality construction increase by 50%.
- Concrete block strength is 4.8MPa. See Manual for adjustment to other strengths if required.
- Building Evaluation, increase by one third for evaluation of a proposed Retrofit Design.
- Block is typical 15cm, between 50% to 60% solid, and not plastered. For other thicknesses and net solid area ratios adjust the required WAP accordingly.

### # Stories in Building

<table>
<thead>
<tr>
<th>Level</th>
<th>1-Story</th>
<th>2-Story</th>
<th>3-Story</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>4.7</td>
<td>For buildings with heavy floors and roofs having concrete slabs, concrete joists, and masonry void forms.</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>4.6</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4.0</td>
<td>6.9</td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3.0</td>
<td>For buildings with light roofs made of sheet metal and wood framing.</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>3.0</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3.0</td>
<td>4.0</td>
<td>6.9</td>
<td></td>
</tr>
</tbody>
</table>

### BUILDING CONFIGURATION

5.0

#### NOTES

<table>
<thead>
<tr>
<th>Story</th>
<th>Required</th>
<th>Provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
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<td></td>
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<tr>
<td>2</td>
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#### NOTES

<table>
<thead>
<tr>
<th>Story</th>
<th>Required</th>
<th>Provided</th>
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<tbody>
<tr>
<td>Longitudinal</td>
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<td></td>
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<td></td>
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<td>2</td>
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<td>1</td>
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</tbody>
</table>

5.1 C NC N/A

TORSION: Walls are located on all exterior sides of the building, or within 25% of the plan dimension at the wall location, including L-shaped and T-shaped plans. Alternatively the estimated distance between the center of mass and the center of rigidity shall be less than 20% of the maximum building width in either plan dimension.

5.2 C NC N/A

ADJACENT BUILDINGS: If floor and roof slabs of adjacent buildings are not vertically aligned, then the contact distance shall be greater than 3 cm for single story structures, 6 cm for two-story structures, and 9 cm for 3-story structures. If floors and roof slabs are aligned the item is compliant.
### 5.0 BUILDING CONFIGURATION

| 5.3 | C NC N/A | VERTICAL DISCONTINUITIES: Second story walls are generally located on top of lower story walls. Second story walls that do not align with lower story walls are supported on both ends by any of the following, and do not span more than 3.0m unsupported:  
- Complying freestanding columns, see separate checklist item for requirements.  
- Perpendicular walls that extend at least 60cm each side of the wall above.  
- Parallel walls with at least ¾ length (30cm minimum) of the upper wall overlapping with the lower wall.  
This statement does not apply to single story buildings. |

### 6.0 BUILDING COMPONENTS

| 6.1 | C NC N/A | FREESTANDING/DISCONTINUOUS CONCRETE COLUMNS: Free-standing columns supporting concrete floor/roof slabs or discontinuous masonry walls shall meet the following minimum requirements:  
- Columns shall be reinforced concrete in good condition, with a minimum clear height of 1.5m.  
- Column bases shall be connected to the remainder of the building by a continuous foundation or reinforced concrete slab.  
- Columns shall have a minimum dimension of 6” when supporting a concrete roof or patio, 8” when supporting a one-story discontinuous wall, and 12” when supporting a two-story discontinuous wall above. |

| 6.2 | C NC N/A | SLAB OPENINGS AT SHEAR WALLS: Slab openings adjacent to shear walls shall meet the following requirements:  
- Openings immediately adjacent to the shear walls shall be less than 25% of the wall length.  
- Slab openings at exterior masonry walls shall be less than 2.5m in length, and a reinforced concrete beam shall extend the length of the wall adjacent to the opening. |

| 6.3 | C NC N/A | PARAPETS: There shall be no laterally unsupported unreinforced masonry parapets or cornices with height-to-thickness ratios greater than 1.5. Masonry parapets must be in good condition with masonry units bonded to each other and to the supporting roof slab. |

| 6.4 | C NC N/A | STAIRS: Stairs shall meet the following requirements:  
- Stairs shall be connected at each elevated level to the building slab or roof by a continuous reinforced concrete landing. Stairs shall not depend on the building walls for vertical support.  
- Vertical support for stairs or landings shall be provided by compliant freestanding columns, or by masonry walls at least 0.6m long.  
- Stair foundation components shall be constructed of rock base or concrete footing that is embedded a minimum of 30cm below grade. On sloped sites (>10%) or soft sites the stair foundation shall be continuous with the remainder of the building. |