THE 2010 HAITI EARTHQUAKE

HAITI EMERGENCY SHELTER REHABILITATION
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1. Introduction

The catastrophic 2010 Haiti Earthquake has had a tragic effect on the lives of more than 3 million people. This report describes the work performed by the Haitian Ministry of Public Works, Transport, and Communications (MTPTC) to assess the safety of much of the affected building inventory in Port-au-Prince and other communities.

In light of the enormity of the damage caused by the earthquake, MTPTC created the Bureau d’Évaluation Technique des Bâtiments (BETB), a dedicated agency charged with the tasks of assessing damage to all buildings in earthquake-affected areas, developing criteria for repair and reconstruction, and providing quality control (QC) for reconstruction. With funding provided by the World Bank and the U.S. Agency for International Development (USAID), field logistics provided by the United Nations Office of Project Services (UNOPS) and the Pan American Development Foundation (PADF), and technical expertise provided by the authors, BETB embarked on an ambitious program to organize and train a cadre of approximately 250 Haitian national engineers to perform rapid evaluation of all affected buildings using the internationally accepted ATC-20 (ATC 2005) and FEMA 310 (FEMA 1998) methodologies.

The authors (Miyamoto, Gilani, and Wong, 2011) led a four-day intensive classroom session on the fundamentals of earthquake engineering and assessment for more than 600 applicants. Course work was followed by a written examination, from which approximately 250 candidates were selected as evaluators. Among those, 10 of the most qualified were selected as division leaders. Division leaders were given additional field training before commencing work with their division members. Each of the divisions consisted of a division leader, four team leaders, and eight to 10 evaluators, all taken from the ranks of the 250 trainees.

From the information gathered during the damage assessments, damage patterns and subsequent repair guidelines were established. For this, damage assessment teams were provided additional training to take yellow tagged structures and determine required repairs for safe occupancy of the buildings. All damage assessment divisions were trained by Miyamoto International. The information gathered during this second tier assessment process is the basis for the repair of yellow tagged buildings.
2. January 2010 Haiti Earthquake

The magnitude 7.0 event occurred at 1653 local time on Tuesday, 12 January 2010, with an epicenter approximately 25 km west-southwest of the capital city of Port-au-Prince. In the two weeks following the main event, at least 52 aftershocks in the magnitude range of 4.2 to 5.9 were recorded. Table 1 presents the shaking intensity experienced in Port-au-Prince (USGS 2010) as represented by the Modified Mercalli Intensity (MMI) scale. Note that a large portion of the capital experienced very large shaking that exceeded the destructive level.

Table 1. Modified Mercalli Intensity (MMI) Shaking Intensity and Affected Population in Port-Au-Prince

<table>
<thead>
<tr>
<th>Est. MMI</th>
<th>Est. Population Exposure</th>
<th>Classification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>–</td>
<td>Weak</td>
<td>Not felt</td>
</tr>
<tr>
<td>II-III</td>
<td>50,000</td>
<td>Slight</td>
<td>Felt by a few</td>
</tr>
<tr>
<td>IV</td>
<td>7,470,000</td>
<td>Moderate</td>
<td>Noticeable</td>
</tr>
<tr>
<td>V</td>
<td>6,360,000</td>
<td>Rather strong</td>
<td>Felt indoors</td>
</tr>
<tr>
<td>VI</td>
<td>930,000</td>
<td>Strong</td>
<td>Felt by all</td>
</tr>
<tr>
<td>VII</td>
<td>600,000</td>
<td>Very strong</td>
<td>Minor damage</td>
</tr>
<tr>
<td>VIII</td>
<td>2,030,000</td>
<td>Destructive</td>
<td>Great damage to poorly constructed buildings</td>
</tr>
<tr>
<td>IX</td>
<td>910,000</td>
<td>Violent</td>
<td>Damage and partial collapse of substantial buildings</td>
</tr>
<tr>
<td>X</td>
<td>120,000</td>
<td>Intense</td>
<td>Most masonry structures destroyed</td>
</tr>
</tbody>
</table>

Although the event had a relatively large intensity, the resulting catastrophic damage was disproportional to its magnitude. Poor design and construction practices and a lack of preparedness contributed to the extensive level of damage and suffering.

2.1 Human and financial Cost of the Earthquake

As listed in Table 2, the human and financial consequences of this event are staggering. Many landmark structures, including the Presidential Palace, the UN headquarters, and the city cathedral, were destroyed. The earthquake also severely damaged the country’s infrastructure, including hospitals, roads, ports, and the airport. A photograph of Port-au-Prince after the January earthquake is presented in Plate 1.
Table 2. Human and financial cost of the earthquake

<table>
<thead>
<tr>
<th>Human and Financial Metric</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>People affected</td>
<td>3,000,000</td>
</tr>
<tr>
<td>Fatalities</td>
<td>300,000+</td>
</tr>
<tr>
<td>People injured</td>
<td>300,000</td>
</tr>
<tr>
<td>People made homeless</td>
<td>1,000,000–1,800,000</td>
</tr>
<tr>
<td>Residences collapsed or damaged</td>
<td>250,000</td>
</tr>
<tr>
<td>Commercial buildings collapsed or damaged</td>
<td>30,000</td>
</tr>
<tr>
<td>Economic cost</td>
<td>US$14,000,000,000</td>
</tr>
<tr>
<td>Cost as percentage of GDP</td>
<td>~15%</td>
</tr>
<tr>
<td>Recovery time</td>
<td>Years</td>
</tr>
</tbody>
</table>

Plate 1. Port-au-Prince after the 2010 Haiti earthquake

2.2 Earthquake Aftermath

This earthquake had a devastating effect on Haiti. Several factors contributed to this outcome, including the following:

- Haiti is the poorest country in the Western Hemisphere, and given its scarce resources, adequate planning was not in place to deal with a catastrophe of such a large magnitude.
- Haiti had not experienced a major earthquake for some time. As such, the country’s resources were diverted elsewhere. This had a twofold effect, including both a lack of proper seismic code
for design and construction and a general lack of preparedness to deal with the consequences of such an event.

- This event struck in the center of a metropolis and adversely affected the institutions (such as the UN and the Haitian government) that would usually be asked to develop a plan and deal with the aftermath of the earthquake. Many personnel who would provide assistance and structures that would be used for emergency operations were casualties of this earthquake.

- Damage to the infrastructure, including roads, adversely affected the response time. Damage to ports and the airport caused delays in humanitarian aid being delivered to the country. After such aid arrived, the lack of adequate infrastructure or a distribution network hampered its disbursement.

2.3 Main Causes of Building Damage

This earthquake caused devastation disproportional to its magnitude. Building damage and the resulting loss of life can be directly attributed to poor design and construction practices and a lack of quality control (QC). For example, if the international standards of seismic design and construction in use in many parts of the world had been used in Haiti, much of the life and economic loss could have been avoided. The main factors contributing to the excessive building damage and exacerbating this tragedy were the following:

- Design and construction practices had not considered earthquake forces.
- Many engineers and contractors had neither education nor experience in earthquake-resistant design methodologies.
- Haiti lacked an earthquake engineering code.
- The past decade has seen rapid growth of low-income neighborhoods because of migration into the city from outlying areas. In these neighborhoods, unsafe housing had been built using substandard construction materials and practices.

Many of the structures in Haiti are of a building type that is vulnerable to seismic damage. These buildings use a variation of confined masonry construction comprising weak hollow concrete blocks (HCBs) with lightly reinforced and nonductile beams and columns.
2.4 Typical Building Characteristics

Although the buildings surveyed displayed a wide variety of sizes and architectural styles, virtually all were constructed using a similar structural system: a cast-in-place concrete gravity frame with unreinforced HCB infill panels (see Plate 2). In typical buildings, these infill panels were not designed as structural elements. However, given their stiffness and their connection to the adjacent members, they acted as infill structural walls and altered the response of the buildings.

Plate 2. Typical Haitian construction

In such structures, the concrete floor and roof slabs are supported by lightly reinforced concrete columns, sometimes as small as 150 mm on each side. Floor and roof framing consists in some cases of a grid of concrete joists framing between the beams; voids between the joists are created using HCBs as stay-in-place forms. Exterior wall cladding and interior partition walls universally consist of HCBs joined with cement mortar.

These infill wall panels effectively serve as the seismic-force-resisting system; however, there was typically no evidence of any system intentionally designed for that purpose. Buildings typically lack a seismic load path; in other words, they do not appear to have a system by which inertial forces generated in one portion of the structure could be transferred to other parts of the structure and then to the ground. In seismic zones, this load path commonly comprises diaphragms, collector elements such as chord and drag reinforcing, special vertical reinforcing at shear wall corners, and doweling.
between the walls and surrounding elements. None of these was present in the vast majority of buildings observed.

Concrete gravity frames utilized numerous design and construction practices that would be considered defective by international standards, particularly in seismic zones.

General design deficiencies include the following:

- Small column size
- Poor seismic detailing, including an insufficient amount of longitudinal reinforcement, the use of smooth reinforcing bars, a lack of confinement such as column transverse bars, and short lap splices (see Plate 3)
- Presence of captive columns (see Plate 4†)

Plate 3. Lack of column confinement

† Captive columns occur when partial-height infills are attached to the columns. This reduces the effective length of the columns and alters the force pattern in them, often resulting in shear or compressive failures.
General construction defects consist of the following:

- Segregation, voids, and rock pockets evident in finished concrete, particularly in columns and at construction joints (see Plate 5)
- Exposed rebar, and poor aggregate shape and grading
- Poorly located construction joints, and paper and other debris left in joints; formwork embedded in finished concrete (see Plate 6)
- Out-of-plumb columns
Plate 5. Rock pockets in concrete construction

Plate 6. Poor workmanship and formwork in concrete construction
Masonry construction also has numerous defects, including irregular coursing, missing or inadequate vertical mortar joints, inadequate horizontal joints, poor material quality, and the extensive use of broken blocks (see Plate 7). These conditions were commonly found in nearly all buildings, regardless of age, size, or number of stories. These design and construction practices led to a combination of heavy buildings with little lateral strength and essentially no post-yielding capacity, and were key factors in the vast majority of failures observed.

Plate 7. Poor workmanship in masonry construction

### 3. Damage Assessment Program

#### 3.1 Overview

After emergency response to an earthquake, the next step is to implement a damage assessment program. In the United States and many other countries, engineers and other professionals are trained beforehand and are sent to the disaster site immediately after an earthquake. These individuals examine and determine the status of each building. This process allows many citizens to return quickly to their homes if they are deemed safe. Such a mechanism was not in place in Haiti. As such, more than 1 million people—possibly as many as 1.8 million—ended up in temporary shelters (tents) after the earthquake (see Plate 8).
Plate 8. Temporary shelters

Damage assessment is also the initial step toward reconstruction and recovery efforts. In addition to identifying safe and dangerous buildings, it is used to identify safe and dangerous construction practices, and to assist in developing demolition plans and reconstruction strategies.

### 3.2 Assessment Program

The primary objectives of the damage assessment program were to:

- Perform rapid identification of building safety using a well-recognized standard geared toward Haiti construction and state-of-the-art technology
- Compile a database of the assessed buildings to assist in accurate estimation of debris for removal and in planning reconstruction strategies
- Build the local technical capacity by educating local Haitian engineers to serve as trainers for a larger pool of Haitians who would serve as both damage assessors and reconstruction evaluators

The remainder of this paper focuses on these particular efforts. In total, approximately 400,000 buildings were assessed, and a new group of Haitian engineers was trained in the process. A companion paper addresses the demolition and reconstruction activities. The assessment program yielded many life-saving and useful results, and in particular allowed many people to reoccupy homes that had been inspected and found to be safe.
3.3 Training and Assessment Process

The damage assessment program was executed by UNOPS and PADF, and was funded by the World Bank and USAID. In total, 600 Haitian engineers were trained. The assessment team was broken into 17 divisions with 250 engineers. Each division comprised a division leader, two assistant division leaders, and 12 engineers. Miyamoto engineers traveled from the United States, and each was assigned to two to five divisions to supervise and consult. Plate 9 depicts one of the damage assessment teams tagging a surveyed building.

With all 17 teams working at capacity, it was possible to assess more than 3,000 structures daily. The damage assessment progress was as follows:

- The initial target of 100,000 structures met by 31 May 2010
- 133,000 structures by 15 June 2010
- 250,000 structures by the end of August 2010
- 400,000 buildings (all 400,000 structures in the earthquake-affected area) by March 2011
Evaluations were performed systematically, with each division given the responsibility to evaluate all the structures in a given zone each day. Zones were determined by MTPTC using aerial maps and were based on communities. The zone maps were updated daily to show the status of each evaluated structure. As each zone was completed, new ones were assigned.

3.4 Damage Assessment Methodology

The evaluation method chosen for this program was based on the techniques outlined in the ATC-20 (ATC 2005) Rapid Assessment. This procedure was modified to adapt to Haitian conditions and to provide information that is more useful to MTPTC. The form was modified to provide evaluators with a checklist of Earthquake Vulnerability Factors per FEMA 310 (FEMA 1998), which allowed the evaluators to list the features of each structure that would make it more prone to earthquake damage. Appendix A presents a sample sheet used for damage assessment in Haiti.

The ATC-20 methodology, which was first developed in California in the 1980s, has been used successfully for evaluation after many major earthquakes in the United States. The Rapid Assessment Form allows evaluators to characterize buildings in one of three ways:

- **Green-tagged (Inspected)**, meaning that the building is structurally undamaged and may be occupied full-time
- **Yellow-tagged (Restricted Entry)**, meaning that the building should not be occupied for extended periods and that parts of the building might be considered off-limits
- **Red-tagged (Unsafe)**, meaning that the building cannot be safely inhabited

Plate 10 presents the completed damage assessment map showing the green-, yellow-, and red-tagged structures.

Plate 10. Completed damage assessment map of Port-au-Prince
One important consideration that was stressed to the evaluators is that while the three-color evaluation system provides an understanding of the hazard associated with a building at the time of the evaluation, it does not state whether a building must be demolished. Some red-tagged buildings were considered repairable, but the nature of the damage had rendered them unsafe to occupy until repairs could be completed. In the same way, the green-tagged designation does not guarantee that a building will not be seriously damaged in the event of future earthquakes. If another major event of equal or greater magnitude were to take place along a section of the Enriquillo-Plantain Garden fault zone closer to the city, in all likelihood, damage would be much more widespread. In general, as discussed earlier, the design and construction practices in Haiti have resulted in nearly all the buildings’ being vulnerable to earthquake damage.

One feature of the damage assessment process was the use of a satellite geographic-coordinate-based computer data collection and organization system. Personal digital assistants (PDAs) with Global Positioning System (GPS) capability were used to assist in performing the evaluations. The PDAs were preloaded with the modified ATC-20 Damage Assessment Form, and evaluators filled out the forms electronically during the course of each assessment. At the end of the day, all the information from the more than 150 PDAs was uploaded to a main server. Because some of the street layout of Port-au-Prince is unmapped and many residences have no street addresses, the GPS coordinates of each structure were used as the primary means of identification. The use of GPS has also proved to be an invaluable tool in developing overall damage maps and a reconstruction strategic plan.

3.5 Collected Data Categories
The damage assessment database includes the following data:

- Building characteristics
- Building occupancy
- Building GPS location
- Information about the assessor
- Observed damage
- Digital photos of the subject building
- Assigned tag
3.6 Damage Classification

During the assessment process, the damage to each structure (regardless of the assigned tag) was classified in the following subsets:

- None (0%)
- 0.1% to 1%
- 1% to 10%
- 10% to 30%
- 30% to 60%
- 60% to 99%
- Total (100%)

These classifications were to some extent subjective. However, they were used to quantify the performance of various types of buildings, as discussed in the following sections. The data was then normalized for each subset of buildings, and the median (50th percentile) damage estimate was computed.

3.7 Damage Assessment Results

3.7.1 Building Damage Summary

Table 3 summarizes the number and the median damage estimate of the 398,829 buildings evaluated. In this pool of assessed structures, 53% were undamaged and safe for tenants to reoccupy, and 26% had moderate damage and likely can be repaired. These numbers are significant, because they indicate that approximately 80% of the buildings affected by the earthquake could be occupied immediately or repaired. This, in turn, allowed citizens to return to their homes and depopulate the temporary shelters.

Table 3. Summary Data of Damage Assessment

<table>
<thead>
<tr>
<th>Tag</th>
<th>Green-</th>
<th>Yellow-</th>
<th>Red-</th>
<th>NA*</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of buildings</td>
<td>213,083</td>
<td>102,147</td>
<td>79,481</td>
<td>4,118</td>
<td>398,829</td>
</tr>
<tr>
<td>Percentage</td>
<td>53%</td>
<td>26%</td>
<td>20%</td>
<td>1%</td>
<td>100%</td>
</tr>
<tr>
<td>Median damage estimate</td>
<td>0%–1%</td>
<td>10%–30%</td>
<td>60%–100%</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

*“NA” denotes not available. Entries for these buildings (approximately 1% of the total) were not recorded.

The majority of the damaged and collapsed buildings are in the low-lying districts west of the airport, which include downtown Port-au-Prince, Nazon, Turgeau, Canape Vert, Carrefour, and the lower portion of Delmas. By contrast, more southerly, and easterly regions, in particular Juvenat and Pétion-Ville, suffered much lighter damage (see Plate 10). The difference in damage levels is mainly a result of soft-soil amplification (Seed and Idriss 1982), geographical effects, and construction quality. Softer soil is found in many of the high-damage areas.
3.7.2 Damage Classification

By far, the most common damage found among the buildings evaluated was cracking or collapse of the HCB walls, which is a natural consequence of both the lack of reinforcing and the poor material quality. Among the buildings evaluated, moderate or serious wall cracking was cited in nearly 160,000 cases. Wall collapse was noted in approximately 120,000 cases. Cracking was observed to be most widespread in the lower levels of multistory buildings, where shear forces were highest. The next most common damage mode was either cracking or crushing failure of concrete columns, in about 91,000 cases. Table 4 summarizes the damage types by number and percentage of total buildings assessed.

Table 4. Comparison of Damage Types Found in the Greater Port-Au-Prince Area

<table>
<thead>
<tr>
<th>Damage classification</th>
<th>Total No. of buildings</th>
<th>Percentage of total*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior, interior wall cracking</td>
<td>159,574</td>
<td>40%</td>
</tr>
<tr>
<td>Exterior, interior wall collapse</td>
<td>119,287</td>
<td>30%</td>
</tr>
<tr>
<td>Column cracking or spalling</td>
<td>91,391</td>
<td>23%</td>
</tr>
<tr>
<td>Slab, beam, joist cracking or spalling</td>
<td>73,899</td>
<td>19%</td>
</tr>
<tr>
<td>Parapet, canopy, deck, stair damage</td>
<td>60,204</td>
<td>15%</td>
</tr>
<tr>
<td>Ground movement or cracking</td>
<td>52,909</td>
<td>13%</td>
</tr>
</tbody>
</table>

*Note: Percentages were taken as the total number of affected structures divided by the number of surveyed units (398,829). Percentages in this column exceed 100% when added because: (a) many structures had more than one classification of damage, and (b) some of the buildings did not experience the classifications of damage listed in this table.

3.7.3 Damage by Building Occupancy

Overall, damage did not vary substantially between building occupancies, but some trends can be seen from the data. The vast majority of evaluated buildings (approximately 290,000 units, or approximately 73% of the total number of assessed buildings) were single-family residential structures. These structures varied widely in quality of construction, and ranged from large, engineered mansions to improvised shacks. Table 5 presents the distribution of damage for various building occupancies.

Table 5. Classification (%) for Various Color Tags and Building Occupancy Types

<table>
<thead>
<tr>
<th>Building occupancy</th>
<th>No. of buildings</th>
<th>Green-</th>
<th>Yellow-</th>
<th>Red-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-family residential buildings</td>
<td>290,381</td>
<td>54%</td>
<td>25%</td>
<td>21%</td>
</tr>
<tr>
<td>Multifamily residential buildings</td>
<td>70,175</td>
<td>54%</td>
<td>30%</td>
<td>16%</td>
</tr>
<tr>
<td>Schools</td>
<td>3,317</td>
<td>49%</td>
<td>30%</td>
<td>21%</td>
</tr>
<tr>
<td>Healthcare buildings</td>
<td>857</td>
<td>64%</td>
<td>22%</td>
<td>14%</td>
</tr>
<tr>
<td>Civic/public-safety facilities</td>
<td>4,061</td>
<td>56%</td>
<td>26%</td>
<td>18%</td>
</tr>
<tr>
<td>Commercial/industrial facilities</td>
<td>15,974</td>
<td>64%</td>
<td>21%</td>
<td>15%</td>
</tr>
<tr>
<td>Other</td>
<td>3,935</td>
<td>51%</td>
<td>28%</td>
<td>21%</td>
</tr>
</tbody>
</table>
The performance of essential facilities, such as hospitals and public-safety facilities was not adequate. In healthcare, for example, the damage rate corresponds to a loss of healthcare capacity of approximately 36% immediately after the earthquake, a time when this capacity was needed most.

It is alarming that one of the worst performance levels among occupancy types was experienced by schools, for which more than 50% were tagged as either yellow or red. An example of a severely damaged school is shown in Plate 11. In general, school buildings are vulnerable for primarily two reasons: (a) The presence of many windows introduces captive columns in the structure, and (b) fewer wall elements are used per square meter of the structure. Although this data was not measured during the assessment, such construction is typical. These vulnerabilities are common in many other countries, as well. For example, the authors witnessed more than 7,000 classrooms that were destroyed in the 2008 Sichuan, China, Earthquake (Miyamoto, Gilani, and Wada 2011).

Plate 11. Damaged school building

3.7.4 Damage as a Function of the Number of Stories

In general, among the structures evaluated, building performance (as measured by the percentage of red-tagged structures in each group) was progressively worse as building height increased, and tall buildings were much more prone to severe damage. Of the buildings that were four stories or more in height, 40% were red-tagged, versus 20% for one-story buildings (see Table 6). In other words, the potential for catastrophic failure or collapse is almost twice as high for four-story or taller buildings than for one-story buildings.
Table 6. Classification (%) for Various Color Tags and Number of Stories

<table>
<thead>
<tr>
<th>No. of stories</th>
<th>No. of buildings</th>
<th>Green-</th>
<th>Yellow-</th>
<th>Red-</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>325,106</td>
<td>54%</td>
<td>26%</td>
<td>20%</td>
</tr>
<tr>
<td>Two</td>
<td>63,547</td>
<td>55%</td>
<td>26%</td>
<td>19%</td>
</tr>
<tr>
<td>Three</td>
<td>8,776</td>
<td>42%</td>
<td>27%</td>
<td>31%</td>
</tr>
<tr>
<td>Four or more</td>
<td>1,365</td>
<td>35%</td>
<td>25%</td>
<td>40%</td>
</tr>
<tr>
<td>NA*</td>
<td>35</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

*“NA” denotes not available.

3.7.5 Damage as a Function of Building Irregularities

Building irregularities such as setbacks, discontinuous shear walls, soft stories, and coupled shear walls had an adverse effect on building performance. Modern seismic codes require engineers to either avoid these cases or design the building for higher forces to account for the adverse effect of the irregularities. Table 7 presents the surveyed buildings with vertical irregularities. For reference, data from Table 3 (which includes all buildings surveyed and is repeated here as the first row of the table) is also included. As the table shows, the introduction of vertical irregularities significantly increased the chance of a building’s being tagged red- or yellow. In particular, it is noted that approximately 50% of all buildings with captive columns were red-tagged. This number is in contrast to the overall 20% red-tagged buildings for the total surveyed population.

Table 7. Classification (%) for Various Vertical Irregularities

<table>
<thead>
<tr>
<th>Vertical irregularity</th>
<th>No. of buildings</th>
<th>Green-</th>
<th>Yellow-</th>
<th>Red-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire pool</td>
<td>398,829</td>
<td>54%</td>
<td>26%</td>
<td>20%</td>
</tr>
<tr>
<td>Soft story</td>
<td>35,624</td>
<td>55%</td>
<td>24%</td>
<td>21%</td>
</tr>
<tr>
<td>Setback</td>
<td>24,707</td>
<td>55%</td>
<td>22%</td>
<td>23%</td>
</tr>
<tr>
<td>Captive column</td>
<td>22,276</td>
<td>36%</td>
<td>15%</td>
<td>49%</td>
</tr>
<tr>
<td>Pounding</td>
<td>43,625</td>
<td>48%</td>
<td>27%</td>
<td>25%</td>
</tr>
</tbody>
</table>

The actual performance of buildings with these irregularities, particularly soft stories and captive columns, was likely worse than shown by the data in Table 7. In many instances, soft stories and captive columns led to the total collapse of a building, making the underlying irregularity difficult to detect.
4. Reconstruction

At the conclusion of the damage assessment program, just a little more than a year after the earthquake, nearly 450,000 people had returned to the buildings deemed safe (green-tagged) as a result of the program. However, many people were still living in temporary camps, many of which may offer only minimal services and minimal protection from natural hazards such as hurricanes, floods, and landslides.

One key component to further depopulating the camps is to repair the yellow-tagged buildings; see Plate 12 for a building being yellow-tagged, and Plate 13 for an example of a building that is yellow-tagged because of out-of-plane wall failure. Considering that currently as of this writing, more than 850,000 people are still living in temporary campsites, meeting the construction needs for these structures in a safe and timely manner is critical. The yellow-tagged structure repair program is an important component to enable all Haitian residents to move back to their communities safely. It is estimated that close to 600,000 people can return home after the yellow-tagged buildings have been repaired.

Plate 12. Building being yellow-tagged
The process to repair yellow-tagged buildings has incorporated the database developed as part of the damage assessment program. The Bureau d’Évaluation Technique des Bâtiments (BETB), created by MTPTC in the aftermath of the earthquake, is responsible for developing criteria for repair and reconstruction and providing quality control (QC) for reconstruction. The repair effort has relied heavily on the expertise of the authors, their colleagues in the United States, and the 250 Haitian engineers who were trained earlier as part of the damage assessment program.

4.1 Repair Procedure

The primary causes of building damage and the resulting loss of life were poor design and construction practices and a lack of QC. Many of the structures in Haiti use a variation of confined masonry construction comprising weak hollow concrete blocks (HCBs) with lightly reinforced and nonductile beams and columns. Virtually all the surveyed buildings were constructed with a structural system consisting of a cast-in-place concrete gravity frame with unreinforced HCB infill panels.

The repair plan focuses on this construction type, which is widespread in Haiti and rather unique to the region. This plan also focuses on and addresses the distinct types of problems documented in the damage assessment database. As part of this process, a repair guideline has been prepared to ensure consistency of repair efforts in Haiti.

The preferred repair method is to place horizontal and vertical reinforcement in the HCB walls, and use superior concrete mortar mix and masonry blocks (see Plate 14). This is one of the procedures discussed in the ASTM guidelines on masonry repair (ASTM 1993). This method was selected as the primary approach for repairing failed HCB walls because of the method’s good earthquake performance and economic benefits, and because local labor and materials are available for implementation. To demonstrate the method’s efficacy, a sample zone was selected and underwent reconstruction before the effort was extended to wider areas of the country.
During damage and repair assessment, the amount of corrosion and the percentage of material loss from corrosion in the reinforcing steel, as well as deterioration in the concrete members and concrete blocks in walls, are also observed and recorded for yellow-tagged buildings. If the effect of combined earthquake damage and material loss and deterioration warrants replacement in lieu of repair, then the structure is reclassified for demolition.

4.2 Quality Management for Damage and Repair Assessment and Construction of Yellow-Tagged Buildings

Unfortunately, there is ample evidence of repair of damaged structures using pre-earthquake, unsafe methods. Continuing such an approach would place the lives of the citizens of Haiti at risk again in the event of another large earthquake. Therefore, it is imperative to use an improved and safe repair plan that focuses on techniques, a QC plan, and an approval mechanism to reduce the future life-safety risk.

A quality management program has been developed to support the yellow-tagged structure assessment and repair program. A construction quality-monitoring platform has been developed and a PDA-based monitoring tool has been implemented for yellow-tagged structure repair. This tool has also been used to provide a construction quality control–quality assurance (QC-QA) process—QC is usually provided by the contractor internally and QA is supplied by the individuals providing construction inspection.

The authors have found that many Haitian engineers are more than capable of being trained in and implementing the yellow-tagged structure programs with a proper QC-QA program. This QC-QA program is also an integral part of the professional (engineering) personnel capacity development program in Haiti. Trained and experienced engineers from the damage assessment phase, yellow-
tagged structure assessment phase, and red-tagged structure assessment phase have been brought over to the QC-QA program.

The QC-QA program has incorporated the following components:

- Develop cost-effective and simple repair methodologies for typical residential buildings. The platform uses the existing research undertaken at leading technical research institutes that focus on these and similar types of construction, as described previously.
- Develop guidelines and programs to communicate to and train contractors and communities on how to repair and reconstruct residential structures. A simple illustrated guideline and training program have been developed. The guideline and training program have been developed for community implementation.
- Develop a repair assessment method and construction inspection plan. A PDA-based repair assessment method and QC-QA plan were developed.
- Develop and implement a project communications program for the repair guidelines. A mass media, strategic public communications campaign was initiated using the available modes of communication (including radio and community meetings) to inform the public about the repair plan and promote the use of improved repair methods.

4.3 Damage and Repair Assessment Programs for Yellow-Tagged Buildings

4.3.1 Overview

A damage and repair assessment program has been created to quantify the damaged buildings and develop repair methods for these buildings. These programs have relied on the data collected during the initial damage assessment phase. The data developed during this activity is then used to guide reconstruction efforts. To date, approximately 18,000 yellow-tagged buildings have been assessed for damage and repair.

4.3.2 Program Staff Training

This damage and repair assessment program is organized by divisions. Ten engineering divisions (150 local engineers) were deployed as part of the repair assessment program for yellow-tagged buildings. Each division has a leader and is made up of 5 to 7 assessment teams consisting of two Haitian engineers. Each engineer has been assigned a unique number and will maintain a list of the total number of structures that he or she evaluates.

To ensure consistency in evaluation, engineers were required to spend one full day of classroom training and one full day of training in the field. During the classroom training (see Plate 15), the attendees were instructed in: (a) the repair assessment program, (b) general information about earthquakes and earthquake engineering, (c) the types of damage expected to be observed in the structures during assessment, (d) probable causes of a given type of damage, and (e) how the damage would be repaired.
During the field training, engineers were divided into groups of eight to 10, and each group performed several repair assessments together. The group observed the outside and inside of the structure and discussed the damage seen. When the group reached agreement, the repair types and extent were marked on the walls. Half of the engineers input the data on the PDA while the other half created a sketch of the structure to plan map the required repairs. After data was collected and sketches were made, the trainer reviewed the sketches for legibility and accuracy, providing any necessary correction or feedback. The trainer also reviewed the data entered into the PDA for accuracy and completeness. For the next repair assessment, the engineers switched their PDA input and sketching responsibilities so that all engineers could practice each repair assessment task. When the full day of field training had been completed, the engineers were ready to start the repair assessments.

Plate 15. Classroom training for damage and repair assessment engineers

4.3.3. Program Components

Evaluation of the yellow-tagged buildings has involved preparing two documents:

- The Damage Assessment Form (DAF) contains detailed documentation of damage that is prepared during the initial visit and includes a preliminary repair plan.
- The Repair Assessment Form (RAF), prepared after the DAF, is a detailed repair plan that includes a procedure, quantities, and estimates.
The DAF includes the following:

- General information—Address, GPS coordinates, owner’s name, and tenant’s name and phone number
- Site and soil information
- Tag confirmation—Confirmation of the original evaluation tag and whether it should be changed
- Damage type—Typical damage types were identified for the most common masonry structures, up to two stories tall, in the database that was generated as part of the assessment program; for yellow-tagged buildings, damage types consist of minor and major cracking or failure of walls, lintel cracking, and concrete column cracking or spalling
- Damage identification—The locations and extent of earthquake damage are documented with a PDA and on a sketch of the floor plan; damage and required repairs are also indicated on the walls and columns inside the structure
- Repair plan—For each damage type, a repair plan has been predetermined, as discussed in the following.

The RAF includes the following information:

- Number and types of repairs
- Quantity of materials needed for repairs
- Cost estimate

The RAF is used by the engineer who is assigned to the repair team to document repairs and changes to the original proposed repairs. The RAF is kept as an official record of the repairs made to the structure by a qualified contractor and engineering team.

**4.3.4 Program Procedure**

For each yellow-tagged building, the damage and repair assessments are conducted by a team of two engineers. Both engineers observe the house from the outside and inside first, and work together to identify the observed damage and repair types, locations, and extent. When the repairs have been identified and damaged walls and columns have been numbered and marked, one engineer records all the required data on the PDA, and the other engineer sketches a plan of the structure to map the damage and repairs required.

When the data has been entered into the PDA and checked for accuracy and the sketch of the structure’s plan is complete—noting all repairs required—photographs of the sketch and the outside of the structure are taken with the PDA camera. The engineers then review the information collected in the PDA and review the information on the sketch for accuracy and completeness. The final step is to place the division number, engineer number, and total number of structures evaluated for the engineer using the PDA onto the outside of the structure. This information is added next to the original evaluation placard, using blue spray paint. For example, “2-15-24” indicates division 2, engineer number 15, and the 24th structure that engineer number 15 has assessed for repairs.
The data from the PDAs is collected at the end of the day and imported into a database. The division leader collects all the hard copies of the plan sketches in a folder and files them for future reference by the date that the sketch was made. A Portable Document Format (PDF) file is created for all the structures that were assessed that day using an Output Form that displays the input data taken in the field. The PDFs are reviewed and spot-checked for consistency with the information documented on the sketches. The PDAs are then gathered and recharged for the following day of assessments.

The next morning, before the engineers go out in the field for repair assessments, the PDAs are checked for GPS functionality and then are assigned to the engineers; the tool bags are replenished (e.g., flashlight batteries, crayon, blue spray paint) and checked out to the engineers; and maps of the areas being assessed that day are created. The maps show the structures that have been originally evaluated with a colored tag (green, yellow, or red). The teams of engineers use the maps to search for the structures that are indicated as having a yellow tag or that were originally tagged with a yellow placard.

Any structures that have been previously assessed for repairs appear as a blue dot on the map (see Plate 16). Because of the variance in GPS accuracy, it is rare to have a blue dot align exactly with a yellow dot. However, when the area is enlarged, structures with a yellow placard that have not been assessed for repair can be determined by counting the total number of dots in a given area.

Plate 16. Map indicating blue and yellow dots
During the repair assessments, structures with yellow placards may not be assessed if the owner or tenants are not present when the engineering team arrives. In these cases, the engineers are encouraged to talk to neighbors to see if the owner or tenants can be reached by phone or can meet at the structure later that day. During the repair construction phase, if an un-assessed structure with a yellow tag is discovered, the engineer performing the QC-QA for the construction can perform a repair assessment. That way, the structure can be repaired while the construction crew is performing repairs for other structures in the same area.

The damage assessment program and repair assessment program were tested with four damaged homes in Delmas 32 in August 2010 as a pilot project. The damage and prescribed repairs were documented for these four structures, and materials and costs were estimated. The repairs to these four structures were completed with local masons who were trained per the repair guidelines.

4.3.5 Repair Procedures
The repair procedures have been developed using the information obtained from the DAFs. During the damage assessment phase, damage types common to the yellow-tagged structures began to have emerged. These damage types include diagonal cracking of walls, out-of-plane wall failures, and concrete column damage.

4.3.5.1 Walls with Diagonal Cracks
One of the most common damage types observed is cracking of masonry walls. The cracks can be grouped into two categories: (a) minor hairline cracks (a piece of paper cannot easily slide through it), which occur through both the plaster and the concrete block; and (b) major, wider-than-hairline cracks (a piece of paper can slide through it or light from outside can be seen through it), which occur through the plaster and the entire width of the concrete block.

The recommended repair for minor cracks is Repair F1, shown in Figure 1. The repair consists of removing the plaster around the crack, attaching metal mesh to the wall over the crack, and re-plastering the wall. The walls with major diagonal cracks require complete replacement because they have lost much of their lateral-load-carrying capacity. Their repair falls into three categories:

- Repair A1 (see Figure 2) for walls without windows
- Repair B1 (see Figure 3) for walls with window openings and no lintels
- Repair B2 (see Figure 4) for walls with window openings and lintel beams atop the openings
Figure 1. Repair F1, minor wall

Figure 2. Repair A1, replace solid wall
Figure 3. Repair B1, replace wall having window opening (without lintel)

Figure 4. Repair B2, replace wall having window opening (with lintel)
4.3.5.2 Out-of-Plane Wall Failures
The next most common damage types related to concrete block walls are out-of-plane movement or failure of the wall, disconnection at the top of the wall, and disconnection at the intersection of two walls. Repair C1 is used when a wall has moved out-of-plane or has bowed (see Figure 5) and entails replacing the dislodged wall. Repair E2 is used when a wall has been disconnected at the top from the concrete floor/roof or wood-framed-with-metal roof (see Figure 6), and entails replacing the top course of the wall. Repair E1 is used where two intersecting walls or wall corners have become disconnected (see Figure 7). In some cases, the lintels over doorways in the concrete block walls have been damaged or are cracked, and for these conditions, Repair D1 is used (see Figure 8) to replace the lintels.

Figure 5. Repair C1, replace dislodged wall
Figure 6. Repair E2, replace top course of wall

Figure 7. Repair E1, Replace displaced portions of wall, stitch walls together
4.3.5.3 Concrete Column Damage

The final damage type relates to concrete columns. This type can vary from minor spalling of concrete columns to column failures. Repair G1 is used when the concrete covering the reinforcing has broken out or spalled (see Figure 9). Repair H1 (see Figure 10) and Repair H2 (see Figure 11) are used when the column has fractured at the top or bottom, respectively. Special care is taken for this damage type to address damage propagation into the slab above. Due to damage of column core, entire column replaced.
Figure 10. Repair H1, complete column replacement

Figure 11. Repair column due to rupture the bottom-
The repair schemes described in the preceding sections of this paper are intended to provide robust and cost-effective structures. Overall, it is estimated that for a typical building, after the retrofit has been implemented, the building’s seismic capacity will be 300% of the level of its original capacity.

4.3.6 Case Study for Damage and Repair Assessment Programs

The Delmas 32 area of Port-au-Prince was used as a case study for the damage and repair assessment programs. The damage database collected in the first assessment phase had identified approximately 1,400 structures as yellow-tagged for this area. These represent the structures to be assessed for repair. Thirty Haitian engineers (two divisions of 15, each including a division leader) from the rapid evaluation program were chosen to conduct the repair assessments for Delmas 32. Each division had seven teams of two engineers conducting the assessments.

4.3.6.1 Field Training

All the division members participated in one day of classroom training and one day of field training, as discussed in Section 0. Before the two divisions began their repair assessments, a meeting was held to introduce and review the functionality of the PDAs. During this meeting, the Haitian engineers were assigned an engineer number and a division. Each division covered different areas of Delmas 32.

During the field training, each division split into two subdivisions, for a total of four smaller groups of engineers. Each group was led by one of our engineering colleagues from the United States, who served as a trainer. When the group came to a yellow-tagged structure, an engineer explained to the owner that the group was there to do repair assessments for the yellow-tagged houses. The group of engineers observed the exterior and interior concrete block walls and concrete columns for earthquake damage. The observed damage was discussed, and the walls and columns were marked with the appropriate repairs, as discussed in Section 4.3.5. Each engineer entered the information on the RAF and made a sketch of the structure’s plan, indicating the damage and repair type. During the training process, the engineers would raise questions regarding specific conditions and what to do under certain circumstances. Each team observed from five to seven structures during the day of training in the field, and the DAFs, RAFs, and sketches were spot-checked.

At the end of the day, the teams met to discuss any outstanding issues that might have come up in the field regarding specific conditions observed, recording data with the PDA, and information to be included on a structure’s plan sketch. The data from the PDAs was then downloaded and saved in the database.

4.3.6.2 Repair Evaluations

The repair assessments for Delmas 32, Simon Pele, and Carrefour Feuilles were completed in 21 days by two divisions. The two divisions met again at the end of the day, and attended a group meeting to discuss various issues and resolve any outstanding concerns. The data from the PDAs were also downloaded. The repair assessment divisions, typically had thirteen members, were similar to the damage assessment teams and were comprised of a division leader, two assistants, and ten engineers. The division was then broken into five teams of two engineers for the purpose of repair assessment.
A typical day of repair evaluations began with mapping the areas to be evaluated that day. The areas to be evaluated were determined by plotting the map of the area to be evaluated showing yellow dots for structures tagged yellow and blue dots for structures that had been previously assessed for repairs. Each division was assigned a certain area to evaluate for the day, and each team of two engineers was given an enlarged map showing the area to be evaluated by their division. One or two of our engineering colleagues from the United States accompanied the Haitian engineers in each division to observe the process, answer any questions, and recommend corrective actions. Plate 17 presents the map of Delmas 32 with evaluated buildings.

During 21 days, 2,478 yellow-tagged structures (averaging to approximately 120 structures per day) were evaluated. Initially, just over 50 structures were evaluated in a day. By the end of the program, this number had grown to over 120 structures assessed daily. This increase was a result of the teams’ efficiency and the experience gained by the Haitian engineers as they worked through the process. Therefore, by the end of this phase of program, each division was evaluating an average of 60 buildings, and each pair of engineers was assessing approximately 12 buildings for repair.

There are approximately 102,000 yellow-tagged that would require assessment for repair. It is anticipated that the repair assessment would require approximately of 100 working days, based on the following assumptions:

- Each pair of engineers assesses 10 structures daily
- Each division (leader and 6 pairs of engineers) assesses 60 structure daily
- 250 trained Haitian engineers (out of approximately 600 total) comprise 17 divisions
- All 17 divisions participate in the program and assess 1000 structures daily for repair
Plate 17. Repair assessments completed in Delmas 32


4.4.1 Pilot repair program

One of the neighborhoods that suffered major earthquake damage in Port-au-Prince was Delmas 32. This neighborhood contained many structures (approximately 1,400) that were yellow-tagged, and therefore it seemed to be a good candidate to test and initiate the repair assessment program (see Plate 18. After the repair assessments were completed, four (4) structures were chosen to test the repair assessment and construction. These pilot structures consisted of three yellow-tagged structures and one red-tagged structure. After the four buildings were assessed, the materials required to complete the repairs were quantified and sources were located.
Each structure took an average of three days to repair, with an average cost of $1,300 per structure. Plate 19 shows one of the buildings, one wall of which had collapsed. During the repair process, all debris was removed; the first row of concrete blocks was placed; and the horizontal reinforcement was added (see Plate 20). The partially completed wall is shown Plate 21, and Plate 22 presents the nearly completed wall. This work was done by certified masons and contractors, using the procedures described in the repair manual.
Plate 19. Collapsed wall of a building in Delmas 32

Plate 20. Placement of the first row of concrete blocks, Delmas 32; note the horizontal reinforcement
Plate 21. Partially completed new concrete block wall, Delmas 32

Plate 22. New wall near completion in Delmas 32
4.4.2 Mason Training

A group of community masons and small contractors have been trained and certified for performing the repairs. Experienced masons (see Plate 23) from the United States were brought in and taught the local masons the proper way to mix materials (see Plate 24) and to construct reinforced (see Plate 25) walls. The local masons were then asked to construct walls, which were checked by trainers (see Plate 26). At the end of the training, the graduates received certification (under MTPTC jurisdiction) that allows them to work on repairing the damaged buildings. To date, more than 150 local masons have been trained on the proper (and seismically adequate) construction of concrete block walls.

Plate 23. Instructing masons on the proper mixing of material
Plate 24. Proper mixing of material

Plate 25. Placement of concrete blocks; note the horizontal reinforcement
4.4.3 Contract administration

To implement a successful repair program for the large number of buildings, a structured but flexible approach that allows good construction quality management is being used. One feature of the repair work is that because the contractors are asked to use higher-quality materials and new construction techniques, it is difficult for them to estimate repair costs. Therefore, the management team decides on the repair cost. The initial award was for each contractor to repair a group of houses. Then, as part of an incentive program, the contractors who performed the repairs adequately were rewarded with additional work, whereas the ones with questionable quality were dropped from further consideration. It is estimated that a typical repair costs (including QC-QA) approximately US$100 to $5,000.

The repair program emphasizes the use of local resources, including materials, contractors, and personnel. This approach serves several purposes: (a) It provides long-term training and establishes good engineering practices for Haiti; (b) it stimulates the local economy and assists in the development of local small businesses, and (c) it empowers citizens with a sense of ownership.

To facilitate training and ensure uniform, low-cost, and consistent repairs, a repair manual guideline has been developed.
4.5 Repair assessment and construction status

The pilot program showed that the proposed retrofit program can be implemented rapidly and with a nominal cost. The quality of the completed work met the project requirements. Following the pilot program and the training of contractors and masons, the repair effort has been expanded. Table 8 presents the repair status as of June 2011. The map of repair-assessed buildings is presented in Plate 270.

Table 8. Current Repair Status

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*Comprising 2,184 by PADF, 62 in the UNOPS program, and 12 in the DAI

Plate 27. Map of repair-assessed (blue-tagged) buildings in Port-au-Prince
5. Summary and Conclusions

The 2010 Haiti Earthquake once again demonstrated the vulnerability of unreinforced masonry and nonductile concrete construction to earthquake damage. The problem was more severe in Haiti because the country was unprepared for a major earthquake. As a result, hundreds of thousands of people were displaced from their homes. To address this issue, a rapid assessment program was developed and implemented, followed by a program to repair damaged buildings.

- To address the special circumstances and damage assessment in Haiti, an international and national partnership was formed, which has focused on inspection and reconstruction. This effort has shown that:
  - An innovative assessment approach that relies on the expertise of international engineers to train national engineers on how to use state-of-the-art technology—such as ATC-20 and FEMA 310 protocols, PDAs, and GPS—is effective for rapid assessment and data collection.
  - This earthquake and its effects provide a unique opportunity to collect field data and to assess the vulnerability of various building types, occupancies, and construction.
  - Publishing a repair guideline for the damaged buildings helps ensure high-quality, low-cost repair for the most common types of observed damage. In addition, uniform and consistent repairs are anticipated.
  - Training Haitian engineers in the classroom and in the field helps ensure accurate assessment and repair. The data collected by the engineers is stored in a database to ensure that future repairs meet and comply with the stated assessments.
  - Training local contractors and masons in proper repair procedures has resulted in work that complies with the repair manual requirements. In addition, good quality control and quality assurance have been implemented. As a side benefit, the local economy and the local technical capacity will increase when the repair program is fully implemented.
  - The methodology that has been developed for use for assessment and repair is effective, as evidenced by the completed pilot study of both the assessment program and the repair construction.

6. Acknowledgments

The authors express gratitude to the management of MTPTC, including Mr. Alfred Pierre, Mr. Jacques Gabriel, Mrs. Viviane Saint Dic, Mr. Evelt Eveillard, and Mr. Raymond Hygin.

The work described in this paper would not have been possible without the efforts of the Haitian engineers who participated in this task. Similarly, the efforts of the engineers from the U.S. offices of Miyamoto International are recognized. UNOPS and PADF are also valuable partners in this program.
The financial contributions by the World Bank and the USAID Office of U.S. Foreign Disaster Assistance (OFDA) are acknowledged.

Most important of all, the authors wish to thank and acknowledge the citizens of Haiti. They never stopped hoping and smiling in the face of the one of the most severe disaster that any human has ever had to endure.

7. References


### Appendix A

**ATC-20 Detailed Evaluation Safety Assessment Form**

**Inspection**
- Inspector ID: ___________________________
- Affiliation: ___________________________
- Inspection date and time: ________________________  AM  PM

**Building Description**
- Building name: ___________________________
- Address: ___________________________
- GPS Coordinates: ___________________________
- Building contact/phone: ___________________________
- Number of floor levels above ground: ________  below ground: ________
- Approx. "Footprint area" (square meter): ________
- Number of residential units: ________
- Number of residential units not habitable: ________

**Type of Construction**
- Wood frame
- Steel frame
- Concrete frame with masonry infill
- Concrete frame
- Other: ___________________________
- Concrete shear wall
- Unreinforced masonry
- Reinforced masonry
- Other: ___________________________

**Primary Occupancy**
- Residential—single unit
- Residential—multi-unit
- Public assembly
- Emergency services
- Other: ___________________________
- Commercial
- Government
- Offices
- Industrial
- Historic
- School

**Evaluation**

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**General Comments:** ___________________________

*Continue on page 2*
## ATC-20 Detailed Evaluation Safety Assessment Form

### Building Name: ____________________________  Inspector ID: __________________

#### Sketch (optional)
Provide a sketch of the building or damaged portions. Indicate damage points.

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<tr>
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<tr>
<td>0-1%</td>
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<td>1-10%</td>
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<td>80-100%</td>
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<tr>
<td>100%</td>
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</tr>
</tbody>
</table>

#### Estimated Building Damage
If requested by the jurisdiction, estimate building damage repair cost + replacement cost, excluding contents.

<table>
<thead>
<tr>
<th>Damage Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0-1%</td>
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<tr>
<td>1-10%</td>
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<td>80-100%</td>
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<tr>
<td>100%</td>
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</tr>
</tbody>
</table>

#### Demolition Complexity

<table>
<thead>
<tr>
<th>Complexity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Complex</td>
<td></td>
</tr>
</tbody>
</table>

#### Posting
Choose a posting based on the evaluation and team judgment. Severe conditions endangering the overall building are grounds for an Unsafe posting. Localized Severe and overall Moderate conditions may allow a Restricted Use posting. Place the appropriate warning rack at main entrance. Post RESTRICTED USE and UNSAFE placards at all entrances.

- **INSPECTED** (Green placard)
- **RESTRICTED USE** (Yellow placard)
- **UNSAFE** (Red placard)

Record any use and entry restrictions exactly as written on placard:

- ________________________
- ________________________
- ________________________
- ________________________

### Further Actions
Check the boxes below only if further actions are needed.

- □ Barricades needed in the following areas: ________________________
- □ Detailed Evaluation recommended:
  - □ Structural
  - □ Geotechnical
  - □ Other: ________________________
- □ Other recommendations: ________________________

#### Comments:

- ________________________

### Vulnerability Factors (check all that applies):

**Original Construction Date:** __________________
**Major structural renovation date:** __________________

#### Site Soils:
- Beach sands
- Soft fill
- Firm Soil
- Rock

#### Building Slope:
- Flat
- Moderate
- Steep

#### Building Setting:
- Beach
- Riverside
- Valley
- Plains
- Foothills
- Hillside
- Hilltop

#### Foundation:
- Slab/Footing on Grade
- Elevated on Post
- Deep piles

#### Plan Shape:
- □ O (Oval)
- □ H (Horizontal)
- □ T (Triangular)
- □ U (U-shaped)
- □ (Other)

#### Vertical Irregularities:
- □ Soft story
- □ Set backs
- □ Coupled Shear walls
- □ Shortened Columns
- □ Pounding with Adjacent Building

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**HAITI EMERGENCY SHELTER REHABILITATION**