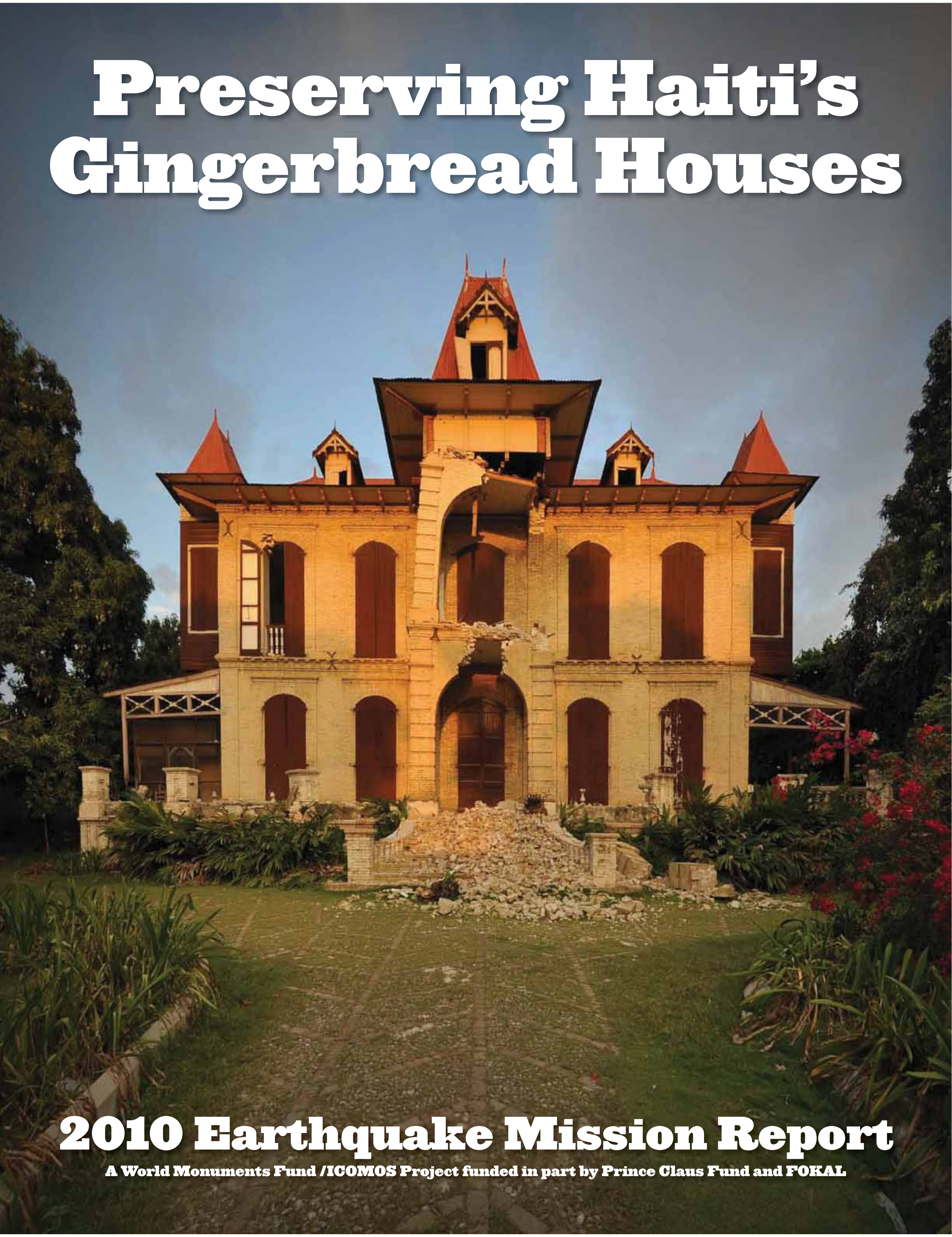
Preserving Haiti's Gingerbread Houses



2010 Earthquake Mission Report

A World Monuments Fund /ICOMOS Project funded in part by Prince Claus Fund and FOKAL

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2010 Earthquake Mission Report
December 2010

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Figure 1 *cover:* The west front of the Villa Castel Fleuri on Avenue Christophe, a grand brick and rubble stone masonry house. This house was occupied by the President of Haiti for a short period in its history. It has suffered extensive damage in the earthquake mainly to the projecting stair tower on the east side, and porches on the west. The plates that hold the iron ties that penetrate the building are visible on the façade.

Figure 2 *above* The Patrice Pamphile House at 4 Rue Casseus, a particularly unusual yet characteristic house in the Haitian vernacular of the Gingerbread era. It combines stone and brick masonry construction with *colombage* and timber frame and clad sections into one composition. The wide porches, tall doors and high ceilings are all characteristic elements of the Gingerbread typology.

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Special thanks also go to the many Gingerbread House owners and residents who so generously gave their time and knowledge to this mission, and who so graciously welcomed the team into their homes and neighborhoods during such a difficult time. Their commitment and collaboration underscore the tremendous spirit of the Gingerbread community and the shared hope for its future.

Introduction

In October 2009, the Gingerbread Houses of Haiti were included on the 2010 World Monuments Watch, to raise international awareness about this unique architectural heritage. Many of these once elegant, turn-of-the-century structures, detailed with fretted wood and intricate latticework, had fallen into disrepair. While political instability and economic strife had precluded substantive preservation efforts in recent decades, the Haitian Leadership and Education Program (HELP) brought the Gingerbread Houses to the attention of the World Monuments Fund (WMF), in the hopes of generating support for the revitalization of these important buildings and communities.

Less than three months later, the devastating earthquake of January 12, 2010, all but shattered the Haitian people and the places they hold dear. Global response to the disaster was profound, and many cultural heritage organizations mobilized quickly to aid in the recovery process. By early February, Norma Barbacci, WMF's Director for Latin America and the Caribbean, was on the ground in Haiti, working with local and international institutions in coordinating assistance efforts. Though many of the Gingerbread Houses suffered significant damage, their traditional construction proved seismically resistant and very few collapsed. Thus, the Haitian government prioritized these neighborhoods and their iconic architecture for international conservation assistance.

Fondation Connaissance et Liberté (FOKAL), in partnership with HELP, then spearheaded a proposal for broad revitalization of the Gingerbread neighborhoods. Liaising with FOKAL, the International Council of Monuments and Sites (ICOMOS), and the Institut de Sauvegarde du Patrimoine National (ISPAN) in Haiti, WMF worked to implement an initial assessment of the Gingerbread Houses, to determine needs and conditions and to jumpstart the broader rehabilitation effort.

During this same period, WMF and the Prince Claus Fund forged a new cooperative agreement for disaster response, aimed at the recovery of monuments and cultural heritage sites in the wake of natural and man-made disasters. This joint program seeks to provide more emergency assistance where and when it is most needed, as well as draw attention to the plight of communities and their heritage in the aftermath of catastrophe. The crisis in Haiti was an immediate focal point of mutual aid. WMF and PCF matched funds, sending a team of ICOMOS experts to Haiti, while FOKAL provided in-country support and funding for the assessment efforts and the international and local team.

This report represents the results of the assessment mission and constitutes a first step in a challenging recovery process. It is anticipated that this data will serve to inform and build the broader program of revitalization for the Gingerbread neighborhoods and to foster continued institutional cooperation and community participation. A key element envisioned by WMF for future phases includes a series of technical briefs cum manual for residents and building owners, enabling them to work toward the repair and conservation of the Gingerbread Houses and the overall revitalization of these once vibrant neighborhoods. This assessment lays the groundwork for such materials and ancillary training, and builds a foundation for information sharing, advocacy, and community development. By emphasizing the common challenges and opportunities faced by the Gingerbread House community, the project team and partners hope to facilitate continued cooperation and engender collective support for recovery.

Project Development: Forging a Collaborative Response

On January 12, 2010 a catastrophic magnitude 7.0 Mw earthquake struck Haiti with its epicenter near the town of Léogâne, approximately 25 kilometers west of Port-au-Prince. The widespread destruction, the loss of life, and the human dimensions of the catastrophe have shocked the world. The Haitian government estimates that approximately 230,000 people died, 300,000 were injured, and approximately 1.5 million were left homeless, but these numbers may never be fully verified. It is also estimated that 250,000 residences and 30,000 commercial buildings either collapsed or were severely damaged.

One of the recurring, long-term consequences of such disasters is the loss of cultural heritage, during the event and in its aftermath. While the rescue and safety of individuals are paramount, heritage is a critical element in the post-disaster recovery of cultural continuity and collective identity. Quick and cursory evaluations are made regarding the viability of damaged buildings, and often many repairable historic structures are demolished or left to deteriorate. The rapid damage assessments after a crisis, as well as the influx of international assistance for rebuilding, often lead to hasty decisions about the surviving architectural fabric. Such decisions about what to save and what not to salvage within the built landscape can have irreversible effects on people and environments.

The international conservation community was quick to respond after the Haiti earthquake. Having already named the Gingerbread Houses to the 2010 World Monuments Watch, WMF had close contact with local Haitian organizations in the aftermath of the earthquake and was invited on one of the very early international missions to survey damage to the historic built environment, from February 3 – 6, 2010. Around the same time, Gustavo Araoz, President of the International Council of Monuments and Sites, established an ICOMOS Steering Committee for Haiti comprised of professionals from around the globe with experience in disaster response for cultural heritage. Norma Barbacci, WMF's Director for Latin America and the Caribbean, returned again to Haiti February 18–21, 2010, with ICOMOS Steering Committee Chair, Dinu Bumbaru. This mission involved further discussions with the Institut de Sauvegarde du Patrimoine National (ISPAN) to identify priority heritage sites in need of international assistance (Figures 5 and 6).

Figure 3 The Catholic seminary at 110 Rue Fleur Du Cheine. This masonry bearing-wall structure exhibits partial collapse of corner tower.

Figure 4 The red painted designation "MTPTC 6" indicates that inspection deemed the tower unsafe for occupancy by the Ministere du Travail Public et Tele Communications.

Figure 5 Dinu Bumbaru (ICOMOS), Herman van Hooff (UNESCO), Conor Bohan (HELP), Norma Barbacci (WMF), Olsen Jean Julien and Frederick Mangones (Assessment Team), Monique Rocourt and Daniel Elie (ISPAN)in front of the National Palace in February 2010.

Figure 6 Frederick Mangones and Olsen Jean Julien (Assessment Team), Conor Bohan (HELP), Dinu Bumbaru (ICOMOS), and the nuns who own the Bazin House, in February 2010.

The Gingerbread Houses, with their intricate ornament and steeply pitched roofs, constitute an important period of post-colonial design and are emblematic of a uniquely Haitian architectural heritage. The Gingerbread Houses are icons of Haiti's rich and vibrant past, as well as a vital symbol for rebuilding the country. Their repair and revitalization were seen as key elements in the recovery process. WMF therefore agreed to help forge a collaborative project aimed at the conservation of the houses in the Gingerbread neighborhoods of Port-au-Prince.

Fondation Connaissance et Liberté (FOKAL), a not-for-profit based in Haiti supported by the Open Society Institute and George Soros, likewise saw in the Gingerbread Houses an important opportunity to aid the recovery of both a community and its heritage. On March 12, 2010, the President of FOKAL, Michèle D. Pierre-Louis, and Executive Director Lorraine Mangonès, met in New York with Bonnie Burnham, WMF President and Lisa Ackerman, Executive Vice President, to discuss FOKAL's proposal for the Gingerbread Neighborhood Rehabilitation Project, which addressed the social, economic, and environmental benefits of preserving this unique heritage and empowering its residents in the process. The combined investment and cooperative interests of WMF, FOKAL, and ICOMOS, along with the financial support of the Prince Claus Fund, led to a technical mission to assess conditions of the Gingerbread Houses.

Members of the ICOMOS Steering Committee for Haiti and the ICOMOS International Committee on Analysis and Restoration of Structures of Architectural Heritage (ICOMOS-ISCARSAH) formed a core mission team and outlined a meth-

Figure 7 Madam Jacqueline Mathon, the owner of 9 Rue du Travail Première (shown in figure 137 on page 71). Her husband's father designed this house, and also another distinguished house, the Bazin House, nearby.

odology of assessing the post-earthquake damage and condition of the Gingerbread Houses, incorporating the following:

- An inventory of Gingerbread Houses in Bois Verna, Pacot, and Turgeau neighborhoods of Port-au-Prince based on oblique aerial survey data;
- A preliminary damage and repair feasibility assessment of earthquake-damaged houses from both aerial survey and ground inspection;
- Systematic photographic documentation of post-earthquake damage to the neighborhood;
- Development of an open platform, context- and technology-appropriate database to manage all information related to the Gingerbread Houses (technical, historic, ownership, etc.); and
- Compilation of existing documentation and analytical materials that could assist in the development of written guides (subsequent project phase) for repairing and conserving structures of the Gingerbread typology in Haiti.

The international mission team included:

- Randolph Langenbach, *Architectural Conservator, Documentary Photographer, ICOMOS-ISCARSAH member (Team leader)*
- Stephen Kelley, *Architect, Structural Engineer Principal with Wiss, Janney, Elstner Associates, Inc., Chicago, Illinois, & Co-President of ICOMOS -ISCARSAH*
- Patrick Sparks, *Structural Engineer, Principal and founder of Sparks Engineering, Inc., Texas; ICOMOS-ISCARSAH member*
- Kevin Rowell, *Builder, Natural Builders, Inc., El Cerrito, California*
- Martin Hammer, *Architect, Berkeley, California*

The aforementioned inventory of Gingerbread Houses began before the team even arrived in Haiti. Through the efforts of team member Randolph Langenbach, the team had access to comprehensive oblique aerial photography by Pictometry International Corp. of Rochester, New York. This remarkable data was donated to ICOMOS by Pictometry through The GIS Corps of the Urban and Regional Information Systems Association. The GIS Corps provides volunteer GIS (Geographic Information System) services to communities in need, often in response to disasters. These oblique aerial photographs enabled the team to undertake a preliminary survey of earthquake damage to the Gingerbread neighborhoods (see *Assessment Methodology* for further information).

The team was on the ground in Haiti from Friday, April 16 to Wednesday, April 28, 2010, where they worked collaboratively with staff of ISPAN and FOKAL to undertake the fieldwork. Each member of the international team partnered with a local team member during the survey process. A key component of the assessment process was to create as many opportunities as possible for the international team to interact with homeowners and local counterparts, so that all parties could benefit from collaboration (Figure 7). Twice during the mission, the team met with Gingerbread homeowners to discuss progress and address questions and concerns. Hosted by FOKAL, these sessions enabled effective dialogue between the community and the professionals and allowed for immediate presentation of preliminary findings (Figure 8). Over 200 owners and residents participated in these meetings, which were successful in bringing the community together and empowering homeowners to actively participate in the repair and rehabilitation process.

The principal outcomes of the assessment mission are summarized in this report and include:

- Identification and mapping of the heritage resources within the Gingerbread District;
- Development of an online Gingerbread Damage Survey Database (accessible at: http://www.wmf.org/project/gingerbread-houses)
- Preliminary damage and repair feasibility analysis of earthquake-damaged Gingerbread Houses; and

- Recommendations for immediate protective actions and long-term strategies for permanent repairs and restoration of heritage structures.

Pending additional funding, the project will expand efforts through continuing institutional collaboration. High priorities are:
1) **Technical Briefs:** A series of detailed damage repair and restoration briefs will be developed that can be distributed to homeowners, architects, engineers, and contractors. They will build upon the assessment findings and will describe best practices for the repair of different construction systems and different levels of damage;
2) **Database:** The online database noted above should be extended to include additional historical data, cost estimates, and engineering assessment data including a vulnerability index;
3) **Exhibition:** A Gingerbread Houses exhibition could be developed using photographs from the assessment and other information to bring attention to the importance of the neighborhood's efforts to restore and protect these structures;
4) **Training:** WMF and FOKAL are working to develop a craft training program in the repair and conservation of historic Haitian architecture.

Figure 8 Homeowners mark their homes on Pictometry® image maps at one of the community meetings.

Assessment Methodology

The scope of work for this assessment was to evaluate the earthquake damage to a core area of the Gingerbread district of Port-au-Prince (Figure 10). Assessment teams concentrated their work in the neighborhoods of Bois Verna, Pacot, and Turgeau, where the largest concentrations of Gingerbread period houses are located. The April mission included more than 200 Gingerbread Houses in a district that is estimated to contain as many as 300. The assessment involved an initial, desk-based inventory and survey of the Gingerbread Houses using oblique aerial photographs. This was followed by a field survey mission to Haiti to undertake systematic photo-documentation and to assess damage and repair feasibility. Post-mission work involved the development of a Gingerbread Damage Survey Database and the reporting of findings and recommendations.

Oblique Aerial Survey

Soon after the January earthquake, the Earthquake Engineering Research Institute (EERI) undertook a remote sensing-based preliminary damage assessment (PDA) using straight-down high resolution aerial photography imported into Google Earth. ImageCat, Inc., an international risk management company located in Los Angeles, coordinated the PDA through the Global Earth Observation Catastrophe Assessment Network (GEO-CAN). Many engineers from their offices around the world participated in the PDA, and the results were then published by the World Bank. This proved useful for the first phases of the response and recovery effort. The methodology for utilizing this image data for the PDA required careful analysis of the image data to detect debris scatter. The height of affected buildings could only be guessed from shadows cast in views taken in full sun, and stories missing because of collapse could not be easily seen, if detected at all.

The straight-down views like those used for the PDA are of even more limited value when evaluating damage to historic architecture. Such assessments require the ability to first discern those buildings of heritage value, and then estimate the earthquake effects. This is particularly true in Haiti where there was limited documentation on historic structures that had not been destroyed by the earthquake. Therefore, the generous donation by Pictometry International Corp. of post-earthquake oblique aerial imagery of Port-au-Prince, Jacmel, and other areas that suffered seismic damage, proved invaluable.

Pictometry's patented aerial survey equipment automatically shoots oblique images in all four directions, north, south, east and west, with a fifth camera pointed straight down (Figure 9). The resolution of these images is high enough to be able to see people in the streets, as well as architectural details down to the shutters and sometimes the mullions in the windows. Also visible are collapsed sections of buildings and also loss of plaster and significant cracks on still standing buildings. It is likewise a relatively reliable resource for detecting the materials and construction systems of many of the heritage buildings in the damage district.

Figure 9 Straight-down aerial view of National Palace after the earthquake, and an oblique aerial view from the north.

Figure 10 Map of the Gingerbread district with underlying Pictometry images.

Using Pictometry's web interface, views of individual structures could be selected and downloaded, enabling the creation of a complete inventory of all of those structures within the Gingerbread District that conformed to this historic typology—before ever stepping foot in Haiti. This proved to be much easier and far more comprehensive than would ever be possible on the ground. By downloading the high resolution images and manipulating them in Adobe Photoshop, the photographs could also be merged into a single mosaic covering whole sections of the city, including the whole Gingerbread Houses District. Thus it was possible to create a series of aerial view maps—very much like axonometric views—of the district from each of the four directions plus straight down. These could then be printed and exhibited, as well as taken into the field by the teams conducting the surveys of each building (Figure 12).

Being able to undertake this even before the team's arrival in Haiti proved to be of crucial benefit. Not only did it inform the development of the scope of work for the assessment in advance, but it also gave team members a tutorial in the kinds of buildings, materials, and conditions they would be facing in the field. Once in Haiti, they were an invaluable resource for locating structures for survey, as almost of the Gingerbread Houses are hidden behind high fences and walls that obstruct views from the ground.

During the mission, an exhibition of these mosaic maps was displayed at FOKAL headquarters in Port-au-Prince during the first homeowners' meeting (Figure 11). During this session, the building owners and residents were encouraged to mark their houses on the plans. This engendered a very positive response on the part of the community. Through this exercise, the idea of the Gingerbread neighborhoods as a cohesive community and historic district was reinforced, enabling the owners to see their houses and the damage they have sustained within the context of the whole community.

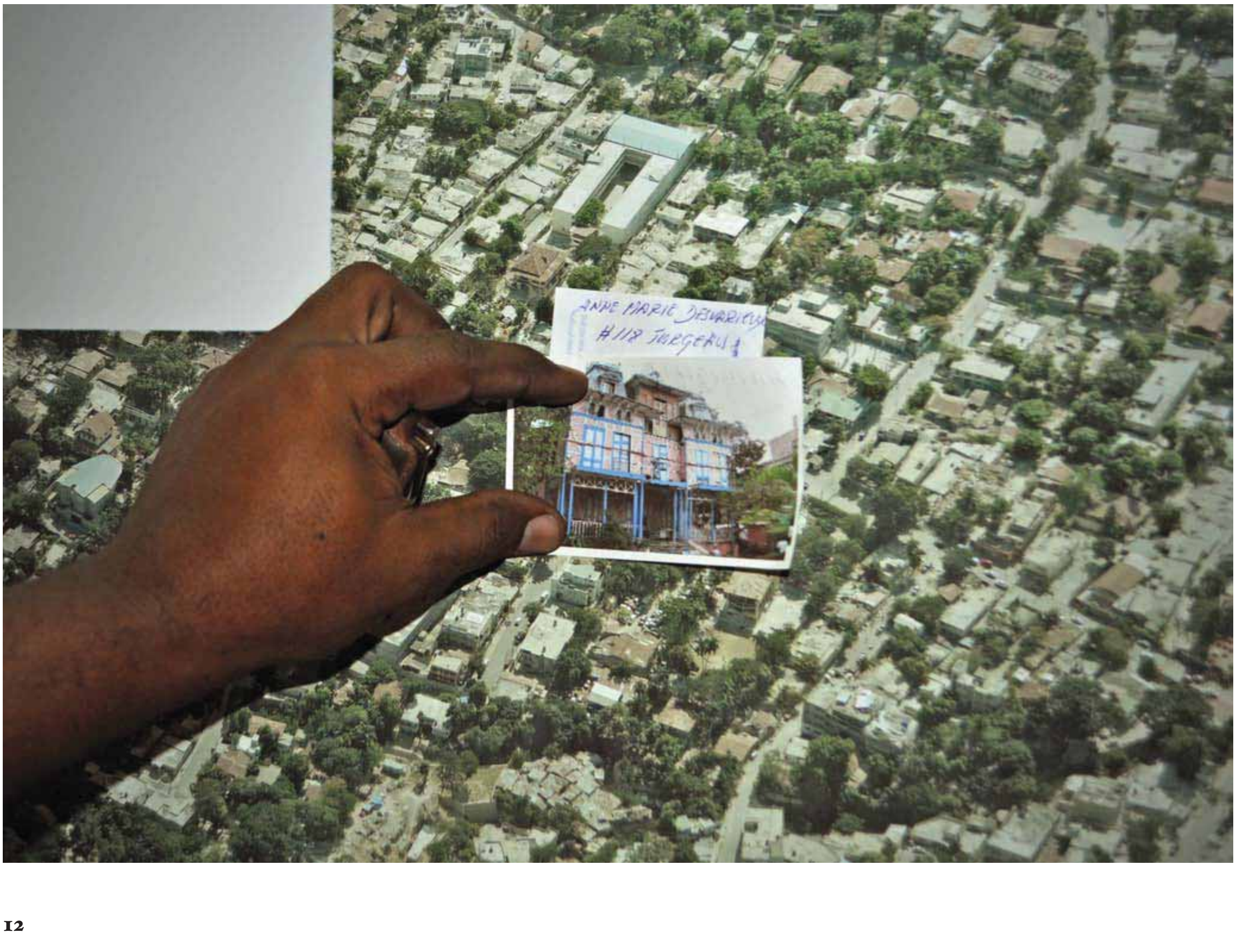

Figure 11 The first owner's meeting and the exhibition of the Pictometry mosaics of the aerial views of the Gingerbread district and downtown Port-au-Prince took place at FOKAL on April 20, 2010. Here, an owner marks his house on one of the views.

Figure 12 Analysis sequence using Pictometry oblique aerial photographs. It begins with the access provided by Pictometry, through their online interface, which at maximum covers only a small area of about one city block in size. This same interface allows one to download each image as shot from the airplane, which covers an area a little less than a quarter of a mile square. The mosaic of the Pictometry images of the Gingerbread District covered an area of about a mile square—16 times the area covered in a single image. The individual buildings in these plans were clear enough to be able to see the exterior damage on many of them. The one shown here, #9 Rue du Travail 1ère was from the ground behind a high fence and partially hidden by trees and surrounding buildings, but clearly visible from the air. The photograph on the bottom right provided by the owner shows the house before the earthquake, revealing that the damage was caused by the collapse of a heavy reinforced concrete porch addition. *Aerial photos by Pictometry. Mosaic created by Randolph Langenbach with Adobe software, Photo on center bottom by Randolph Langenbach, and on the bottom right courtesy of the owner.*

Field Survey

The assessment followed the Methodology for Building Assessment and Mitigation developed by the International Council on Monuments and Sites (ICOMOS) exclusively for use in Haiti. Principal authors of the methodology were Stephen Kelley and Patrick Sparks, both members of ICOMOS-ISCARSAH (Figure 13). The assessments were performed by teams utilizing the ICOMOS Post-

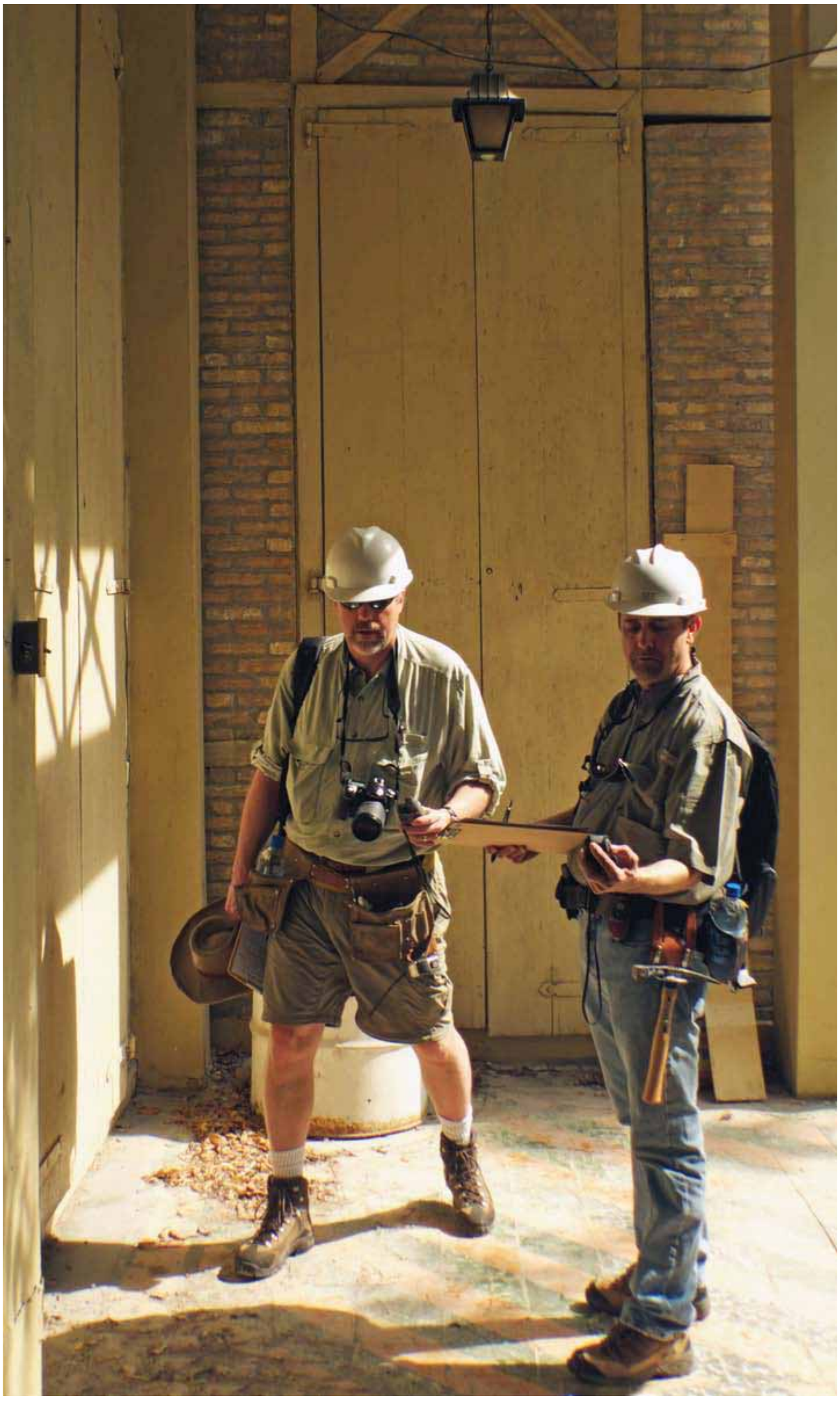

Figure 13 Stephen Kelley and Patrick Sparks surveying one of the buildings.

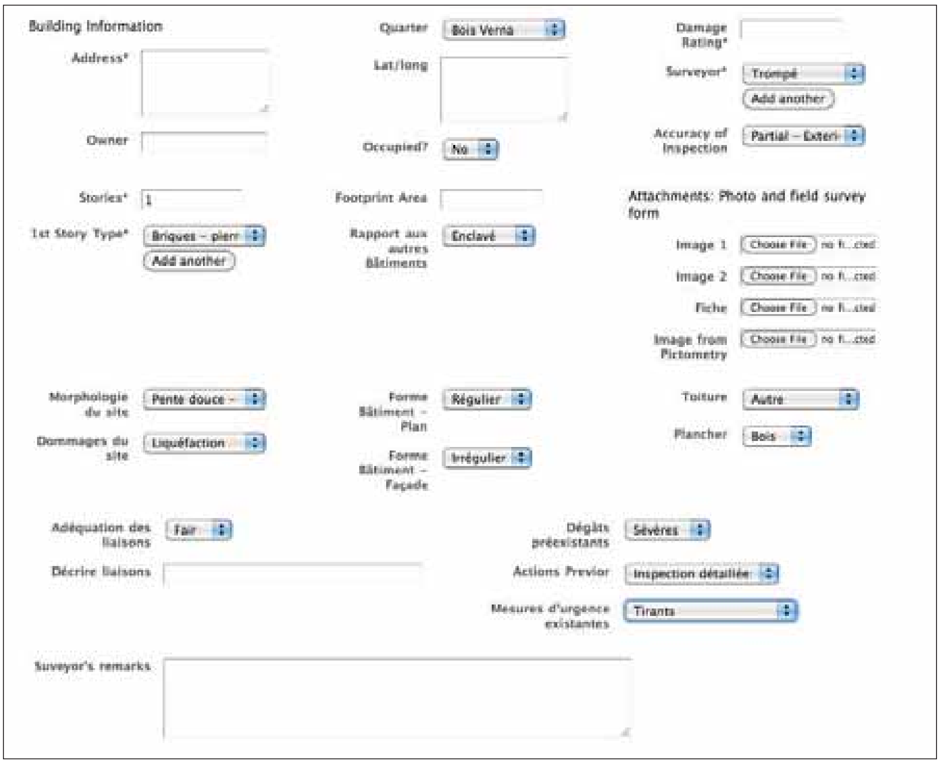

Figure 14

Building Information

Address*:
Owner:
Stories*: 1
1st Story Type*: Briques – pierr
Morphologie du site: Pente douce -
Dommages du site: Liquéfaction
Quarter: Bois Verna
Lat/long:
Occupied?: No
Footprint Area:
Rapport aux autres Bâtiments: Enclavé
Forme Bâtiment – Plan: Régulier
Forme Bâtiment – Façade: Irrégulier
Damage Rating*:
Surveyor*: Trompé
Accuracy of Inspection: Partial – Exteri
Attachments: Photo and field survey form
Image 1: no fi...cted
Image 2: no fi...cted
Fiche: no fi...cted
Image from Pictometry: no fi...cted
Toiture: Autre
Plancher: Bois
Adéquation des liaisons: Fair
Décrire liaisons:
Dégâts préexistants: Sévères
Actions Previor: Inspection détaillée
Mesures d'urgence existantes: Tirants
Suveyor's remarks:

Earthquake Damage Assessment Guidelines and Forms that were developed as part of the methodology for rapid assessment. The Forms were based on the Italian earthquake damage assessment protocol as well as the ATC-20 post-disaster form. They were also tailored to the traditional building typologies of the Gingerbread buildings. The Guidelines and the Forms (in English and French) are included in Appendix A of this report.

A key component of the field survey process was pairing international team members with local counterparts, providing important exchanges of knowledge regarding the Gingerbread Houses and assessment approaches. The aforementioned Forms were filled out by these teams, allowing for quick and efficient data collection about each home and its construction, as well as information on the level of damage to the structures and recommended actions to be taken. Additional information was exchanged and collected during the two residents meetings as well.

Database and Reporting

The data collected were entered into an open platform, context- and technology-appropriate database (Figure 14) to manage all information related to the Gingerbread Houses (technical, historic, ownership, etc.), which can be accessed at:
http://www.wmf.org/project/gingerbread-houses

Observations, analyses, and recommendations were also prepared by each team member. These individual contributions were compiled and integrated to produce this report.

History and Construction Typologies

History

The Gingerbread Houses represent a small piece of the rich architectural heritage of Haiti. While homes of this style can be found in various parts of the country, including Petionville and the more distant cities of Jacmel and Cap-Haïtien, the largest concentration and some of the finest examples are found in the approximately 1.5 square kilometer area southeast of downtown Port-au-Prince, incorporating five neighborhoods: Bois Verna, Turgeau, Babiole, Pacot, and Desprez. Developed from what Georges Corvington called "the green hillside" and characterized by the traditional residences of the Haitian elite,[1] these neighborhoods together present a high level of urban integrity and can thus be considered a cohesive historic district.

The term "Gingerbread" was adopted in the 1950s as a result of American tourists visiting Haiti who likened them to the similarly ornate Victorian-era buildings in the United States (Figure 15 and 16). However, this Gingerbread style is at once a mélange of international influences and uniquely Haitian. The significance of these residences has been celebrated in architectural literature[2] and was well summarized in their nomination to the 2010 World Monuments Watch:

> The Gingerbread movement began in 1881 with the Haitian National Palace, built during the presidency of Lysius Salomon. It 'served as a model and set new standards of construction in Port-au-Prince: a timber frame, filled with brick and adorned with carved wood on the façade and roof banks, high ceilings and large openings onto vast porches.'[3] In 1887 the building currently housing the famous Hotel Oloffson was commissioned by the son of President Augustin Sam. Built by the French architect Brunet, it was originally a private villa modeled after European resort architecture. The building is an internationally known icon of Haitian architecture and was the setting of Graham Greene's 1966 bestselling novel, *The Comedians* (Figure 17)
>
> In 1895 three young Haitians traveled to Paris to study architecture and returned to Haiti inspired to build on this nascent architectural movement by adapting the contemporary French resort style to Haiti's tropical climate. Georges Baussan, Léon Mathon and Joseph-Eugène Maximilien filled the void of Haitian architecture, designing homes which brought together the Haitian flair for elaborate patterns and bright color with the grandeur of French resort architecture, creating a true Haitian style of lattice-work houses. These three men led a movement responsible for scores of elegant houses in the upscale neighborhoods of Port-au-Prince. Unfortunately this great period of Haitian

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[1] *« La zone périphérique que la ville va peu à peu absorber est encore constituée de grandes propriétés appartenant à des personnages qui se sont enrichis dans la politique, le négoce ou l'agiotage. C'est sur ce site champêtre, éloignés des rumeurs de la cité, à l'abri des funestes incendies, que la bourgeoisie jette son dévolu. Pour tous bourgeois qui se respecte et tient à son prestige économique, la grande mode sera de posséder une villa à Turgeau, à Peu-de-Chose ou à Desprez. Se trouvera dès ce moment fixé le dessin aristocratique de ces zones suburbaines. .... Zone résidentielle déjà en pleine évolution, Turgeau, grâce à la situation sociale de ses habitants, tous, hommes politiques influents, barons de la finance, membres de l'élite du commerce haïtien et étranger, voit se consacrer sa réputation de quartier d'élégance et de luxe. A partir du Petit-Four, commencent à s'échelonner de coquettes et riantes villas, celles d'Eugène Poulle, de Mme Messac, de Frédéric Carvalho, ouard Caze, des héritiers Gateau. Plus on se rapproche de la montagne, plus s'accentue la rectitude des lignes, le fini des maisons. Au milieu d'une abondante végétation tropicale dresse l'imposant chalet des époux Ed. Pinckombe, Babiole. Un peu plus loin, on admire la gentille villa des Godefroy, celles de Frédéric Marcelin, La maison Tranquille, de Tracy Riboul, de Louis Horelle, d'Eugène de Lespinasse, le chalet du président Solitude-Villa, et là-haut, dans la fraicheur et la verdure, à la limite des propriétés bâties, le domaine des Bambous, appartenant à la famille Soulouque. On y distingue deux confortables demeures, celle où loge le ministre des Etats-Unis, construite en 1849, et celle plus vaste et à étage des Soulouque. L'impératrice déchue y coule une paisible retraite en compagnie de sa fille, Mme Amitié Lubin, ex-princesse Olive, femme cultivée et de haute distinction. »* Georges CORVINGTON, Port-au-Prince, Au Cours des Ans, Tome II, 1804-1915, Editions Cidhica, 2007. Page 342-344.

[2] Most notably, Anghelen Arrington Phillip's, *Gingerbread Houses: Haiti's Endangered Species* (1975) and Suzanne Slesin's *Caribbean Style* (1985).

[3] *Guides Panorama Haiti, The Art of Tropical Living In Architecture*, p. 8.

Figure 15 The 1912 Peabody House in Pacot. This *colombage* and timber frame house survived the earthquake almost undamaged.

Figure 16 A prominent Gingerbread House at 32 Lamartiniere built by former president Tancrede Auguste, also shown in Figures 59, 120, 124, and 140.

Figure 17 View of the upper balcony on the Hotel Oloffson. See also Figures 19, 99, and 100.

architecture came to an end in 1925 when the city's mayor ordered all new buildings to be made of masonry, reinforced concrete, or iron to prevent fire.

The Gingerbread houses capture a time of prosperity when Haiti was a vibrant part of the international community, hosting the Paris Exposition in 1900 and adapting and incorporating foreign influences into Haitian popular art and architecture. The brightly painted fret work, ornate balustrades and the cut-outs adorning doors and windows are emblematic of the culture and time. The intricate patterns found throughout these houses are thought to be representative of the traditional 'vévé' patterns traced on the floor to call the spirits to a voudou ceremony. These houses, with their unique Haitian style and native architects are symbolic of Haiti's hard fought independence. While this architecture incorporates elements from abroad, it can truly claim to be indigenous, setting it apart from the mostly colonial architecture in the rest of the Caribbean.

Due to Haiti's tropical climate, the Gingerbread houses were designed to take advantage of ventilation and shade, and exclude moisture. Large windows and doors allow for cross breezes. Tall ceilings and large attics with ventilators allow hot air to rise, collect, and be expelled. Deep porches that extend from the front façade to the side walls provide shading for the windows and allow the living space to extend outside the walls of the house. Heavy shutters on the windows allow them to be closed quickly and securely in the event of a tropical storm or hurricane. Raised first floors help prevent dampness from reaching wood framing and interior spaces, and provide for control of insects. Steep roofs quickly shed water during frequent rain storms.

Originally and almost exclusively, the Gingerbread buildings were constructed as

Figure 18 A smaller and simpler Gingerbread house at 26 Rue 7.

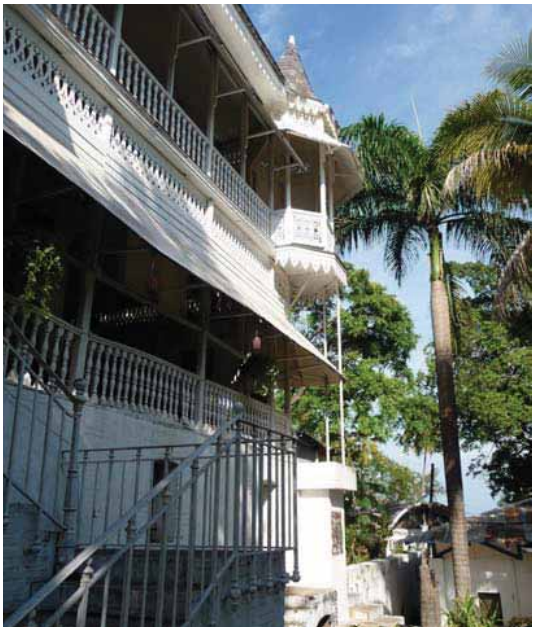

Figure 19 Non-residential uses of Gingerbread buildings: *above* College de Jeunes Filles, at 10 Lavaud 1; *top right* the Hotel Oloffson has been a hotel since 1936, and was a U.S. military hospital from 1915 to 1935; *right* 84 Lamartiniere is being repaired and renovated as a restaurant. *bottom* Two characteristic Haitian wooden buildings on Avenue John Brown with commercial space on the ground floor. All of these are iconic Haitian vernacular architectural forms derived from the "shotgun" house type that is long and narrow, with gable fronts, and rooms that extend across the whole width of the dwelling.

single-family residences (sometimes accommodating servants), mostly for affluent Haitians. However, there also were built—and still exist mainly in the northern and western portions of the district—many smaller and humbler buildings that exhibit simpler Gingerbread characteristics, and employ the same methods of construction (Figure 19 right).

The majority of Gingerbread buildings in the area surveyed still serve as residences, and many are owned and inhabited by residents with direct lineage to the original owners. Some Gingerbreads are now occupied by extended or multiple families, or have been divided into apartments. However, many Gingerbread buildings in current neighborhoods of mixed-use have been adapted for non-residential use, including religious institutions, offices, numerous schools, and a prominent hotel. One Gingerbread building is currently being repaired and renovated as a restaurant (Figure 19).

The original Gingerbread residences were typically set on generously sized properties (Figure 20). Decades of development

Figure 20 A large and elaborate Gingerbread house, still surrounded by its original spacious property, at 9 Rue Bellvue.

pressure, especially close to the city center, commonly resulted in single or multiple subdivisions of properties, with subsequent construction of residential or non-residential buildings on the new properties. Since the mid-twentieth century, most new buildings have been constructed of concrete frame and/or concrete block walls with reinforced concrete slab floors and roofs. Increased urbanization of the Gingerbread district and associated security concerns have led to the prevalence of tall security walls and gates surrounding the Gingerbread properties. These security walls, as well as the infill buildings and the commonly seen additions of concrete and concrete block, have all conspired to cut off many of the Gingerbread buildings from public view (Figures 21 and 22).

Figure 21 A security wall and a modern streetside residence obscure most of a weathered Gingerbread house from public view.

Figure 22 A concrete addition at 4 Ave. Christophe all but conceals the original building's identity as a Gingerbread.

Figure 23 View of the mountains between Port-au-Prince and the south coast. Haiti's mountains were once covered with old growth hardwood and softwood tree species. By 1988 only about two percent of the country had tree cover remaining.

Figure 24 Limestone deposit in the mountains between Port-au-Prince and the south coast.

Construction Materials

Wood: Haiti was once a lush tropical island, replete with pines and broadleaf trees such as walnut and mahogany. Much of this building material was exploited and sent to Europe and North America, and by the late nineteenth century the forests were decimated (Figure 23). The wooden structural members surveyed during the mission were of heartwood of a durable species of softwood, such as Caribbean pine or fir, or sometimes of tropical hardwood. Wood for building construction is no longer locally available and must be imported.

Clay (brick, mortar, plaster, and stucco[4]): There are readily available deposits of relatively pure clay in and around Port-au-Prince. In the early part of the twentieth century calcareous clay deposits were used in the manufacture of ochre-colored brick and ferruginous clay deposits were used for red-colored brick. There were once several brick kilns in the Port-au-Prince area as well. The ochre and red bricks that were manufactured were used extensively in construction and can be seen on the Gingerbread houses. These bricks and hollow tiles come in rectangular and also decorative shapes in order to form architectural ornament such as water tables and cornices. Reportedly there were also clay roofing tiles produced, though clay roofing tiles were not seen during the Mission. The brick industry is no longer active in Haiti and has been dormant for quite some time.

Clay was also used extensively in mortar for masonry construction—principally with rubble stone rather than with brick in the Gingerbread Houses. The clay in samples tested contained lime. It is not known whether additional lime had been added to the clay or if what was observed is the naturally occurring calcium in the calcareous clay.

Lime (mortas, plaster, and stucco): Lime was a necessary ingredient for the manufacture of sugar and the raw material to make lime mortar is plentiful in Haiti, but the manufacture of quick lime from which lime mortar is made has disappeared in recent years with the introduction of the manufacture of cement. We know from archaeological research that lime kilns were constructed on Martinique and Jamaica in the seventeenth century. Limestone deposits found on the slopes of the Haitian mountains, shown in Figure 24, have been further exposed due to deforestation and consequent erosion from rainstorms. In addition, kalk lime was readily available by burning corals and shells. Lime mortars were typically used to lay up the brick in the Gingerbread Houses.

Contemporary masonry construction in Port-au-Prince is almost entirely concrete block laid up with Portland cement mortar, usually as an infill to a poured-in-place

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[4] In this report, the term *plaster* refers to both interior and exterior applications. The term *stucco* refers to exterior applications only.

reinforced-concrete frame. To our knowledge, lime mortar is no longer used in construction. Contemporary quarrying in Haiti has been limited to limestone (primarily for the manufacture of cement—a leading industry in 2002), and also clays, sand, gravel, and marble.

Stone: Based on visual and initial acid testing, the principal constituent of the rubble stone masonry in the Gingerbread Houses is made from calcareous deposits, most seeming to originate from lifted oceanic deposits. On hydration, these stones became very friable and revealed clay constituents as well. This supports a hypothesis, yet to be proven by scientific testing, that the stone when quarried was originally found to be much harder and stronger, but that after it was removed from its natural bedding in the hillside and used in the construction, it lost its strength from loss of the overburden weight and subsequent exposure to the atmosphere. This may have been because it was geologically too young to have yet completely consolidated into natural rock before it was quarried. This would account for the almost uniform weakness of the stones used in this work in Port-au-Prince, regardless of their exposure or distance from the ground. By comparison, the stones in the rubble work in Léogâne and Jacmel are much harder because those locations had access to igneous rocks, not only weak limestone (Figure 25 and Figures 94–96).

Structural Iron and Steel: Iron and steelwork was imported from France and Belgium, and can be seen as lateral ties within masonry bearing-wall construction of

Figure 25 *left* A barn in Léogane is an example of rubble stone *colombage* made with stronger igneous rocks than those used in Port-au-Prince, and not stuccoed. *right* A heavily damaged *colombage* wall showing the rubble stone infill characteristic of Port-au-Prince. See also figure 86.

Figure 27 An example of the ornate metalwork in the second-floor balconies of Le Manoir. This metal work is obscured by wooden exterior walls.

Figure 26 View of decorative end plates at the corner of this brick structure indicate horizontal ties along each wall of the intersect.

Figure 28 The *Palais Nationale,* constructed in 1918, is an example of early reinforced concrete use in Haiti. These buildings typically suffered full or partial collapse.

Figure 30 Concrete frame/confined masonry Gingerbread. This is the only variant of this type seen. It was undamaged.

the Gingerbread Houses (Figure 26). Le Manoir was the single Gingerbread house in Port-au-Prince observed that had extensive metal detailing on its balconies (Figure 27), though this ornament had been obscured by added enclosures.

Concrete: The use of reinforced concrete was introduced into Haiti around the turn of the twentieth century. Some monumental buildings of the era used reinforced concrete including the Cathedrale de Notre Dame (1912) and the Palais Nationale (1918) (Figure 28). Concrete slabs were incorporated into some of the Gingerbread Houses as original fabric, such as the upper floor of the entry tower on the Villa Castel Fleuri (Figure 29) and the entire second floor of Le Manoir. In addition, concrete, concrete block, and Portland cement mortar have been used in many of the Gingerbread Houses for repairs and additions, typically providing a negative result from the earthquake, with a few exceptions (Figure 30).

After the middle of the twentieth century, reinforced concrete and concrete block became prevalent for three primary reasons: a) a ban on wood construction was declared in Port-au-Prince in 1925 in response to a number of devastating fires in the city; b) after the 1940s, concrete and concrete block were increasingly seen as the building materials of choice in Haiti because they were considered to be more durable, technologically advanced, and modern, even becoming a status symbol; and c) concrete and concrete block are resistant to the strong wind and rain of hurricanes.

Figure 29 The east (back) elevation of the Villa Castel Fleuri on Avenue Christophe, a grand brick and rubble stone masonry house. This house was occupied by the President of Haiti for a short period in its history. It has suffered extensive damage in the earthquake mainly to the projecting stair tower on the east side, and porches on the west. The plates that hold the iron ties that penetrate the building are visible on the façade. See also Figure 47 on page 29.

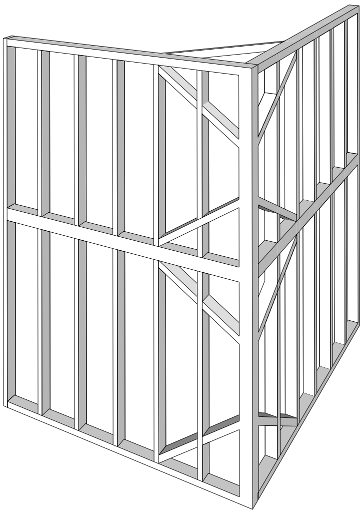
Construction Systems

The character and heritage quality of the Haitian Gingerbread Houses is a product of design and craftsmanship realized through a number of different construction systems and structural materials. There are three primary construction systems utilized in Haitian Gingerbread houses:

- braced timber frame,
- *colombage* (braced timber frame with masonry infill), and
- masonry bearing wall.

It is important to note that the use of exclusively one construction type in a Gingerbread house is rare. Typically the construction types were combined, resulting in hybrid typologies. After a description of the three most common construction types, this section also examines additions, foundation systems, roofs, floors, and interior finishes.

Figure 31 Drawing of a braced frame structure with sills, studs, and diagonals that are mortise and tenon and pegged together.



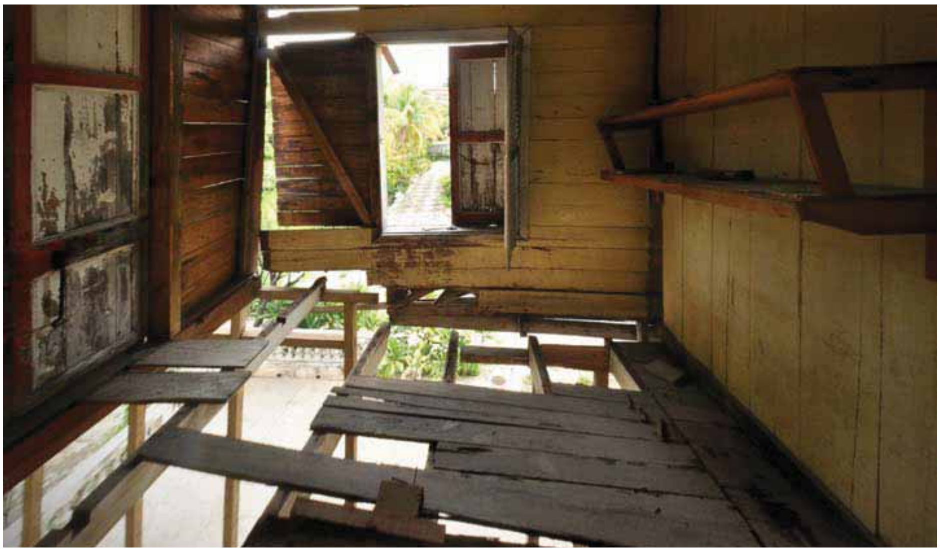


Figure 32 *top* The interior of a room constructed on what had been the porch of the Patrice Pamphile House at 4 Rue Casseus, shown in Figure 2. This interior shows the characteristics of the typical timber frame construction in Haiti, which lies somewhere between the heavy timber framing with mortise and tenon jointing common in Medieval and Renaissance French construction, and the sawn light timber "balloon frame" of nineteenth-century American construction. *bottom* This example of a mortise and peg is from the Bazin House at 8 Rue du Travail Deuxième.

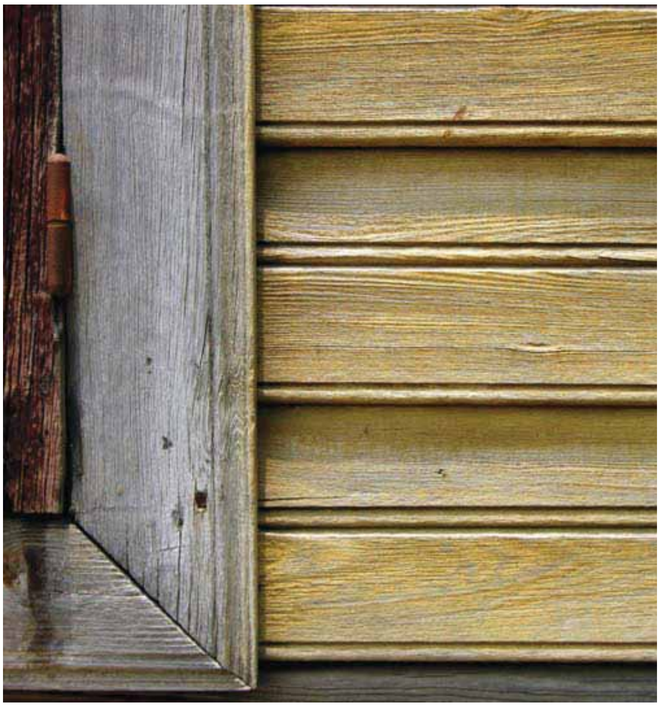


Figure 33 Some Gingerbread Houses have wood siding on the exterior as well as board sheathing on the interior.

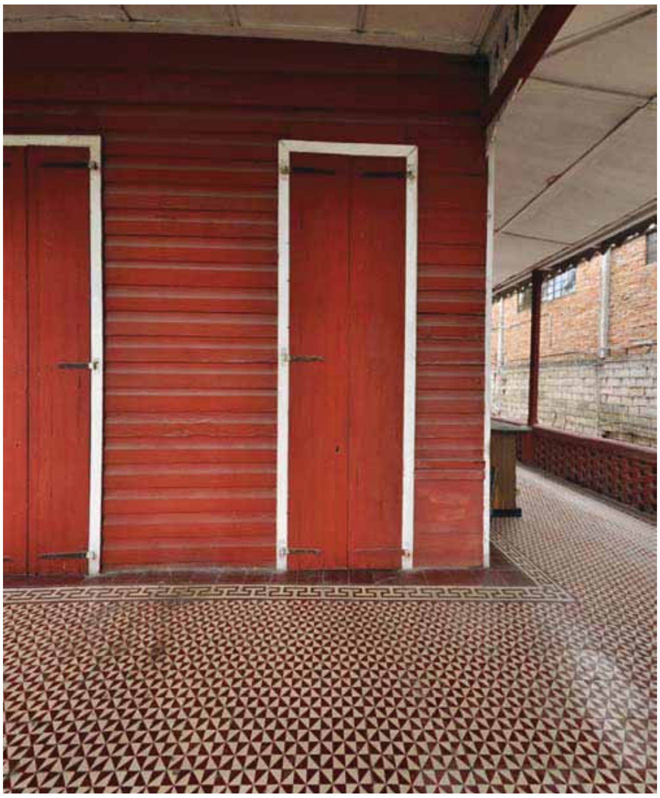


Figure 34 The house at 24 Avenue Lamartiniere, showing the characteristic shiplap siding of the braced timber frame Gingerbreads, as well as simple undecorated doors common in all construction types, and an unusually ornate tile surface on the lower porch.

Braced Timber Frame: Braced timber frame construction is composed of vertical wood members—principally sized at four inches square—that are mortised into wood sills and top plates of each story, and mechanically connected with wooden pegs known as trenails. Diagonal timbers are placed at corners and other locations to brace the frame assembly (Figure 31). Later timber-frame assemblies adopted the use of nails rather than mortise and tenon connections with trenails, but the overall composition is similar.

This is a European building technique that was exported to the Americas during colonial times. In North America this building technique had been entirely replaced with balloon framing by the middle of the nineteenth century. However, this technique was still being used in Haiti into the twentieth century, well after it had been supplanted by other techniques, even in Europe (Figure 32).

There are a number of dwellings built of braced timber frames with masonry infill between the framing members (see *Colombage* below). When there is no masonry infill between members, the 100 percent timber frame construction is clad with horizontal lapped-wood siding on the exterior, also known as shiplap siding (see Figures 33, 34, and 35).[5] There are also a number of examples where the ground floor is of *colombage* and the upper floor is timber with shiplap siding.

In the examples of 100 percent timber construction, in addition to the shiplap siding, the interior walls are also sheathed with wooden boards (typically about 1" x 8"). On the inside surfaces of the framed exterior walls, this board sheathing is almost always installed horizontally. Cut nails attach the boards to the interior of the framing and are typically fastened with two nails in each board at each post in the frame. Interior partitions are sometimes constructed without studs and with the board sheathing installed vertically (running from floor to ceiling), with surface-mounted cross timbers to hold this thin wall of boards in place. There does not appear to be any systematic use of what are called "firestops" where horizontal blocking is installed to reduce the length of the vertical pockets in the wood walls.

Figure 35 24 Avenue Lamartiniere, the wood-frame house also shown in Figure 34.

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[5] *Shiplap* siding (also referred to as *bardage*) consists of horizontal wooden siding applied so that the bottom edge of each board laps over the top edge of the board below, with the boards beveled and grooved to enable them to lie flat upon the outside surface of the studs. This is distinct from *clapboard* siding where the boards are overlapped without the bevels and grooves, such that the boards are at an angle.

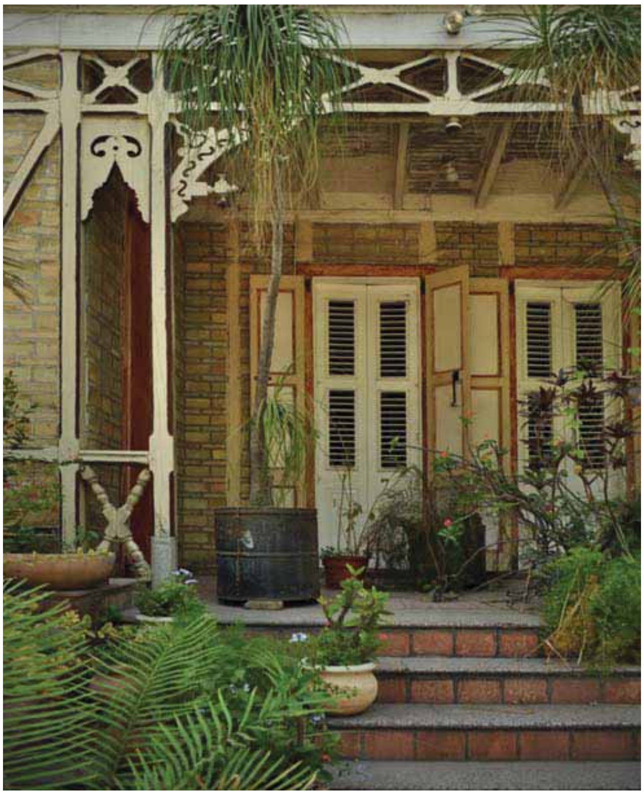

Figure 36 79 Avenue Christophe showing *colombage* with brick infilling.

Figure 38 *Colombage* with brick and lime mortar infill at 30 Lamartiniere.

Figure 39 *Colombage* at 5 Rue Jose Marti with limestone and earth mortar infill, with lime plaster finish. Interior board sheathing can be seen.

Figure 37 A detail of *colombage* construction. The wood frame is pegged with a trenail and the panel voids are filled with stone and lime mortar. The fill on the left still has the clay stucco in place. Note the carpenter's marks carved into the wood members.

Colombage: The *colombage* building technique utilizes the braced timber frame with the distinction that the spaces between timber members are infilled with masonry[6](Figure 36). Timber framing includes top and bottom plates, vertical studs, and diagonal braces. Again, the frame construction generally employs mortise-and-tenon joinery. The tenons are typically pegged with hand hewn wooden pegs, or with nails. Most of the members show obvious markings on them for assembly, suggesting that these could have been prefabricated (Figure 37).

The masonry infill for the Gingerbread Houses is composed of either rubble stone[7] laid in clay mortar or brick laid in lime mortar (Figures 38 and 39). In many examples, brick infill was used on main facades and stone infill was used on the secondary elevations.

Where stone is utilized, it is typically finished on the exterior with lime plaster that is sometimes painted. Often there were two or three coats of lime wash on the exterior of these buildings; in some instances the final coat contained a pigment in the wash (Figure 44). Whether the infill is of brick or stone, the building exterior is expressed by the exposed timbers and brick or plaster in a manner that gives a distinct architectural vocabulary to *colombage* construction (Figure 42).

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[6] *Colombage* and *pan de bois* are French terms referring to timber framing in which (usually) masonry is used to infill the spaces between timber studs and braces of a timber frame. In some contexts, these two terms may be interchangeable, and in others they may have different meanings. This form of construction dates back to pre-history, and can be found in classical Rome. Since then, variations of it can be found in most European and Asian regions at different times in their history. In English, it is called "half-timber," in German, *fachwerk*, in Turkish, *hımış*, in Persian and Kashmiri, *dhajji dewari*. In this report, the term *colombage* will be used.

[7] Rubble stone or rough stone are terms describing masonry construction in which the stones are of irregular shape and are not bedded in horizontal layers, but in an irregular manner. The problem with the absence of horizontal bedding layers and regularly shaped stones in an earthquake is that the stones tend to work their way down, causing a wedging effect that can progressively cause the wall to expand and blow out, leading to collapse of the building.

Where rubble stone infill was used, it was often reinforced with barbed wire laid haphazardly within the space to be filled, and nail fastened to the wood members on both sides of that space (Figures 40 and 41). In almost all cases, horizontal board sheathing was nailed to the inside of the frames, then the earthen mortar and stones were placed between the wall framing members. Nails were used at roughly six-inch intervals in most buildings to help hold the infill (Figure 43).

While horizontal board sheathing is typical on the interior face of rubble fill framing, it is employed in only a few instances on the interior face of brick fill framing. Interior bearing and non-bearing walls use the same method of board sheathing on one or both sides of framing, or utilize single planking centered between framing with beveled wood stops to hold it in place.

Colombage construction is employed not only in high-style Gingerbreads, but also in many small, vernacular buildings. Many of these smaller buildings lack the stylistic details associated with the classic Gingerbread, but are nevertheless important as seismically safe, and more affordable dwellings.

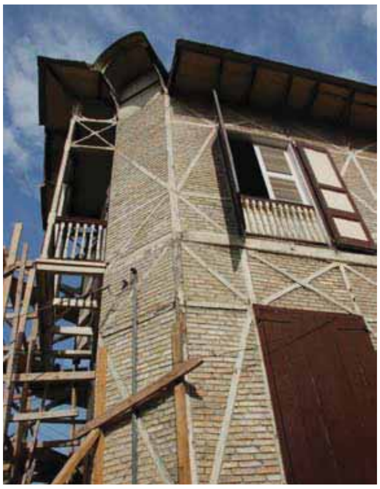

Figure 42 The house at 32 Lamartiniere. The braced timber frame and brick infill is a large component of the architectural vocabulary.

Figure 40 In this *colombage* construction the stone infill has collapsed due to the earthquake revealing the barbed wire reinforcement. This is an example of a non-construction material being adapted for construction due to its apparent availability. The barbed wire was galvanized and is still in good condition.

Figure 41 House at 15 Rue M showing plastered rubble stone infill. On the left, one panel fell out in the earthquake, revealing that it was reinforced with barbed wire inserted into the bay in a zigzag layout.

Figure 43 Nails help hold the earthen infill.

Figure 44 House at 15 Rue M showing undamaged second floor panels coated with a colored whitewash, giving an attractive patina to the surface of the stucco.

Figure 45 *left* Wall of a commercial building on Avenue Lamartiniere showing the characteristic layout of the mixed brick with rubble stone masonry found in many Gingerbread houses in Port-au-Prince. The brick piers and horizontal brick courses are crucial in restraining the walls from complete collapse. *right* Interior view of wall of the Villa Castel Fleuri (see Figure 1) showing a rubble stone panel which has completely collapsed out from between the brick masonry piers. Notice the brick keys that had extended into the rubble stone panel.

Masonry Bearing Walls: Masonry bearing walls are principally used only for exterior walls, though there are cases (in larger structures) where bearing walls are used for interior walls as well. The masonry bearing walls consist of three types: brick laid in lime mortar, rubble stone laid in clay or lime mortar, and a combination of the two.

In some examples, brick masonry is used on main façades and rubble stone masonry on the secondary elevations. There are also examples where brick masonry is used to form building corners, window and door openings, and cornices—forming a "frame" of brick piers, horizontal bands, and arches—with the infill panels constructed in rubble stone masonry[8] (Figure 46). These infill panels were often crossed at one-meter levels with two courses of brick on the inside and outside faces of the wall[9] (Figure 45). These brick courses crossing the rubble masonry panel may have been intended to serve as crack-stoppers and to help stabilize and confine the rubble stonework.

Where brick is used, it is usually multi-leaf brick, approximately 45 centimeters thick, sometimes with rubble stone fill in the inner leaf. The fired bricks themselves appeared of consistent quality and good strength. The mortar between them was in most circumstances the original lime and sand mortar. The quality of construction was high, indicating both good oversight and good training of workers. Occasionally the mortar in bearing structures has been repointed with a stronger cement pointing. In some instances houses that had been repointed with cement showed wear in the cement pointing possibly related to its incompatibility with the underlying lime/sand mortar.

Figure 46 Characteristic 'brick frame' with rubble infill construction

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[8] In similar types of construction found in Europe, the rubble work is typically hidden in the interior of the wall behind full wythes of brick or ashlar masonry, while in Haiti, a pattern of construction developed where the rubble part of the wall is in panels surrounded by brickwork piers that form corners and window surrounds.

[9] This use of brick courses in rubble stone walls continues a building tradition that can be found in many other places, including ancient Rome and in Medieval and Renaissance construction. In Haiti, it is probably a carryover from French Medieval and early Renaissance masonry construction practices.

In cases where brick is used, several buildings surveyed had original lime stucco over the exterior wall. These homes often had a lime wash done in multiple layers, the final coats often containing an ochre-colored pigment. The quality of bonding between plaster layers indicated a high purity of material as well as proper construction practices between coats. Where stone or a combination of stone and brick masonry is utilized, the stone is typically finished on the exterior and interior with a clay or lime plaster that is then painted. When brick and stone masonry are used together on a façade, the changing patterns of brick and painted plaster provides a pleasing aesthetic similar to that rendered with *colombage* construction (Figure 47). The masonry walls are generally reinforced only by iron rods running horizontally through the wall section, usually at each floor level and at the roof. These iron rods may occur singly or in pairs, and may have exposed end-plates or embedded anchors. The rods are a key reinforcement and helped prevent total collapse in many cases. Where they existed, they were typically in all exterior walls and sometimes across the building in interior cross-walls. The locations of these ties are easily seen due to the decorative (e.g. fleur-de-lis) end plates on the exterior walls that are sometimes incorporated into the architectural vocabulary of the façade (see Figure 101, page 49.)

Figure 47 View of the back elevation of Castel Fleuri. The use of brick masonry surrounding the windows, at the corners, and at floor lines in tandem with the stucco over the stone masonry elsewhere forms a pleasing composition. Note the X-shaped end plates of the iron rods visible on the façade, which were not installed at the building corners in this case. See also Figure 108.

Figure 48 Concrete additions are often awkward or compromise the Gingerbread buildings architecturally, like this one at 51 Avenue Christophe.

Hybrids: As noted previously, it is very common for a single Gingerbread building to exhibit two, and occasionally all three exterior wall systems. Hybrid buildings typically utilize a different system for each story, with the heavier system for the first story walls, and the lighter system(s) for the second story and/or attic walls. For example, some have lower floors with masonry bearing wall construction and upper floors of *colombage* (Figure 49). Others have *colombage* on the ground floor and just braced timber frame above. And in some cases, *colombage* was intermixed with masonry for portions of first- and second-story construction.

Additions: Concrete and concrete block additions to the Gingerbread buildings are very common, especially close to the city center (Figure 48). Less common, and older, are additions of unreinforced brick and rubble stone masonry. Occasionally remodels using concrete and concrete block were built to replace a portion of the building that had suffered deterioration or damage, or replacement may have been seen as an upgrade. These additions were often added for new kitchens or bathrooms, and thus were constructed with heavy concrete and tile interiors. When bathrooms were installed at the second-floor level, the additions sometimes were constructed on reinforced concrete legs, and thus their weight under lateral loads was imposed onto the historic house.

Figure 49 Hybrids are very common. This Gingerbread house at 59 Lavaud 3 utilizes all three wall-construction systems:
Attic walls—wood frame
Second story—colombage
First story—masonry bearing wall
Note also the one-story concrete addition at the back left corner.

Figure 50 Spalling of the exterior finish plaster of the house at 84 Lamartiniere reveals two contiguous sections of foundation stem wall. One of irregular limestone *left*, and one of brick *right*.

Figure 51 The original brick masonry foundation pier can be seen and is infilled on either side with stuccoed stonework. Rising damp from the ground has caused extensive deterioration to the exposed stone masonry. This results from the migration of soluble salts to the surface where they expand on drying, causing the surface of the masonry to spall.

Figure 52 An excavated crawl space in the house at 84 Lamartiniere shows an original above-grade brick pier, and its uncovered, original limestone and earth mortar footing.

Foundations: Examination of a few foundations and readily visible portions suggests stone and brick continuous foundation walls, or fired-brick columns with lime mortar and infill between columns of earth and stone (Figure 52). It is a fair assumption that all original foundations are unreinforced. However, the foundation depth, width, reinforcing (or lack of), and a thorough determination of material makeup require further investigation. The foundations themselves seem to have performed very well, showing little sign of direct displacement either due to horizontal pressure in the soil, liquefaction, or settlement.

Gingerbread Houses almost never have basements, and the first level is typically raised as much as one meter above grade. It is apparent that many of the smaller Gingerbread Houses composed of wood were originally raised on masonry piers rather than erected on continuous foundation walls. The practice of erecting structures on masonry piers was once prevalent in the Caribbean to aid in control of insect problems and address chronic dampness. Though these piers can sometimes still be seen (Figure 50), the spaces between these piers typically have been infilled with masonry (Figure 51).

Roof Systems: The roofs of Gingerbread Houses with their steep pitches (often greater than 1:1 slope), spires, and turrets are principal architectural features. They are framed using braced frame techniques, typically with mortise-and-tenon joinery with wooden pegs (Figure 53). In nearly all cases observed the roofs were clad in ferrous, corrugated sheet metal over purlins (Figures 54 and 55). In one case observed, Le Manoir, the roof was a stamped decorative metal sheet tile (Figure 56). There were a few houses surveyed that had original slate shingle roofing over skip sheathing, though this was rare (Figure 57). An examination of the accessible attics revealed that the strength and configuration of the original frame appeared to be designed to accommodate only light weight roofing such as sheet metal, rather than heavier materials that come in smaller pieces such as slate or tile. This suggests that sheet metal roofing was likely to have been the original roof cladding type for most houses (Figure 58).

Figure 53 Attic framing with mortise-and-tenon joinery with wooden peg.

Figure 54 Corrugated steel roof over purlins and braced roof framing.

Figure 55 Corrugated ferrous metal roofs are quite common on the Gingerbread houses. This house has a metal crest at the ridge as well.

Figure 57 Original, thin slate roofing at 14 Avenue John Brown.

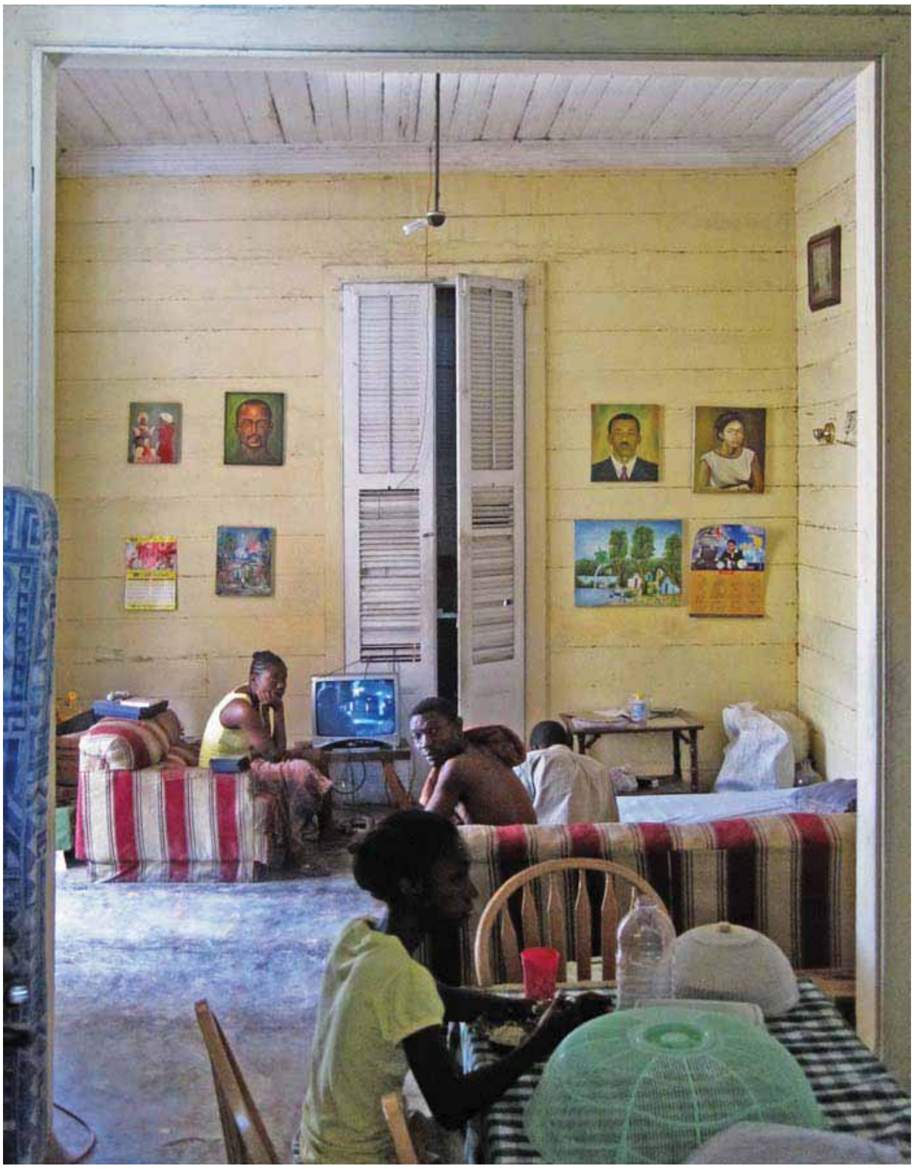
Figure 56 The roofs of the turrets of Le Manoir utilize decorative pressed metal roof shingles.

Figure 58 The wood structure and purlin spacing of this attic would only accommodate corrugated metal roof, indicating that these roof materials were original.

Figure 59 Wood floor framing with wood plank floor removed at 32 Lamartiniere.

Figure 60 Tile over slab on grade at 5 Lavaud 1.

Figure 61 A typical interior of a Gingerbread house with wood floors, horizontal wood boarding on the walls, and wood board ceilings.



Floor Systems: The floors of the Gingerbread Houses tend to be wood framed with perpendicular wood plank flooring (often tongue and groove). This is usually the system for the first floor, over a shallow crawl space, and for any second or third floors (Figure 59). In some instances the first floor is of mortar (or concrete) on grade, usually with a tile finish (Figure 60). In one instance, Le Manoir, the second floor has an original concrete slab.

Interior Finishes: Interior walls are typically finished with painted board sheathing (Figure 61), except when masonry bearing walls are employed. In such cases the painted brick or plastered stone typically serves as the interior finish, with rare examples of board sheathing. Ceilings are also typically finished with board sheathing This is an important detail as interior finishes entirely of wood are flexible and will not be as easily damaged during a seismic event.

Conditions and Performance

Figure 62 Termites thrive in Port-au-Prince, and many of the wooden structures are severely damaged due to termite attack.

Pre-Earthquake Conditions

The Gingerbread Houses of Port-au-Prince were in various states of repair prior to the January earthquake, mainly due to the level of regular maintenance (or lack thereof). There were a number of pre-earthquake conditions that made these houses more vulnerable to seismic damage, including the following:

Insect and fungal decay: The principal condition that was seen in the structures composed of wood was the evidence of termites (Figure 62). Termite damage and, to a much lesser extent, wood rot were commonly observed in *colombage* and timber frame buildings and appeared to play a role in the extent of earthquake damage suffered, especially where decay affects the tie between floor and wall, or wall-to-wall at a corner (Figure 63). For example, severely rotted or termite-damaged bottom plates sometimes failed and allowed entire masonry panels to fall out under their own weight (Figure 64). Wood elements directly exposed to weather or to leaks in the building envelope were subject to rot (Figure 65). This is especially true at locations that invite rainwater collection (bottom plates, 'V'-shaped diagonal-to-vertical joints, bottoms of porch posts) and at locations in poor drying environments (areas of constant shade and/or limited air movement).

Figure 63 Heavily rotted and termite-eaten house on Avenue Lamartiniere, which partially collapsed during the earthquake.

Figure 64 The post tenon is still present; the sill has rotted away.

Figure 65*:* The Patrice Pamphile House (shown also in Figures 2 and 32) showing the heavily deteriorated wooden part of the structure, which at one time probably had been an open porch.

Figure 66 Poor construction and detailing have made many balconies vulnerable to decay and structurally unsafe. For those balconies supported on the cantilever extension of the floor joists, decay can extend into the house, putting both the balcony and interior floor at risk.

Figure 67 Rot of timber frame members at corner of *colombage* house at 32 Lamartiniere.

Figure 68 Termite damage in second story floor joists.

Termites are extremely aggressive in Haiti and have left numerous balconies and floor boards in an unsafe state (Figure 66). Termite damage was most often seen in the following structural elements: timber framing in *colombage* walls and in wood frame walls, floor planking (first and second floor), floor joists, and porch posts (Figures 67 and 68). Wood members within *colombage* construction, and within frame construction with pocket walls, allow termites to propagate undetected to the upper floors through timbers that are set in masonry or which are clad on both the inside and outside.

In addition, evidence of woodworm was observed in a few of the houses inspected, but this type of insect-related damage occurs more slowly than that caused by termite infestation, and its detrimental effects are overshadowed by the termite damage.

Figure 69 Hole in the masonry wall of Castel Fleuri caused by a concrete vault constructed in the exterior side and adjacent to this wall.

Inappropriate Repairs & Alterations: Several types of inappropriate repairs and alterations implemented prior to the earthquake contributed to the seismic damage sustained by the Gingerbread Houses:

Concrete Additions: The first was the widespread use of reinforced concrete and/or concrete block to build additions to the Gingerbread Houses. These additions become a structural concern during seismic loading (Figure 69). Houses constructed of braced timber frame or *colombage* have a relative deformability compared to concrete, so during an earthquake the original structure and concrete addition act as separate structures and strike each other. This typically led to damage of the Gingerbread house where it interfaced the addition, and also led in some cases to collapse of the addition (Figure 70).

Concrete floor slabs: Concrete was also used in numerous cases to replace the presumably rotted or termite-damaged first floor with a concrete slab. This was done by removing the flooring and joists, filling the crawl space below the floor with an uncompacted rubble fill, and then pouring a slab over that fill. This alteration would subject the foundation walls to a lateral loading for which they were not constructed, thus making the foundation walls rotate outward (Figure 71). During the earthquake, the fill below the slab would compact and settle and the slabs would dish downward and crack, causing the foundation walls to rotate even more.

Figure 70 This second floor concrete bathroom addition at 5 Lamartiniere landed on the ground after its concrete columns buckled as it pulled away from its parent Gingerbread house. Note sewer pipes in the center of the rebar of the buckled columns.

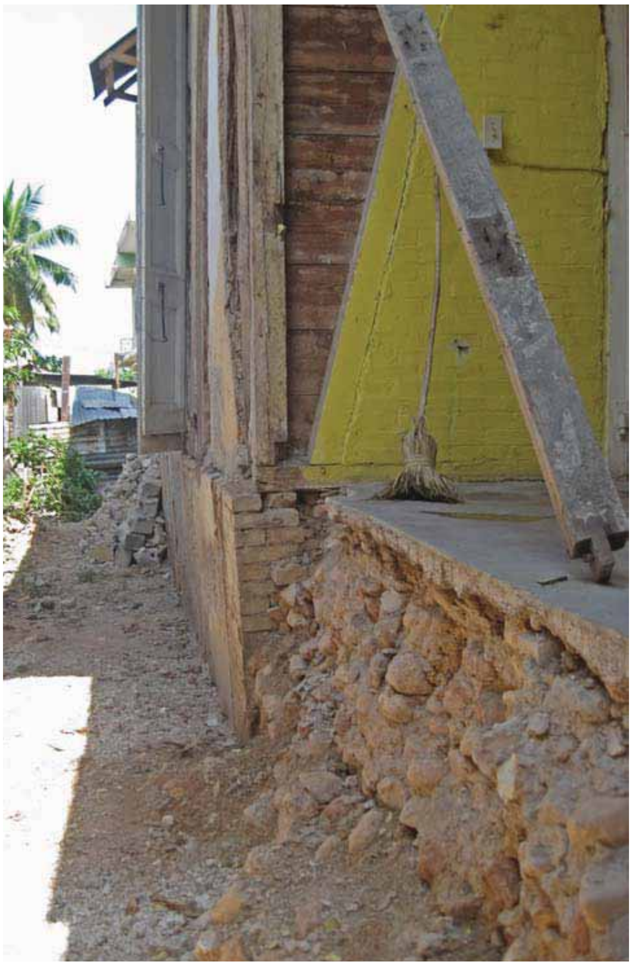


Figure 71 A portion of the foundation wall has collapsed at the house at 2 Avenue N, revealing that the crawl space below the first floor had been filled with rubble and the wood floor had been replaced with a slab on grade. Lateral loads on the wall from the fill caused it to collapse. The foundation wall remaining has rotated outward.

Figure 72 A replacement side wall of concrete block at 19 Lamartiniere suffered partial collapse.

Figure 73 These are examples of *colombage* where the rubble infill has been replaced with concrete. This has accelerated the rotting of the timber framing, which then broke during the earthquake causing the collapse of the heavy concrete infill.

Another form of damage seen in several buildings was the replacement of second and third floor verandas originally constructed in wood with heavier, less-flexible concrete slabs. The slabs typically extended off of the buildings three to four feet and were poorly tied to the building's structure. Typically this caused a separation of the parallel wall from perpendicular walls. In some instances the wall would be levered out from the building at the connection between the wall and the porch.

Concrete replacement walls and interior partitions: Some replacement exterior walls and added interior partitions were made of concrete block. The softer, more flexible earthen-based masonry walls were able to flex with the seismic movement, while the rigid concrete walls were not (Figure 72). The concrete walls caused a hammering effect against the original walls and forced parts to fall out. In most circumstances the concrete walls have failed completely as a unit, falling over inside the structure and often causing further damage.

Use of cement and concrete to repair/replace rubble stone infill: In many places where rubble stone infill panels on *colombage* walls were previously damaged or required repair, it was either consolidated with Portland cement mortar or the fill was removed altogether and reconstructed with concrete infill or concrete block with cement mortar (Figure 73). These repairs constitute a fill that is much stiffer and more cohesive than fills using traditional materials, which results in detrimental performance of the system in an earthquake (Figure 74). In some instances houses that had been repointed with cement showed wear in the cement pointing possibly related to its incompatibility with the underlying lime/sand mortar.

Building height (number of stories) and tall or slender above-ground foundation walls were also apparent indicators of earthquake vulnerability.

Figure 74 Improper repair of stone infill of *colombage* using concrete. These repairs constitute a fill that is much stiffer and more cohesive than the fill it replaced.

System Performance and Pathologies

The earthquake performance of the buildings of Port-au-Prince in general can be ranked from best to worst in the following manner: wood structures, masonry structures, and concrete structures. The observations of the mission revealed that this was true of the Gingerbread Houses as well (Figures 75 and 76). Both the braced timber frame and the *colombage*, with their more flexible, energy dissipating systems, tended to perform best.

Braced Timber Frame: If these structures were in good condition and were well maintained, they basically performed well and, where damaged, can be repaired. Most of the significant earthquake damage to these structures was often related to pre-existing damage caused by termites, and in some instances other forms of wood rot, such as:

- Collapsed porch structures that had previously been severely compromised by unchecked termite damage (Figure 78).
- crushed sill plates causing the entire structure above to settle lower on its foundations making operation of doors difficult or impossible (Figure 79).
- Collapsed exterior walls especially when they are not load-bearing and therefore not engaged by compression into the structure as a whole.

There were also examples of severely termite-damaged structures that collapsed entirely. These houses were probably unsafe prior to the earthquake, as earthquake damage tended to be concentrated and most severe where the termites had been most active.

Figure 75 A pancaked concrete-frame building on the left and a *colombage* house on the right showing the comparative performance of these building types in a seismic event.

Figure 76 This two-story Gingerbread house survived amid the collapse of numerous concrete buildings. The owners do not want to tear it down. However, it needs temporary stabilization and long-term repairs.

Figure 77 The Dufort House, a hybrid structure, exhibited substantial damage to the masonry first-story walls, including its limestone panels and brick piers, but significantly less damage to its *colombage* and wood frame second-story walls. Notwithstanding the increased seismic loads on the first-floor walls, the difference in performance of the systems is indicative of a tendency seen throughout the surveyed buildings.

Figure 78 Second-floor porch structure made unsafe by termite damage.

Figure 79 The wood sill that was previously termite damaged was crushed during the earthquake. This caused the entire structure to settle on its foundation. The result is that many of the doors to the exterior cannot be opened or closed.

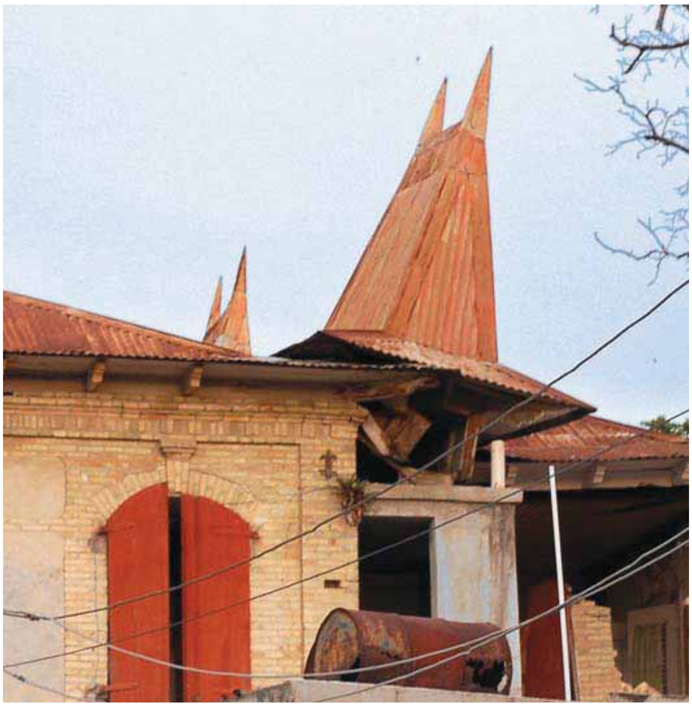


Figure 80 Both of the steeples of this Gingerbread house were shaken out of plumb during the earthquake.

The mission saw a couple of examples of turrets on towers within the house assembly that had been pushed out of place during the earthquake (Figure 80). It was not possible due to inaccessibility to determine if termite damage played a role or whether it was the geometry of the structure which caused it to fail.

A number of timber framed houses were not well connected along the sides parallel to the joists. Thus those walls are not bearing the floor loads and, as a consequence, are not as well tied to the rest of the frame. These have shown a tendency to separate from the building and fall. There is also evidence that some of the more modest houses were not as well tied together during construction as were some of the grander Gingerbreads.

Many braced timber framed houses were constructed with cut nails rather than wire nails, contributing to a number of conditions:

- Before the wide distribution of cost-effective wire nails, cut nails were used. Because cut nails were more expensive, they were used more sparingly in construction. For earthquake resistance, more nails are usually better.
- The cut nails often have not rusted excessively (Figure 81). This could be attributed to the elevated terrain of the Gingerbreads (away from the direct effects of salt), to the prevailing winds being from the east/southeast, and also to the relatively dry climate of the west end of Hispaniola. However, the oxides still tend to cause the nail holes in the wood to widen, weakening the nailed connection. Iron oxide (rust) from bare steel nails can also react with the cellulose in wood, causing the hole to grow in size over time, reducing the friction holding strength of the nail.
- Cut nails are more rigid, tend to be brittle, and have a wedge shape to them. This can make them more likely to snap off when under strain, especially if rusty. Because of the wedge shape, once loose the nail will pull out without imparting much friction (energy dissipation) to the system. Modern wire nails have cylindrical shanks, thus continue to have friction and holding power even if partially pulled out.

Figure 81 Cut nails of iron or steel are common in the Gingerbread houses. Many of the original cut nails show surprisingly little corrosion.

Figure 82 Wood frame Gingerbread at the Episcopal University at 14 Rue Légitime next to the site of a collapsed concrete building.

Figure 83 Marie Céleste Florence Jacob, seen here, continues to live in this century-old wood frame house at 14 Rue Marcelin. This house was extensively consumed by termites prior to the earthquake which damaged it further. Even in this badly compromised state, this structure remained standing after the earthquake only a few short blocks away from the National Palace and many other concrete frame structures which collapsed.

Figure 84 Despite extensive termite damage, the remainder of this post is hard and dense, still holding the nail firmly.

Overall, in terms of earthquake performance, the well-maintained wooden houses survived with much less damage than the ones with little or no maintenance, especially if the termite damage was extensive. However, they still performed significantly better than many of the reinforced concrete buildings—even when considerable deterioration and termite damage were present (Figure 82). This is attributable to the natural redundancy, light weight, flexibility, and lateral resistance of the board-sheathed frames. In general, wooden buildings have proven to be reasonably robust in earthquakes when compared to other types of construction. This has been true with the exception of heavy timber post-and-beam construction that lacks strong but flexible connections, or which is lacking nailed wood cladding and other elements that provide some redundancy to the structural system. With heavy timber construction, the timbers can be easily pulled apart leading to structural collapse, as for example occurred with Japanese house construction in the Kobe earthquake.

Copiously nailed stud-frame construction with a reasonable level of structural redundancy has demonstrated good performance in both earthquakes and hurricanes. Traditional Haitian construction in the Gingerbread district generally does have good redundancy, especially since many of the walls are clad on the interior with flush boards instead of plaster in addition to the *colombage* or shiplap siding that covers the exterior.

Some of the buildings inspected were found to have such extensive termite damage that they could reasonably be considered to be beyond repair. Even where this was the case (Figure 83), collapse of these timber frame structures in the earthquake was extremely rare. However, localized damage caused by the earthquake in many of the houses has served to reveal how extensively they had been consumed by termites (Figure 84).

Colombage: *Colombage* construction, which incorporates the braced frame, behaved in a similar fashion to braced frame construction and exhibited similar conditions and pathologies as noted above (Figure 85). With *colombage*, however, the masonry infill panels (of either fired brick or rubble stone) in many cases became loosened or completely fell outward (Figures 86 and 87). This should not be considered a failure of the *colombage* technique as the masonry behaved as an energy absorber and protected the building frame as a whole by absorbing the lateral movements in a sacrificial manner.

In places where masonry infill had been replaced with cement mortars or concrete block the infill would fall out as cohesive units which caused damage to roof structures below as they fell (Figure 88). They also posed a falling hazard to persons below. Generally, soft fill like rubble stone in mud mortar performed better than hard fill (bricks in cement mortar) by absorbing energy. Hard fill usually failed en masse, rather than crumbling (Figure 89).

While the earthquake caused a number of the infill panels to fall out of the frames, the integrity of the overall timber structures did not appear in any case to be dependent on the presence of the masonry infill. The Haitian form of *colombage* is unusual because in most cases the inside surface is clad with horizontal wood boards. The resulting building is thus essentially a wooden building (Figure 90). In the earthquake, this interior wood cladding may have been important in that it prevented the infill masonry—particularly the soft rubble stone masonry—from falling inwards where it would then have put the occupants at risk from the falling debris.

Figure 85 Despite severe damage, this timber frame building did not fully collapse. Note that the wall that fell away is the one on the side parallel to the joists, thus not having substantial tie to the floor.

Figure 86 Much of the *colombage* stonework fell out of the walls of the second story during the earthquake.

Figure 88 Stone infill that had been relaid with cement mortars would fall out of the wood frame voids in huge pieces during the earthquake causing damage also causing a safety hazard.

Figure 87 Close-up view of the failed *colombage* stonework. This infill, if laid up in clay, crumbles away and does not compromise the integrity of the wood braced frame.

Figure 89 Brick infill that had been relaid with cement mortar fell out in huge pieces during the earthquake, causing damage to construction below.

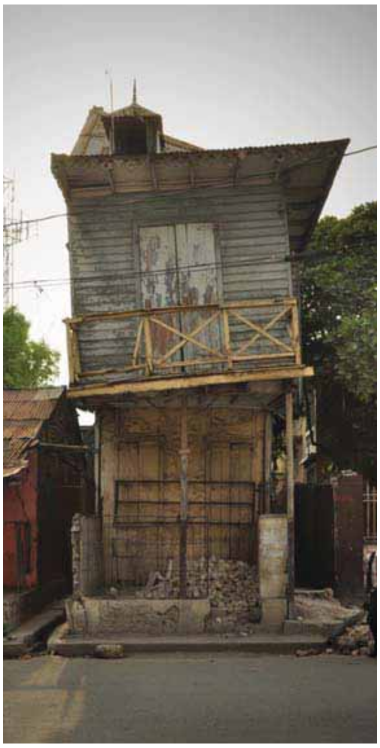


Figure 90 A wood clad and *colombage* structure of the most basic type on Rue Geffard near the National Palace. This structure appears to have been designed to be expanded to double its width, but never was. As a result, it was subject to the earthquake with a width at the base of less than 12 feet (3.6 meters). Also, at the time of the earthquake, it was in extremely poor repair. In spite of all of this, the earthquake did not cause it to collapse.

The question of whether the Haitian infill masonry (when compared to *hımış* in Turkey during the 1999 earthquakes, and *dhajji dewari* in Kashmir during the 2005 earthquake) has contributed to the prevention of collapse of the buildings is not easily answered, because the interior timber cladding also would have resisted collapse without the aid of the infill masonry. However, when one considers the destructive effect of the termites, it is possible that *colombage* with rubble masonry may have reduced the progression of the termite damage because of its high lime content.

Because of friction with the infilled panels, it may also have dampened the earthquake vibrations in the structures, thus reducing the likelihood of collapse. The April mission was too long after the earthquake to make a comprehensive analysis of the causes of complete collapse in the small percentage of Gingerbreads that suffered that fate. There is evidence that buildings of 100 percent timber construction were among the victims of the earthquake, together with others of mixed construction containing *colombage* and masonry. However, a study of the Pictometry aerial images

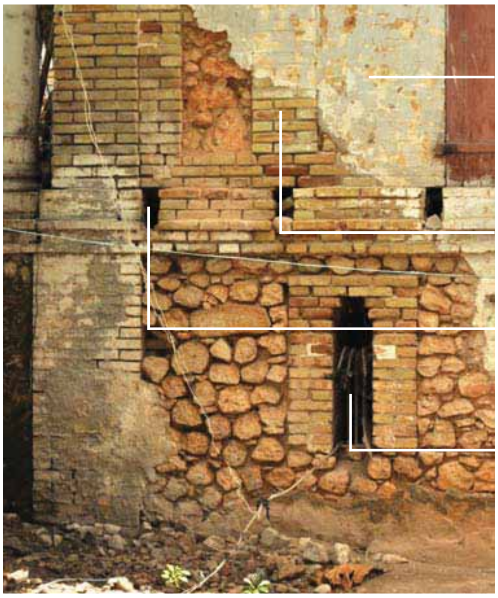


Figure 91 Examining masonry structures

The finished plastered wall surface hides the substrate material from view. Years of rain and lack of maintenance have caused erosion on the building revealing the structure

Notice the bearing-brick column straddles the floor joists and bears on masonry on both sides.

Pockets for the floor beams; in many instances the ends of the beams showed extreme rot.

Sub-floor ventilation

Figure 92 Basal erosion of the wall surface and foundation.

Figure 93 The masonry bearing walls of the ground floor of the Dufort House on Rue du Travail Deuxième are significantly damaged and partially collapsed, while the wood framed second floor remained almost undamaged. The horizontal iron ties, visible here and in Figure 95, were effective in preventing the collapse of this corner pier despite extensive masonry damage. Without these ties, it is likely that the entire building would have collapsed.

after the disaster indicates that the numbers of collapses for these construction types was very small—perhaps less than 3 percent.

In those buildings with masonry bearing walls below a *colombage* level, as for example in the Dufort House, the extra weight of the infill masonry may have been critically important in pre-compressing the masonry below, which helps it resist collapse (Figures 93, 94, and 95). The *colombage* construction may also be effective in reducing damage from hurricanes, which can be quite severe in Haiti, because it adds considerable weight to what would otherwise be a light framed wood clad house.

Masonry Bearing Walls: The masonry bearing-wall buildings as a class performed better than the concrete and block buildings in the same areas, but not as well as the *colombage* and timber frame construction systems (with the notable exception of the Oloffson Hotel described on page 48). Substantial seismic damage to the masonry walls was common, while many showed signs of pre-earthquake deterioration as well (Figures 91 and 92). Masonry walls—being inflexible—immediately cracked, sometimes buckled, and occasionally collapsed altogether. In numerous houses with a first story of masonry and upper levels of wood framing, the first floor was damaged almost to the point of collapse while the upper levels remained intact with only minor damage (Figure 93).

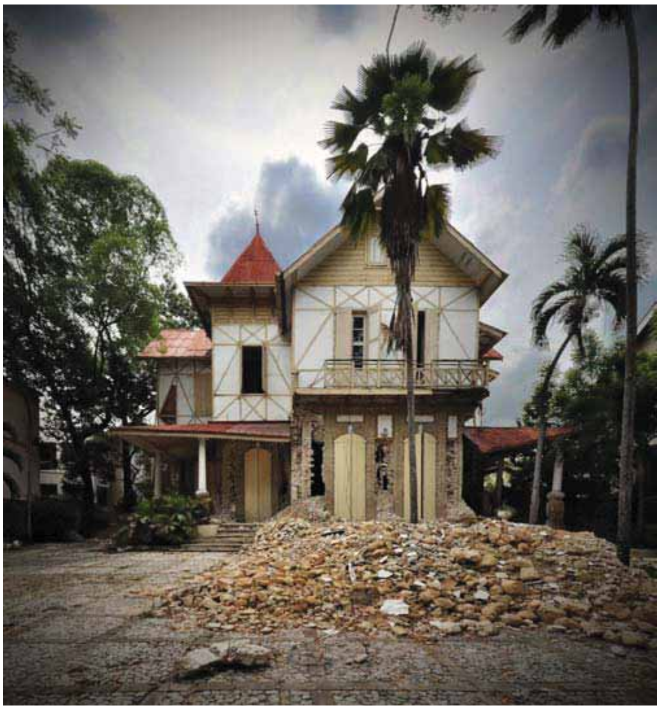
Where rubble stone and brick masonry were combined, the stonework was typically more severely damaged than the brickwork. The weak, limestone masonry panels (with earthen or lime mortar) between the brick piers commonly exhibited shear cracks. The panels often suffered enough loss of material to subject the brick columns to increased shear or buckling stress, and also tended to cause collapse of the horizontal brick 'spandrel beams.' These two courses of brick on the inside and outside faces of the wall, crossing the infill panels at approximately one-meter levels (as previously shown in Figure 26 on page 28), may have been intended to serve as crack-stoppers and to help stabilize and confine the rubble stonework. Unfortunately, it was observed in disrupted examples that the brick courses were not bonded

Figure 94 Ground floor interior of the Albert Dufort House on Rue du Travail Deuxième showing complete disruption of the rubble panels in its construction. The interior wall on the left, which did not have brick piers walls because of the lack of window and door openings, collapsed completely.

through the wall. Instead, they were extended across the inside and outside surfaces only—which is not as effective as a fully bonded brick layer.

The earthquake damage to masonry walls that have the mixture of brick and rubble stone seemed to fall into two distinct categories: (1) damaged but not heavily disrupted, with surface plaster having fallen off, with some ejection of small parts of the rubble stonework, and (2) fully disrupted and on the verge of collapse, with the falling out of much of the rubble stonework, and displacement and partial collapse of the brick piers (See Figure 94). In other words, most walls were either lightly damaged or very heavily damaged, rather than there being an even gradation of damage severity from light to heavy. These observations are consistent with the likelihood that, as the walls rapidly degraded, the frequency response of the buildings moved into that of the earthquake—leading to an even more rapid degradation to the verge of collapse. This is consistent with the fact that the distance from the epicenter meant that the vibrations at the site were of a fairly long period. This is also consistent with the observation that the rubble masonry in the Port-au-Prince heritage buildings was unusually vulnerable, leading to rapid degradation once there was an onset of inelastic behavior in the rubble panels themselves.

In a number of instances where the rubble stone panels were fully degraded or collapsed, the buildings (such as the Dufort House and Le Manoir) were saved from total collapse by the brick piers that surrounded and confined the rubble stone (see Figures 95 and 96). Unfortunately, this brickwork was not bonded one wythe to the



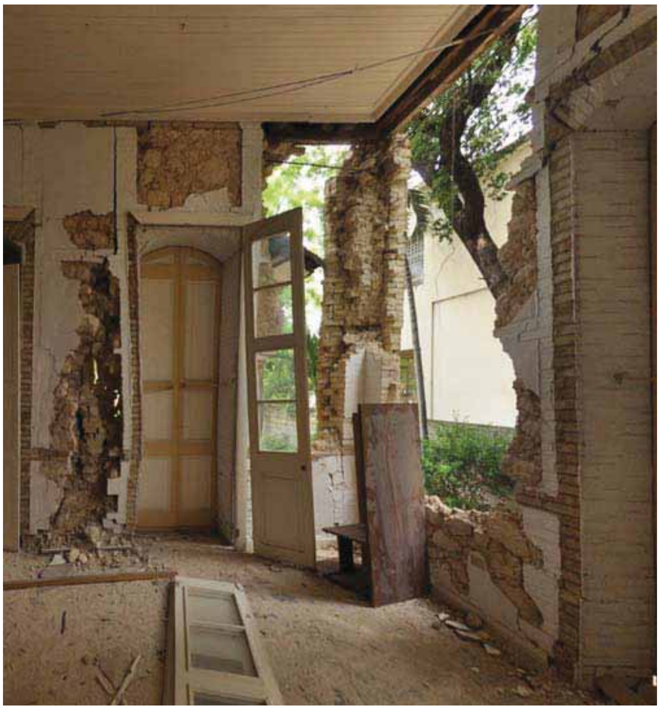
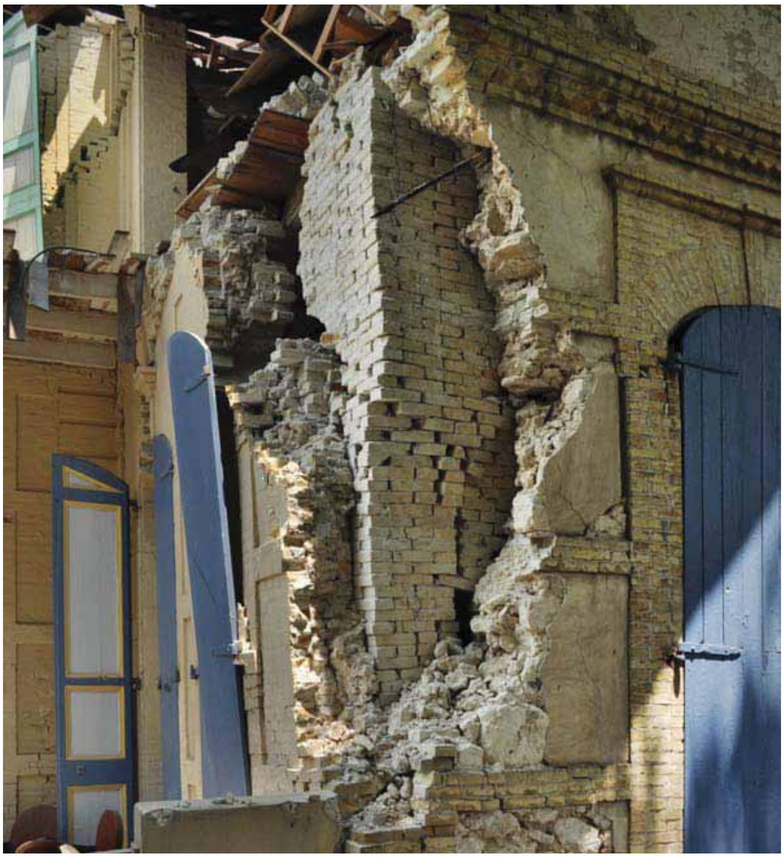


Figure 95 *above left* The Dufort House showing the collapse of the rubble panels, leaving the piers standing holding up the almost undamaged upper floor structure. The remarkably large pile in front shows the volume of rubble masonry removed from the house after it had collapsed. *above right* The interior of the Dufort House, also shown in Figure 77, showing how the collapse of the rubble panels left the house standing on the brick piers which were left like free standing columns. *left* This house also had steel or wrought iron reinforcing chains made up of rods hooked together for the full length of the exterior and major interior walls. In this case, rather than exterior plates to hold them, their wall anchors were imbedded under the outer wythe of masonry. The rods are also visible where they intersect at the corner pier that is still standing, which can be most clearly seen in Figure 93.

Figure 96 *top* Exterior view of Le Manoir on Avenue John Brown. *middle* interior view of Le Manoir showing a fully disrupted ground-floor wall where the rubble panels have collapsed, but the buildings remained standing on the brick piers. (view is a mosaic of several photos connected together). *bottom* House at 65 Avenue N showing infill panels manifesting the onset of damage, but little displacement during the earthquake.

Figure 97 Two-story masonry house at 46 Avenue Christophe. During the earthquake, part of the second floor collapsed, followed by the subsequent collapse of the rest of the second floor. These photos show the ground floor, which remained standing, but with major rupture to the masonry walls, particularly at the corners. *right* The iron rod that had held the building together at the floor level is visible where it had failed because of corrosion. This image also reveals how the inner wythe of brickwork was not bonded to the outer layers of rubble stone. To form the inner corner of the room there is a layer of brick, whereas in the middle of the room, the rubble stone panel goes through the entire thickness of the wall.



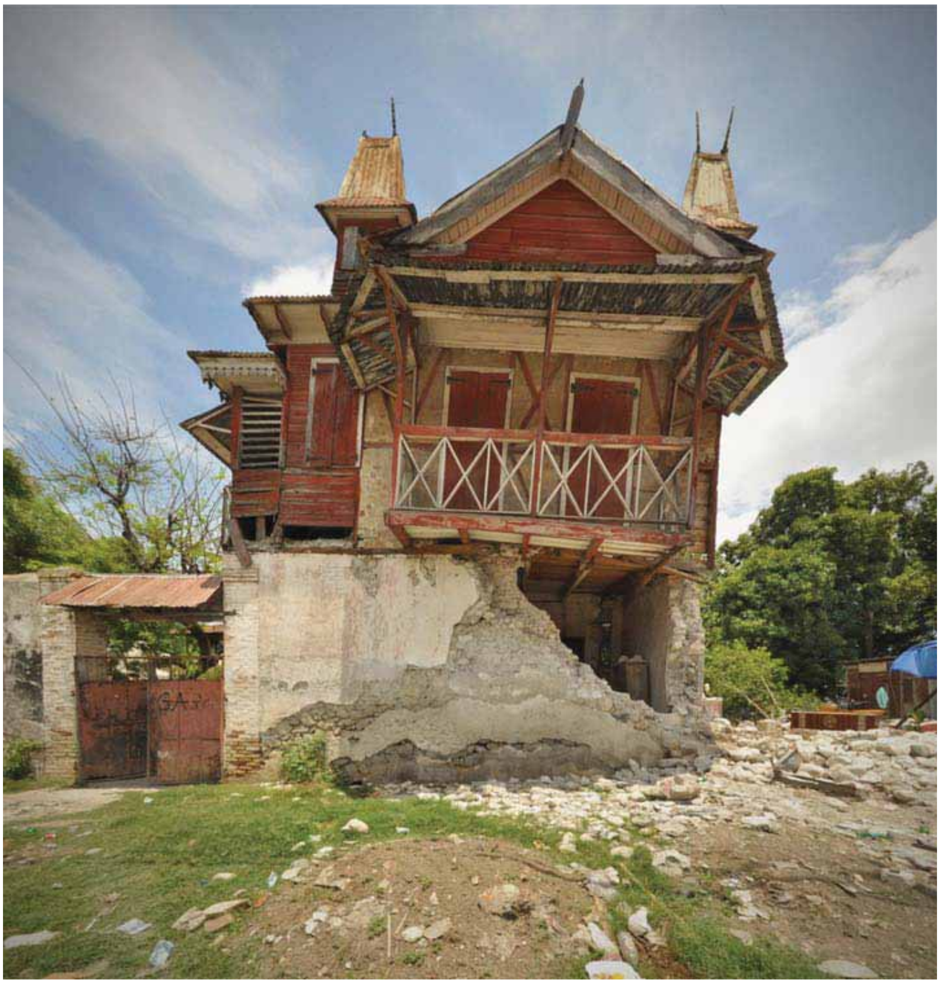


Figure 98 House in Léogane where the solid rubble stone wall on one side partially collapsed, while the side with the two door openings with brick piers and rubble panels seen through the collapse remained standing with much less damage.

next, so the piers have been shifted in those locations where rubble has been heavily disrupted or collapsed (see Figure 97). However, because of the horizontal bedding of the masonry, they remained stable. Walls that were disrupted to this extent will need to be rebuilt, and when rebuilt, a more stable masonry can be substituted for the rubble masonry. Since the rubble was always in recessed panels covered with plaster, substitution with better material should not result in a visual change.

A comparative observation in Léogâne was of the performance of the walls with brick piers compared with solid walls of rubble masonry. One house there had a solid rubble stone wall on its south side without any penetrations by windows or doors, and on the north side, the wall had two tall door openings, which accounted for approximately 40 percent of the width of the wall, leaving three rather narrow piers that made up the remainder of the wall (Figure 98). The standard expectation of earthquake resistance would be that the south wall would be a more competent shear wall, and thus protect the structure from collapse better than the north wall. However, during the earthquake it was the south wall that failed, almost causing the collapse of the wood-framed second story, while the north wall showed the onset of damage to the rubble stone panels between the brick piers on the corners and surrounding the doors. This serves to reinforce the observations in the Port-au-Prince Gingerbreads, which have window and door penetrations on all sides: that the brick piers were crucial to protection against collapse, while the rubble stone was particularly vulnerable to collapse from earthquake vibrations. Moreover, this vulnerability was worse where the panel size was larger both in length and thickness.[10] This is also

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[10] This observation is consistent with what was observed after the Bam, Iran earthquake of 2003, where thick solid walls of unfired clay construction of the ancient Arg-e-Bam were found to collapse, while much thinner sections of wall were found more likely to survive.

directly related to the low cohesion of the material used, combined with the tendency of non-horizontally bedded low-strength masonry to suffer vertical collapse from the internal settling and consequential horizontal jacking (expansion) forces within the core of the wall from earthquake vibrations.

Much like the rubble fill in *colombage* construction, the infill stonework within the brick 'frame' absorbed energy from the earthquake. The transmission of energy across the wall plane tended to jostle stones loose and the soft nature of the bonding medium allowed for failure to occur in stages. Thus, the working of the structure caused by the earthquake vibrations resulted in the rubble collapsing from between the piers, leaving the buildings standing on the piers as a series of legs. It is clear that some of the buildings may have swayed considerably while the earthquake was ongoing as the infill panels degraded. The breaking of the rubble undoubtedly served to dissipate a lot of energy, and thus may have ultimately saved the structures from collapse, even though the weakness of this material made for an extremely low threshold for the onset of significant damage.

This is a stark contrast to many of the concrete structures where the concrete block infill walls acted as a rigid structure, in large part due to the higher bonding strength of the cement mortar. They tended to resist the movement of the frame to the point where the undersized columns of the reinforced concrete frame failed completely, often causing pancaking of the structure.

An interesting and important point of comparison is the Oloffson Hotel (Figures 99 and 100). This building is unique among the masonry Gingerbread Houses be-

Figure 99 The Hotel Oloffson. This building is constructed of brick masonry without the rubble stone panels. The masonry walls are hidden in the front by the wide wooden Gingerbread-clad porches, but are visible below.

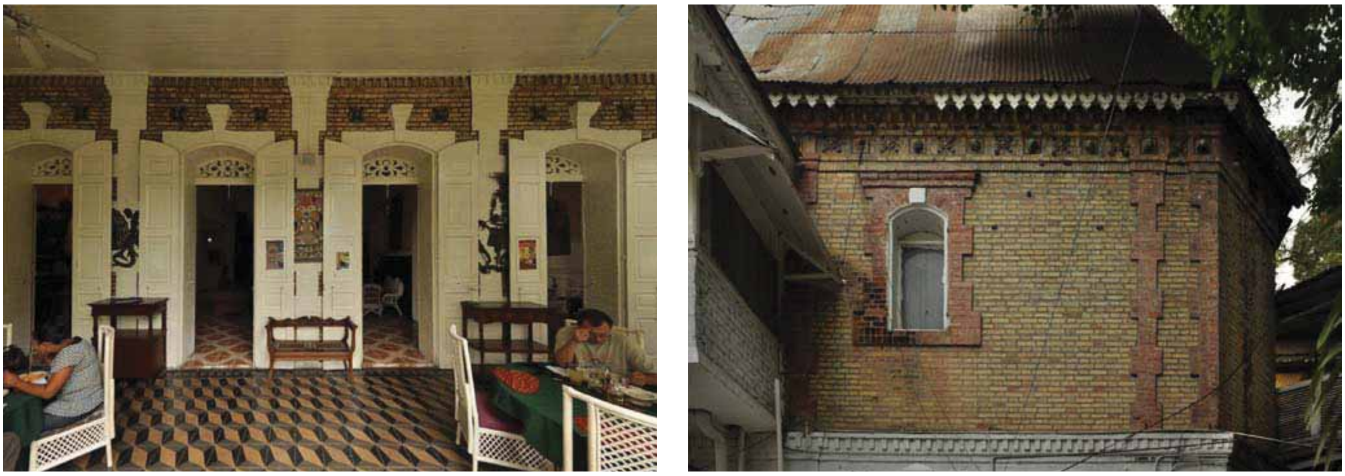


Figure 100 *left* First-floor porch of the Hotel Oloffson showing brick façade with the many door openings that surround the building on all sides. *right* Typical brickwork where it can be seen without the porches.

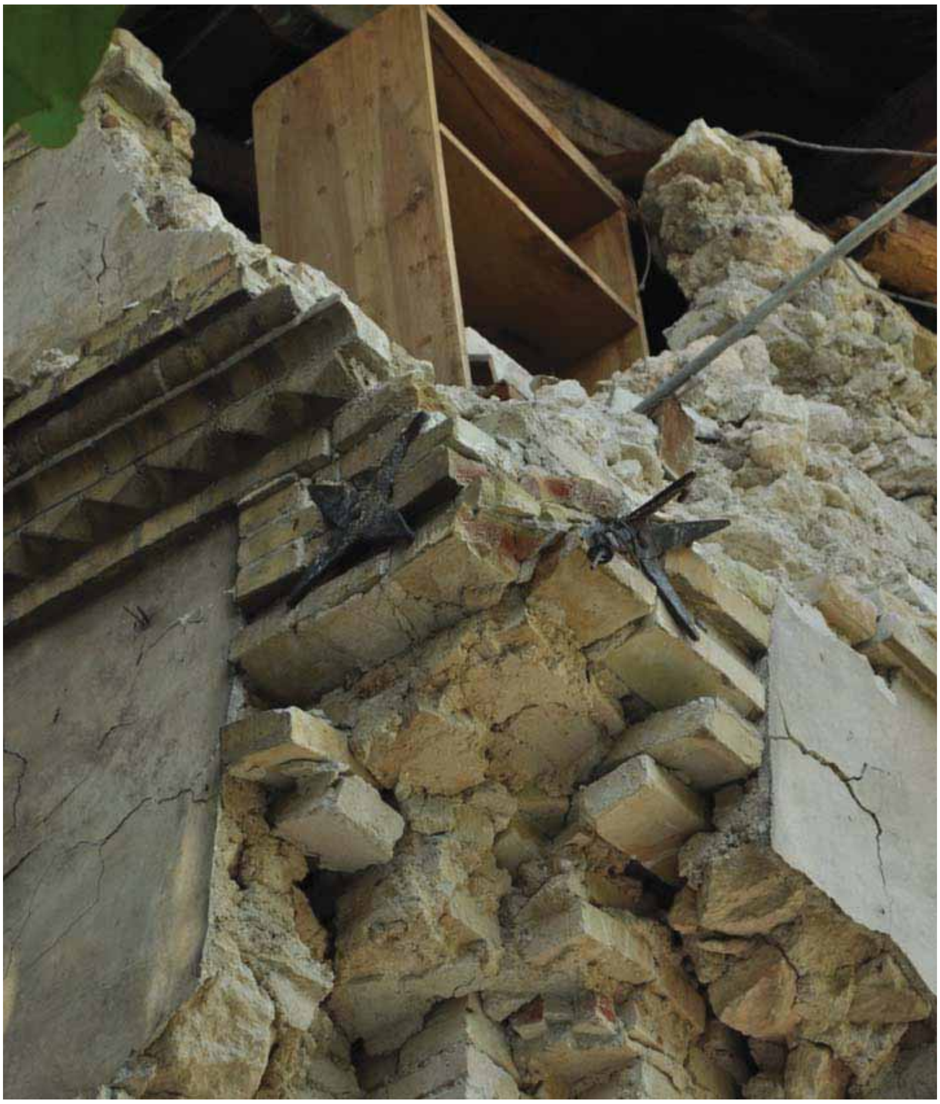


Figure 101 Iron chains are common in many of the masonry walls of the Port-au-Prince Gingerbread houses. Above is the first section of the chain with the star-shaped metal plate, and the view at left shows the metal plates where they remain holding the wall at the floor level in place, thus stopping the further separation of the walls at the corner. Had these floor level reinforcement rings not been installed, the lower floor walls would probably have collapsed as well.

cause it was constructed of load bearing masonry but without rubble stone panels. The walls appear to have been laid up in brick all the way through. The walls were of similar thickness (about 20 inches or 50 centimeters) as in other buildings, and the building is two stories on a high undercroft, so the loads were by comparison significantly higher than in most other houses, but the damage to this building was almost non-existent. Behind the Oloffson was a multi-story concrete hotel building that pancake collapsed completely, so there is evidence of considerable shaking at the site. The survival of the Oloffson Hotel in an almost undamaged state provides a good data point; it corroborates the observation that the greater damage to many of the other masonry buildings was largely a result of the unique weakness and vulnerability to blow-out of the rubble masonry panels.

While the damage to some of the bearing-wall masonry buildings was severe, few of the houses built with masonry actually collapsed, which is not typical of unreinforced masonry structures in other earthquake damage districts. The more usual damage in load bearing masonry buildings tends to be at the top of the structure where the accelerations are the greatest because of the resonance of the structure and where the overburden loads that pre-compress the masonry, which gives it strength, are the least. In the Gingerbread Houses, the damage was most often concentrated in the ground floor, with far less damage in the upper story.

A critically important protective feature of many bearing-wall masonry Gingerbreads is the "iron chains"—the iron or steel rods at the floor and roof levels that tied the walls together (Figure 101). Most of the rods that were observed in the survey appeared intact. Where exposed by the earthquake damage, they were often not heavily corroded, but in a few instances they were observed to have been rusted through. In many of these examples, the tie rod originally surrounded by masonry had been covered by cement; some of these showed a more rapid deterioration from rust, possibly due to the low desorption rate of cements with low porosity.

As noted by several team members, the role of these lateral metal ties in preventing even more severe damage is without question; the masonry buildings performed best when horizontal iron tie rods were present at the tops of the exterior walls (see Figures 93, 102, 103, 104, 105, and 106). These rods were hooked together to form chains and laid into the masonry walls, typically spanning through the entire wall section in the center of the wall plane, usually at the level of a floor or roof. Many have ornamental plates at either end in the form of a star or something resembling a double-ended fleur-de-lis, while others were simply embedded in the masonry, though sometimes the embedded ends did not fully overlap at the corners. In examples where the plates

Figure 102 In this case the horizontal metal ties failed to prevent the collapse of these masonry walls, but may have helped prevent the collapse of the rest of the building

Figure 103 Embedded tie rods cross at the corner, anchored by iron bars. Also note rubble fill between inner and outer leaves of brick masonry.

Figure 104 Total collapse was avoided in this heavily damaged masonry building due to embedded iron rods at the top of the walls, with exposed end plates.

Figure 105 Severely damaged arch, and displaced wood framing above. Absence of tie rods, combined with decay of the timber sill plates made the building more vulnerable.

Figure 106 Linked iron tension rods exposed after the limestone infill panel was discharged. The rod may have prevented complete wall collapse.

Figure 107 112 Rue La Fleur Ducheine, showing the metal plates at the end of the iron chains that are laid into the walls at the floor level. The end of the second floor wall on the left suffered damage because the plate around the corner to the left had fallen off probably because of rusting of the rod, whereas the plate on the right hand corner of the same wall shown on the right was intact, and thus the earthquake did not damage the wall at that end.

Figure 108 The Villa Castel Fleuri shows the effect of the absence of iron chains at the 2nd floor level corners. The pier on the right has been slightly displaced to the right at the second floor level. It is possible to repair it without rebuilding it, but the deflection will then remain visible. A better quality and more resilient restoration will require shoring and relaying of the masonry of the corners of the building with new masonry units to replace the rubble stone. The rebuilt masonry need only extend across to about the middle of the arch.

failed from rust or were not installed at the time of the building's construction, their failure/absence was associated with a greater amount of damage and disruption of the masonry (Figure 107). One good example is the Villa Castel Fleuri, where for an unknown reason rods were not installed at the corners of the second floor, but were installed at the first bay location and at the roof level. In this instance, the second floor corners were more dislocated by the earthquake than were other parts of the building where rods were present (Figure 108 and 47).

Concrete Additions & Alterations: Many of the Gingerbread Houses have additions that were built subsequent to the Gingerbread era. These are usually made of reinforced concrete or concrete block. As noted above, typically additions and alterations that were composed of either concrete block, reinforced concrete, or a combination of these materials caused damage to the Gingerbread Houses that they abut. During seismically induced lateral movements, the additions would typically behave as a distinct structure, rather than the original structure and addition working as a whole (Figure 109). Apart from their independent performance, the additions often caused damage to the Gingerbread buildings through pounding, or by otherwise laterally loading them with their substantial mass. That is to say, as the original structure and addition had varying displacements and frequencies dictated by the materials from which they were composed, they would strike each other. This often resulted in damage to the original structure (Figure 110). With braced frame and *colombage* structures, there was typically a hole in the wall left where the intersection with a concrete addition took place. In masonry structures, concrete additions led to further collapse of masonry walls. It was also observed that when there was a partial collapse, most often it was of the concrete addition, rather than of the original timber, *colombage*, or masonry building (Figures 111 and 112).

These additions were often added for new kitchens or bathrooms, and thus were

Figure 109 Interior and exterior of 51 Avenue Christophe showing reinforced concrete addition to the timber and *colombage* house. The two parts pulled away from each other during the earthquake.

Figure 110 The concrete addition to the right of this Gingerbread house at 34 Lamartiniere collapsed and took down the second floor adjacent wall of the house as well.

Figure 111 The wooden portion of this building remained standing, while the two-story concrete addition pancaked completely. This house is also shown in Figure 136 *right*

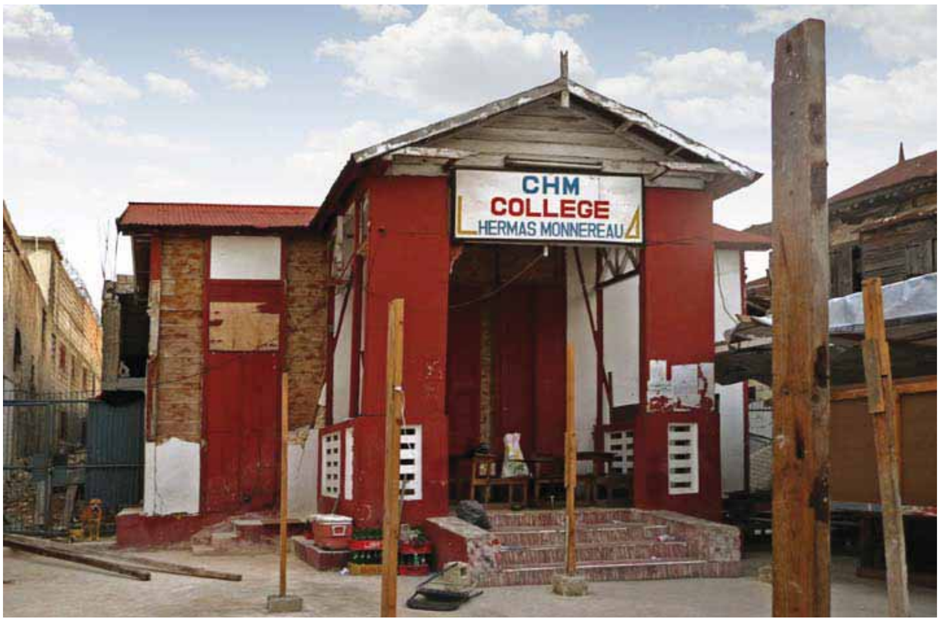


Figure 112 A small *colombage* school building at 16 Lamartiniere that had a two-story addition behind it. Large portions of this addition collapsed completely, but the original building is still intact and in use.

Figure 113 Owner of Rue 5 Jose Marti points to adjacent collapsed concrete and concrete block school building.

constructed with heavy concrete and tile interiors. When bathrooms were installed at the second-floor level, the additions sometimes were constructed on reinforced concrete legs, and thus their weight under lateral loads was imposed onto the historic house, leading to damage both to the addition and to the main house. One example of this can be seen at the Bazin House. Sometimes these additions were old enough to have suffered serious deterioration of the reinforcing due to corrosion. At the Bazin House, the legs that supported the second floor bathroom were broken by the earthquake, revealing that the reinforcing bars were seriously corroded, weakening the structure. This bathroom addition came very close to collapse and the house was badly damaged and out of plumb. (Figure 114)

Again, Le Manoir provided an example of the flaw in introducing concrete into a Gingerbread house. As previously stated, this structure was unique in that it had a concrete slab second floor as an original component. Though the slab would inherently provide a diaphragm to tie the masonry bearing walls together, it also raised the center of gravity of the entire structure, thus increasing the lateral loads on the bearing walls during the seismic action. The result was that the lower rubble masonry walls were significantly damaged by X cracking in a manner that is typical for concrete-frame structures, rather than what is commonly seen in a masonry bearing wall (Figure 115 and Figure 96 middle on page 45). If upper wood floors of other masonry bearing wall Gingerbread Houses were replaced with concrete, as is often done, similar damage would occur in a future earthquake event.

In a few instances, nearby concrete buildings that collapsed ejected walls or slabs onto a Gingerbread building, causing the greatest damage that it suffered (Figure 116). However, on rare occasions, well-designed and well-built concrete additions came through the earthquake with little damage, and sometimes may have helped the attached Gingerbread structures resist the earthquake as well.

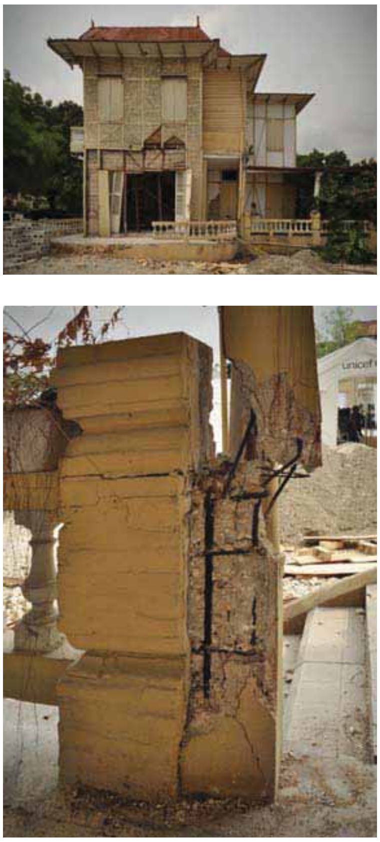


Figure 114 The Bazin House on Rue du Travail Deuxième. An upstairs bathroom of reinforced concrete and block construction clad with wood visible in the middle of the left photo almost caused the collapse of the entire house because it was standing on thin legs of heavily deteriorated concrete with rusted rebar. It was heavy, causing the whole house to sway, almost collapsing the bathroom wing, which may then have carried part of the house down with it.

Figure 115 The characteristic X-cracks seen on masonry wall infills of concrete frames are also present at Le Manoir. These are due to the reinforced concrete second floor slab (above the damaged wall in this picture).

Figure 116 The most damage this Gingerbread suffered was from a concrete slab ejected through its back door from the collapsed concrete building behind. The building's front porch roof was also damaged, by a collapsed concrete building to its side (see Figure 82, page 40).

Recommendations

One of the team members made a poignant observation during the April mission:

> *There were four men standing on the collapsed roof of a pancaked multi-story reinforced concrete building, working with small sledge hammers to break loose the concrete from its reinforcing, so as to demolish the ruins of the building. The sledge hammers themselves were too small for the job, and the job was like that in the Greek myth of Sisyphus. In the absence of heavy equipment, the progress was so slow, and the work so great, that finishing the task of clearing these sites will take years (Figure 117).*
>
> *This observation caused me to revisit the question of what constitutes the threshold between a repairable building and one damaged beyond repair. It led me to realize that so long as a building is standing and has cultural value, perhaps there is a way to repair it. I realized that such an effort would be far more productive than that of tearing it down by hand—especially as it would allow for the training of craftsmanship and the furtherance of creative rather than destructive work.*

Figure 117 Demolition of a collapsed reinforced concrete building using small sledge hammers.

Figure 118 In a typical scene, a Gingerbread stands intact beyond the tragic collapse of a modern concrete building

A review of the Pictometry oblique and aerial views views of the entire district taken one to two weeks after the earthquake confirmed that of the total number of Gingerbread Houses, only a few—perhaps less than 5 percent—partially or totally collapsed. Port-au-Prince suffered tremendous loss and tragedy. But within this immense zone of destruction, it was immediately clear that the *colombage* and wood-framed buildings had survived better than concrete buildings (Figure 118). Furthermore, even unreinforced traditional masonry had fared better than some of the more modern buildings of reinforced concrete and concrete block.

On many occasions during the team's mission, building owners or dwellers made reference to this distinction, saying that their house was "better because it was wood," and that they did not want them demolished. This clearly adds support to the idea that there is something "human" about traditional construction: it is accessible and intuitive. By comparison, reinforced concrete is not intuitive at all. In concrete, the part that gives tensile strength (the steel bars) is not visible, and its proper design requires a level of calculation and analysis, as well as construction knowledge that is not available to most people. A wood or even a brick house with timber floors can be built by a few workers, and made to survive earthquakes by following only basic rules of construction.

The following recommendations have therefore been outlined so as to advance the repair of the Gingerbread Houses and improve survivability. Recommendations are organized under the following headings:

- Immediate and Short-term Interventions
- Research and Analysis
- Materials and Industries
- Typology-specific Interventions
- Education and Training
- Protective Policy
- Funding

Immediate and Short-term Interventions

Discourage Demolition of Gingerbread Buildings: Identify buildings where demolition is being considered. Educate owners about repair and restoration possibilities of their buildings. This may include encouraging a thorough assessment (see "Full Diagnostic Assessments" below), helping to estimate costs of repair, and exploring or making owners aware of funding possibilities.

Temporary Protection from Weather: Encourage or assist owners in the protection of their earthquake-damaged buildings from additional damage from rain and hurricanes until permanent repairs and protection are achieved. Simple tarps can help to protect buildings from water infiltration, but should not be left loose so that they can become a sail and cause further damage in the event of high winds.

Salvage Materials: Initiate a campaign to salvage materials from Gingerbread buildings that require partial or full removal. Encourage that such buildings be dismantled, not demolished, in order to salvage materials for reuse in the repair and restoration of those or other Gingerbread buildings. Of particular value are fired brick, wood framing in good condition, doors and shutters, and ornate finish carpentry assemblies. Designate a common storage yard for owners not willing or able to keep such materials on their property. A revenue-generating business could be created to facilitate the purchase, collection, storage, and sale of salvaged materials for the Gingerbread buildings. (Could be same property as "Training Facility," see *Education and Training* below)

Figure 119 Temporary measures are important: this lateral brace is a good idea, but it is too slender and there is only one.

Emergency Shoring: Create and distribute guidelines, and educate owners and builders about safe shoring methods to protect against collapse from fatigue or an aftershock. Examine reconnaissance forms to see which buildings surveyed were deemed to require shoring. Conduct broader and more thorough survey to fully identify such buildings.

Shoring is of crucial importance for two reasons: (1) it can prevent risk of further collapse of structures which are in a dangerous state or of falling debris, and (2) it can give psychological comfort to the owners or tenants, so that they feel safe in re-occupying the structure, thus improving their living conditions and protecting the house against the ravages of temporary abandonment.

Team members observed that the shoring in place during the April mission was often under-structured and not configured correctly for best protection, whether due to a lack of resources or a lack of knowledge (Figures 119 and 120). This seemed

Figure 120 Scaffolding and shoring at 32 Lamartiniere, and shoring on the interior of 22 Rue Pacot.

Figure 121 Examples of shoring in Italy after the Molise earthquake, showing the heavier timber diagonal braces in the example on the left, and polypropylene straps holding the building together on the right.

to be particularly true of lateral bracing, which is less intuitive to most people than vertical shoring. Training would improve the safety of this work. Also, it may be helpful to establish a group of contractors and assist them in securing shoring materials and equipment. In general, the team found that shoring should consist of timber (or other material) members leaning diagonally against a vertical wall to counteract the overturning action or placed vertically beneath a structure where the original bearing members or walls had been compromised. Other materials that are missing or in short supply include adjustable steel columns with threaded steel extensions, and polypropylene straps that can be wrapped around a structure. For examples of post-earthquake shoring in Italy, see Figure 121 and also: http://haiti-patrimoine.org/wp-content/uploads/2010/02/ItalianShoring-MoliseEQ.pdf

Additional information on Immediate and Short-term Interventions can be found in Appendix B: ICOMOS Post-Earthquake Emergency Protection and Mitigation Strategies.

Research and Analysis

During this assessment process, the team discovered that there is a dearth of information regarding Haitian built heritage in general and the Gingerbread Houses in particular. The earthquake, though a terrible disaster, afforded the opportunity to view numerous examples of construction types with the walls and additions peeled away like the skin of an onion. Port-au-Prince consequently served as a laboratory to view traditional construction materials and techniques, and to understand how they perform under normal conditions as well as during seismic loading. However, there is much more that can and should be accomplished through research.

Historical Research: The designers of the Gingerbread Houses should be researched in the library archives. In the case of the house on 7 Pacot, for example, it is known that the architect and builder were Gustav Keitel and Leon Mathon, respectively, and the building was completed in 1912. Many of the Haitian architects of the period were trained in France and would have imported French technologies. However, there is limited information on the dates, designers, or builders of the vast majority of the remaining Gingerbreads. Understanding, at the very least, the chronology of the development of these buildings would be immensely helpful to interpret the significance of this building style.

Further understanding the historical development of the city of Port-au-Prince through maps would also be extremely helpful in further interpreting the chronological development of the Gingerbread Houses.

Full Diagnostic Assessments: It is recommended that the Gingerbread owners have their buildings more thoroughly examined and assessed. The April mission assessments were conducted to establish global understanding and patterns of performance of the Gingerbread buildings, not to thoroughly assess and make recommendations for any particular building. Such subsequent assessments should be made by a qualified professional (i.e. architect, engineer, trained builder). Assessment Forms can be examined to see which buildings surveyed warranted further inspection, but the overwhelming majority need more in depth evaluation.

Materials Analyses: In the laboratory, analyses of brick, stone, clay and lime mortars, and metals that are carefully selected from various buildings can provide guidance as to the origins and periods of use of these building materials. Additionally, the careful documentation of wood framing techniques, nail types, timber sizes and cutting patterns, board siding sizes inside and outside, door styles, window styles, trim styles, and the like will help to develop stylistic and construction categories to help interpret the architectural vocabulary of the original builders.

Materials and Industries

The earthquake has revealed that traditional construction techniques have value in resistance to earthquakes. The reuse of these traditional techniques should be strongly encouraged. However, to accomplish this, traditional materials are needed, including wood, brick, stone, and clay and lime mortars. Thus, the post-earthquake repair of the Gingerbread Houses also should be viewed as an opportunity to help further some important initiatives for agricultural and industrial growth in Haiti. Consideration should be given to revitalizing the timber, brick, lime mortar, and clay mortar industries in Haiti. A key to the success of such a venture would be to make the industry adaptable to the general population rather than creating a cottage industry that exists only to restore a handful of buildings.

Efforts should be undertaken to reactivate or establish new lime kilns in the country. Good quality hydrated and hydraulic lime is an important and necessary material in the repair and restoration of the Gingerbread buildings for mortar, grout and plaster finish. Other industries include pressure treating of timber products, brick making, and the establishment of either hot-dipped or mechanical galvanizing of metal connectors, rods, bolts, ties, and nails. Certainly one of the most important, and most difficult, initiatives is to re-establish forest agriculture to grow trees suitable for building construction (Figure 122). Once established, their harvesting will also have to be deferred until there is enough heartwood for the commercial production of insect and rot resistant lumber.

Figure 122 The mountain landscape between Léogane and Jacmel shows the terrible beauty of a landscape largely stripped of its historic tree cover.

Figure 123 Typical vulnerability: the wall pulls away on the side parallel to the floor framing due to lack of connectivity between the floor and the wall. This is easily improved in most houses.

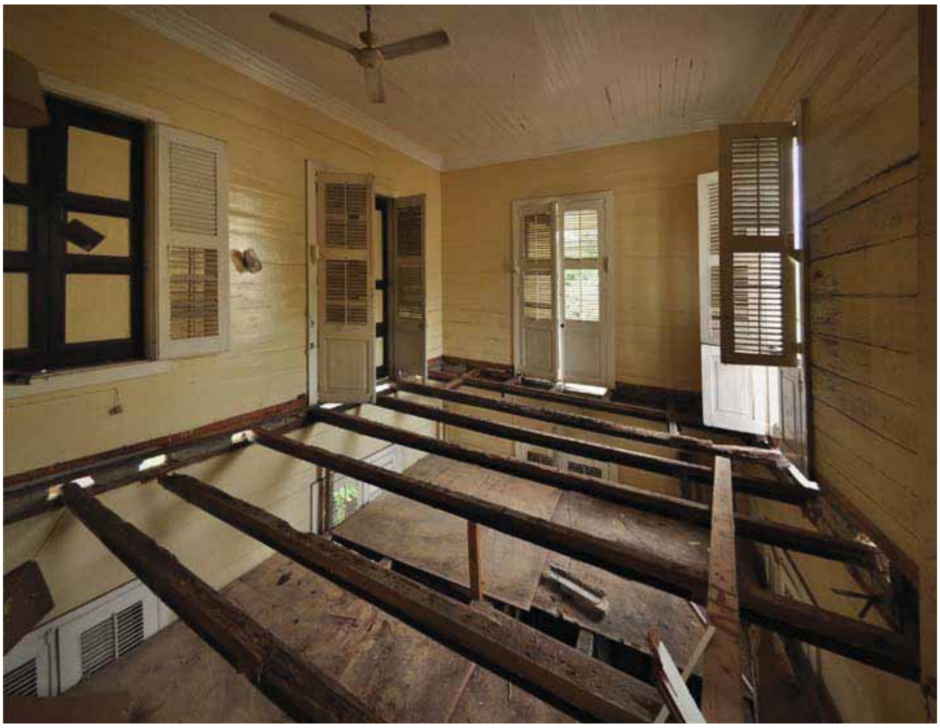


Figure 124 House at 32 Avenue Lamartiniere now under restoration, showing the decayed ends of the joists.

Typology-specific Interventions

Braced Timber Frame and Colombage Timber Elements:

- Improve connectivity between various building elements. Mechanically connect wooden structures to their foundations, floors to walls, between wall framing members, and roofs to the building below (Figure 123).
- Replace damaged or decayed timbers (Figure 124). All newly added timber must either be natural heartwood from a species of tree known to be resistant to the local insects, or pressure treated (Figure 126). Because of the presence of toxic chemicals, pressure-treated wood should be painted when used on the inside surfaces of a house, and should never be used for kitchen cabinets or counter tops.
- When a portion of the timber structural frame of a building is eaten through by termites and thus in need of replacement, the whole timber should be replaced, not just the rotted or eaten part of that timber. Even with colombage construction, the studs, braces, and cross pieces must be continuous from intersection to intersection for the frame to have structural integrity.
- Re-nailing of the siding and of the timber connections throughout the house with galvanized nails will significantly strengthen the timber frame and the seismic re-

sistance of the structures, especially if the existing nails are found to be rusty, and/or are cut nails rather than wire nails. It is strongly recommended that all new nails be galvanized. The existing nails do not need to be removed. The nail heads should be pounded flush with the surface of the boards. (With shiplap siding, if nails are placed far apart, one at the top and one at the bottom of each board, the normal swelling and shrinking of the board may cause the board to split. The new nail and the pre-existing nail should be separated by no more than about half the width of the board.) The sheathing on the inside can also be re-nailed if it is found to be loose or if the existing nails are found to be rusty or few in number. This inside sheathing will provide a significant contribution to the earthquake resistance of the house.

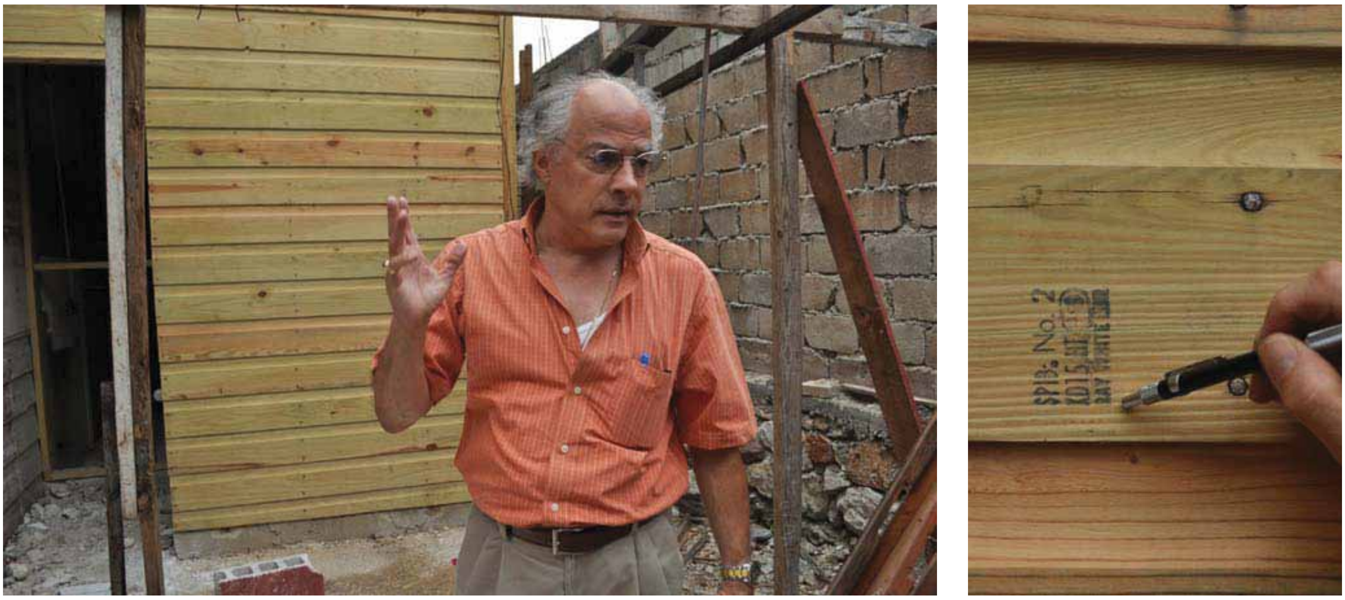
- Re-establish wood floors where previously replaced or overtopped with concrete.

Colombage:

- The *colombage* should be re-laid into the timber bays where it has fallen out. In those instances where it has come loose, but not fallen, care should be taken to evaluate its condition before electing to retain rather than rebuild the panels from the same material. It would be advisable to establish a secure connection between the infilling and the frame, which is harder to accomplish without re-laying the masonry.
- Avoid the use of cement mortar when reconstructing the *colombage*. There were many examples where panels that had been reconstructed with cement mortar fell out of the frames as large pieces causing greater risk to life during the recent earthquake. Use mortar of the same character and strength as the mortar used originally, and mortar that is appropriately soft for the rubble stone.
- There is evidence in a few houses that the rubble stone infill masonry was reinforced with barbed wire at the time of the original construction. Continuing this tradition when rubble infill is reconstructed is advisable (Figure 125). Other types of mesh, including plastic geogrid, could be explored as a reinforcement, but barbed wire may be ideal for the following reasons: (1) it is widely available in Haiti for farming purposes, as well as security fencing, (2) it is almost always galvanized (which is essential if it is to be used for permanent construction), (3) it can be easily installed as the masonry construction is laid up. It is, however, recommended that a different configuration for its layout be used so as to improve the reinforcement effect. Historically a zigzag layout was used. If it is installed primarily as a horizontal bedding reinforcement with some strands crossing over the exposed exterior surface of the masonry (behind the plaster finish), then it can better hold the masonry in place.

Figure 125 Barbed wire is frequently seen in the wall cavities as a restraint for the rubble fill. This is a good practice and should be continued.

Figure 126 Owner and architect Gilbert Mangones explaining the restoration work he is doing on his house at 24 Avenue Lamartiniere, shown in Figures 24, 35, and 134. The new ship lap siding is pressure treated imported timber. The timber grade stamp is shown below.



Masonry Bearing Wall:

Several general recommendations can be made with regard to masonry bearing walls to improve survivability, including:

- Where missing or damaged, install tie rods at the top of walls, tying buildings in both directions and reinforcing arches and other openings as needed (Figure 127). Rebuild severely damaged areas. Inject cracks with lime grout. Only use lime mortar, not cement.
- Reinforce existing interior walls with well-nailed plywood so that they will serve as structural cross-walls, or add additional nails to existing interior horizontal wood cladding on interior walls. In the absence of adequate interior walls, add new interior plywood-sheathed interior cross-walls.
- Stitching of un-bonded multi-leaf walls may be needed in some cases.
- Restore timber floors that have been replaced by concrete.

More specific recommendations for masonry bearing wall systems and conditions follow:

A. **Repair of masonry walls with rubble stone panels and brick piers where the rubble stone has become exposed from the shedding of portions of its plaster coatings, but the rubble stone is still complete and confined within its brick frame, and the brick piers do not show any displacement. Cracks in the rubble stone and the brick bands may be visible.**

   ❑ For those walls where the rubble stone is not significantly disrupted (Figure 128), it can be repaired in place. Minimal repair will involve the re-plastering of the rubble panels on the interior and exterior of the buildings. An easy way to accomplish minimal strengthening of these panels is by installing a galvanized wire mesh or expanded wire lath on both sides of the panel. To increase the effectiveness of this by confining the masonry against its vertical compression and lateral expansion, these two ferro-plaster skins can be secured one side to the other with galvanized pins or threaded rods drilled and inserted through the wall and secured with washers and nuts or other types of secure clips. *Other*

Figure 127 Typical 'brick frame' with rubble infill construction. Note crack pattern/energy absorption in rubble fill. The addition of ties to resist the spreading of the arches at the tops of the openings will improve earthquake resistance, especially when the arch is close to the corner of the building as in the figure on the left.

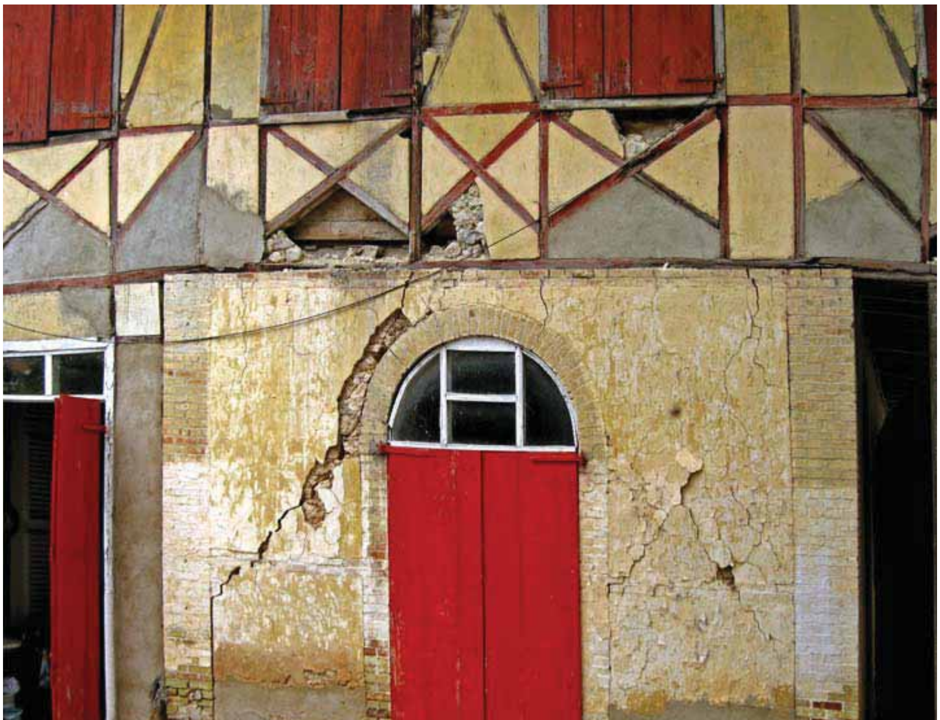


Figure 128 Interior and exterior examples of low levels of damage to rubble stone panels in masonry walls.

repair and strengthening procedures for the rubble masonry panels will be researched and presented in greater detail subsequent to the publication of this Report.

- ☐ In all repairs, care should be taken to avoid the use of strong Portland cement mortar. Ideally, hydrated lime should be used (which may need to be imported). If lime mortar is not available, it may actually be better to use clay mortar than to use Portland cement mortar, if the existing mortar for the surrounding brickwork is of similar strength and consistency as clay mortar. There are two primary reasons for this approach: (a) Portland cement mortar is too strong, rigid and brittle, such that the repaired section of the wall will act as a stiff plug, attracting all of the shear forces not only from earthquakes but also from wind, thermal expansion, and differential settlement leading to cracks in the wall, and (b) Portland cement can infuse the surrounding low-fired brick masonry with soluble salts, leading to its rapid erosion and exfoliation.
- ☐ The integrity of the system of iron or steel chains that were originally installed at the floor and roof levels of many of these buildings should be checked and where missing or broken, repaired. If they are absent, (for example as was found at the second-floor corners of the Villa Castel Fleuri), or broken (for example on the north-east corner of the second-floor level of 112 La Fleur Ducheine), it is recommended that a surface-mounted equivalent be designed and installed to serve the same purpose. Buildings should be tied in both directions. Some buildings may need additional ties along the line of the arches to prevent spreading.

Figure 129 The collapsed rear entrance of the Villa Castel Fleuri on Avenue Christophe, which suffered extensive damage in the earthquake.

Figure 130 *below left* A rubble panel on the second floor of the Villa Castel Fleuri that collapsed showing the displacement of the bottom of the brick pier into the doorway which resulted from the expansion forces from the panel. *below right* Le Manoir on Avenue John Brown showing a heavy level of disruption of the masonry walls caused by the rapid degradation of the rubble stone panels during the earthquake.

B. **Repair of masonry walls with rubble stone panels and brick piers where the rubble stone is damaged and disrupted, but still largely in place, and the brick piers have suffered only minor dislocations.** *The repair of this type of construction presents problems that may require further research to design the best strategies, but based upon the preliminary an*alysis the following can be stated:

- ☐ In instances where the rubble in a particular panel is heavily disrupted, with gaps appearing at the top or in parts of the panel, and a "belly" appearing in the middle of the panel from the expansion of the front to back thickness of the rubble wall, the best course is probably to dismantle and replace the panel. In such cases, in those instances where a "repair" approach (rather than a "restoration" approach) is to be taken—that is for non-museum level work on private homes—the replacement of the rubble panel with other material is probably the best course. Of the choices for masonry materials seen in Haiti, the small hollow clay tile bricks observed to be used in Haiti may be the best alternative because they are lighter than solid bricks. Because of their horizontal bedding and compatibility with the solid brick piers, they will perform much better in an earthquake than the rubble stone.
- ☐ This reconstruction work should be set back far enough to allow for it to be covered with the same kind of plaster that is currently found over the rubble stone panels.
- ☐ As with the lightly damaged walls in "A" above, in all repairs, care should be taken to avoid the use of strong Portland cement mortar. Ideally, hydrated lime should be used (which may require it being imported). Should lime mortar not be obtainable, it may actually be better to use clay mortar than to use Portland cement mortar, if the existing mortar for the surrounding brickwork is of similar strength and consistency as clay mortar. There are two primary reasons for this approach: (a) Portland cement mortar is too strong, rigid and brittle, such that the repaired section of the wall will act as a stiff plug, attracting all of the shear forces not only from earthquakes but also from thermal expansion, and differential settlement leading to cracks in the wall, and (b) Portland cement can infuse the surrounding low-fired brick masonry with soluble salts, leading to its rapid erosion and exfoliation.
- ☐ As with the lightly damaged walls in "A" above, the integrity of the system of iron or steel chains that were originally installed at the floor and roof levels of many of these buildings should be checked and where missing or broken, repaired.

C. **For those buildings still standing where the masonry walls are heavily damaged or collapsed.**

- ☐ The criteria of whether or not a building can be saved will take further analysis and discussion, but as mentioned above, given the lack of machinery and the time and effort to demolish and remove rubble by hand in Haiti, it begs careful consideration of what is deemed "damaged beyond repair." The question clearly is raised with respect to two buildings where the damage is extreme: the Dufort House, and Le Manoir. In the opinion of the team, the Villa Castel Fleuri also lies on the "feasible to repair" side of that line despite the collapses of parts of its two projecting elements, the second story front porch on one side, and the stair tower on the other (Figure 129).
- ☐ In the case of the Villa Castel Fleuri, the two collapsed elements can be rebuilt (and strengthened). The more serious concerns are with the main walls where in some areas the rubble panels have been disrupted and partially collapsed, but these can be repaired following the strategy in "A" above. Some portions where the brick piers have shifted are best dismantled and rebuilt, but the cultural and economic value of the building as a whole, compared to the estimated amount of work needed to repair it, makes it very feasible to rebuild.
- ☐ In the case of the Dufort House and Le Manoir (Figure 130), the damage consists of very heavy disruption to the masonry walls on the ground floor level—including dislocation of the brick piers as well as the collapse of the rubble ma-

sonry panels. The partial collapses of the walls have revealed that the brick piers themselves were not well bonded in their construction, and the mortar had become unusually weak and powdery. Repair essentially requires the re-laying and reconstruction of most of the walls of the ground floor level of the buildings. To accomplish this, a carefully engineered and constructed system of shoring will have to be undertaken, and then, section by section, the walls can be rebuilt. Considering the example of the Hotel Oloffson (Figures 99 and 100, page 48), the best rebuilding will be to carry the brick masonry throughout the walls, without the brick pier and rubble panel configuration. The architecture can be restored by recessing the panel areas and plastering that section. All brickwork should be bonded, so that all wythes are interconnected across the collar joints, the absence of which has contributed to the extensive damage in the earthquake.

- ☐ The question of whether to use Portland cement mortar and steel reinforcing in these rebuilt walls can be raised because the rebuilt walls will essentially be new construction. This leads to an interesting debate, but for the reasons enumerated above, Portland cement mortar is incompatible with the low-fired brick used in these historical buildings, which presumably will be reused in the reconstructed walls. Lime mortar should be used, with hydrated lime imported as necessary (cement is now imported anyway), with its purpose and proper use taught to the masons. Installation of the kind of floor level reinforcement found historically in these buildings is encouraged, rather than installing conventional modern vertical and horizontal reinforcement into the masonry walls because of the likelihood of corrosion damage over time as seen in the concrete and reinforced masonry buildings throughout Port-au-Prince after this earthquake.
- ☐ Surface-applied steel reinforcement like that seen in the Saint Louis de Gonzague Chapel, and the small chapel next to the Cathedral (Figures 131, 132, 133), has performed well in the Haiti environment, probably because of protective coatings and subsequent application of paint. This kind of strategy can be considered, especially where the floor level chains are missing or corroded, and replacing them *in situ* internal to the wall is not possible. The remarkably good performance of those two churches could be considered an inspiration and a model for good performing masonry construction.

Figure 131: interior of the *Cathédrale Notre Dame de L'Assomption* after the 2010 earthquake suffered a complete roof collapse, collapse of sections of its interior arcades, and collapse of the tops of its two bell towers. Remarkably, all four of its two-story exterior facades remained largely intact. The building was constructed between 1884 and 1914, with walls of reinforced concrete with infill masonry construction. Much of the reinforcing had become heavily corroded by the time of the earthquake. Weak bonding due to the use of smooth rebar also made this and other reinforced concrete structures particularly vulnerable to seismic damage.

Figure 133 Saint Louis de Gonzague Chapel on Rue Du Centre after the earthquake. While the modern buildings of the Roman Catholic School collapsed, the Saint Louis de Gonzague Chapel survived without major damage. The Brothers of Christian Education founded the School in 1890, and the Chapel dates from after that date. This chapel is as large and tall as the nave of the Cathedral had been. Its iron frame, which serves to confine the masonry walls, was prefabricated in France. This structural system proved remarkably resilient compared to the early reinforced concrete construction found in the Cathedral as well as the National Palace.

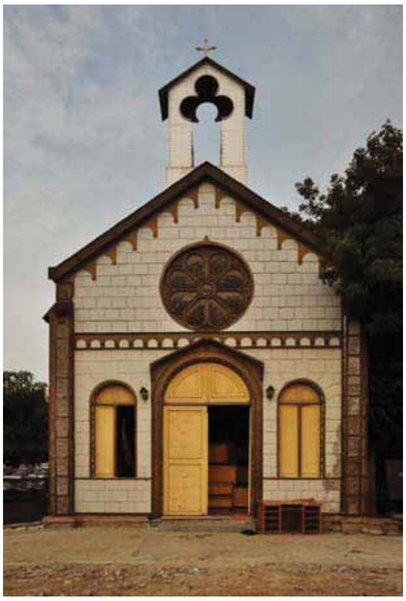


Figure 132 This small chapel next to the Cathedral has the same surface-applied steel reinforcement system as the Saint Louis de Gonzague Chapel and fared very well in the earthquake."

Figure 134 The modern reinforced-concrete frame with concrete-block back additions to the house at 24 Avenue Lamartiniere collapsed in the earthquake and have been removed. The owner, architect Gilbert Mangones, is now doing all of the repairs with timber framing and cladding, which will be much more compatible with the flexible timber frame of the original house, and less likely to collapse in a future earthquake.

Additions:

To the extent possible, additions should be constructed of materials and structural systems compatible with the original house (Figure 134). Any additions not constructed of the same material and structural system of the original house—particularly when they will have a different lateral stiffness—should (1) be designed and engineered as separate structures with their own seismic system, rather than relying on the existing structure for either vertical or lateral support, and (2) be separated from the existing structure with a seismic joint. The seismic joint needs to be sized for the expected sway of both structures to avoid pounding, so that the two structures will not strike against each other during any future seismic event. It is recommended that a structural engineer be consulted to determine the size of this joint, and on the design of the floor and enclosure system on both sides of the joint. The joint can be bridged so that there is no gap in the weather enclosure of the house with its addition.

Figure 135 Well-intentioned but improper repairs with cement mortar in brick work (*above and right*), and cement plaster for colombage infill (*below*). Lime mortar and lime plaster should be used.

Education and Training

As noted repeatedly throughout this report, traditional construction techniques have value in resistance to earthquakes. Revitalizing such techniques and practices will require education of owners and other decisions makers, as well as training of contractors and craftspeople. Ongoing repairs of numerous Gingerbread buildings were witnessed during the April mission. Some repairs appeared to be incorrectly done, including the use of cement mortar for laying brick, or cement plaster finish or monolithic concrete infill in *colombage* construction (Figure 135). Lime mortar and lime plaster are appropriate in these applications. A contractor converting a *colombage* residence to commercial use said he was considering not reinstalling the brick infill where it had been discharged. He did not understand that the brick infill is an important part of the structural system. These and other errors in repair point to an urgent need for more detailed guidance documents and training programs to follow this report.

Encourage good construction practices in the field: Disseminate guidance documents, such as this report, and provide access to technical assistance to owners, contractors, and trades people to encourage proper repair and restoration practices. This should include the subjects of: shoring, material choices, retrofitting (making improvements to the original structural system), and maintenance. In general, it is recommended that the following good practices be followed: (1) use wood with natural resistance to decay (heartwood from tropical species) or that is pressure treated with biocides; (2) avoid the use of Portland cement, and use clay or lime mortar of similar strength and character as the existing mortar for repairs of brick and stone masonry; (3) use galvanized steel when introducing or replacing steel fasteners; (4) where rubble stone panels are collapsed or heavily damaged in masonry bearing walls, use fired brick to replace the rubble stone. To preserve the historic architectural appearance, the new panels should be recessed and plastered (with lime plaster) in the original manner.

Training program: Establish a training program for builders and tradespeople to properly repair the Gingerbread buildings and to redevelop the lost skills of wood framing and of proper masonry construction with the use of clay and lime mortars. A certificate could be awarded after the training is complete as a means of demonstrating minimum competence to building owners. A good example of such a program can be found in the U.S.-based Falmouth Heritage Renewal program, with the mission of preserving and restoring the historic buildings of Falmouth, Jamaica, while improving the lives of the people who live there. Another is the program established in the Murad Khane district of Kabul, Afghanistan by the Turquoise Mountain Foundation, a British-based NGO.

Training facility, demonstration project, Gingerbread headquarters: Collectively purchase a spacious property with a prominent, accessible, moderately damaged Gingerbread building that exhibits all three construction systems. Repair and restore the building as a demonstration project, a facility for the Training Program, and as headquarters for dissemination of information and advocacy for the repair and restoration project. (FOKAL has indicated interest in possibly undertaking such an effort.)

Protection Policy

As noted previously, the Gingerbread neighborhoods constitute a unified heritage district and unique cultural resource. Measures to ensure the protection of this historic urban landscape should be explored and implemented. Suggestions from the team include designation of the Gingerbread District by working with the Government of Haiti to designate the area as a National Historic District. Such an official designation would give further credibility and stature to the repair and restoration effort, and is a necessary precursor to the dedication of funds from certain international preservation and aid organizations. Because such designation can take time, this should be pursued sooner rather than later; doing so could also work to further empower the community of owners and residents.

Funding

Although outside the purview of the WMF team's work, the importance of adequate funding of the repair and restoration of the Gingerbread buildings deserves mention. Access to sufficient financial resources will be the largest obstacle for many property owners. This was expressed by numerous owners. There is a need to secure funding and to implement financing tools (such as revolving loans and micro lending) for supporting repair and restoration work.

Conclusion

The Gingerbread buildings are greatly valued for their aesthetic qualities by their owners and others who reside in and use them, but also by the many Haitian citizens who see them from the street in their day-to-day lives, or see them in their collective memory. Successful restoration of these buildings has a value that goes well beyond the direct value to the property owners, and extends to realms such as neighborhood identities, civic pride, tourism, local and regional economies, and national cultural heritage (Figure 137). The importance of repairing and reviving these buildings and their neighborhoods as a bright spot in Haiti's reconstruction cannot be overstated.

Two very poignant comments were made to the team during the April mission. A Haitian driver and translator whose services were utilized during reconnaissance efforts said:

"I can't tell you how happy I am that you will try to save the Gingerbread Houses."

This individual does not own a Gingerbread property, nor has he ever lived in a Gingerbread house. But his comment is indicative of the love that so many Haitians have for these buildings.

During the first meeting of the team with the Gingerbread owners, one resident asked:

"The ugly modern houses that collapsed around the Gingerbread buildings—can they be prevented from being built again?"

The countless concrete buildings that became death traps during the 35 seconds of the earthquake are the product of a process of building that betrayed the very people it should serve (Figure 136). In addition to their catastrophically poor quality in terms of safety, these concrete buildings have little of what can only be described as "spirit" or "soul." This becomes especially clear when compared with the ample spirit and soul proudly exhibited by the Gingerbread buildings.

It is the fervent hope of the team that this important Haitian resource—the Gingerbread Houses of Port-au-Prince—will be restored and preserved for generations to come. They are uniquely Haitian, and contain a piece of the history and soul of the Haitian people.

Figure 136 *left* House on Rue Jose Marti where the concrete addition collapsed, leaving the Gingerbread house cantilevered over the rubble. *right* The son of the owner of this house is pointing to the place where his cousin remains buried in the rubble of the collapsed concrete addition. This house is also shown in Figure 111 on page 52.

Figure 137 The owner, Madam Jacqueline Mathon, stands in front of her home at 9 Rue du Travail Première.

Appendix A

ICOMOS Post-Earthquake Damage Assessment Guidelines and Forms

The assessment effort followed the Methodology for Building Assessment and Mitigation developed by the International Council on Monuments and Sites (ICOMOS) exclusively for use in Haiti. Principal authors of the methodology were team members Stephen Kelley and Patrick Sparks. The assessments were performed by teams utilizing the following ICOMOS Post-Earthquake Damage Assessment Guidelines and Forms that were developed as part of a methodology for rapid assessment.

The methodology for assessment ranges from basic to sophisticated techniques. Assessment techniques should always begin with the most basic and work towards the more sophisticated techniques as they become necessary. The range of techniques would span from historical research, visual survey, close-up inspection, creation of inspection openings, sample removal for laboratory analysis, *in situ* testing, and long-term monitoring. For the ICOMOS assessment, the techniques should focus only on non-intrusive techniques (research and visual assessment). The seismic event will have already created ample opportunities to look within the building construction due to collapse.

Archival Research

This assessment step is meant to serve as a starting point only. Collect any maps, historic documents, photographs, books, records of previous damages and repairs and restorations done in the past (regardless of text language). Such information found in Haiti may not be available elsewhere.

Rapid Initial Visual Survey

Distress that is observed during the overall initial visual survey should be recorded with labeled digital photography. The visual survey should determine the overall condition of the building. Global behavior and patterns should be assessed, such as overall stability, displacements, and areas of significant distress.

Close-up Inspection

Based on the results of the visual survey, representative locations with typical representative distress conditions or specific unique conditions are selected for further evaluation through close-up inspection. During the close-up inspection, some hands-on non-destructive investigative work may be performed. Sometimes tapping or "sounding" a wall with a small hammer can provide an indication of delamination or loosening of masonry. Specific measurements may be made to quantify cracks, displacements, and out-of-plumb building components. ALSO: In order to reduce the risk of unsupervised demolition, it is useful to put a notice on the historic buildings stating that these are heritage buildings and should not be demolished.

Completing the ICOMOS Post-earthquake Damage Assessment Form

It is recommended that the entire squad performing assessments begin by assessing one to two structures together. All teams are required to fill out and submit their assessment forms (one form per property) at the end of each day. It is recommended that all forms be backed up by taking a digital photograph of it before submittal.

Digital photographs of each property must be taken that document the overall building, and details of its architecture, structure, and damage. These should be dated and properly labeled. The following labeling protocol is required: yyyy.mm.dd-location name-photographer initials-chronological number (example: 2010.05.14 Jacmel SJK_27.jpg). All survey sheets, notes, and photo files must be provided to the team coordinator so they can be compiled as a single body of work.

Inspection summary

An important part of the completion of the assessment forms for each building is establishing a damage summary. This is at the top of the first page so that anyone can immediately see the damage description at a glance. However, this field is to be filled in at the end of the assessment after the building has been inspected. The categories are as follows:

- ***Category 0—No Damage.***
- ***Category 1—Building is serviceable.*** The building is intact with no damage at all, or is only slightly damaged.
- ***Category 2—Building is temporarily unserviceable.*** The building has suffered significant structural damage (seriousness to be defined visually e.g. displaced columns that can be shored or repaired) but can be quickly repaired and brought back in to service. This also includes localized damage of risk to life, such as broken or leaning parapets that could easily fall unless removed or shored.
- ***Category 3—Building is not reusable without major structural repairs.*** Significant structural dislocation e.g. structural components are seriously damaged or dislocated or walls are split and separated, and cannot be easily repaired to a safe condition.
- ***Category 4—The building is destroyed and is beyond repair.*** Partial or complete collapse of the building.

Prior damage assessments and tags

This refers to any damage status assigned to the building prior to this assessment by inspectors not associated with ICOMOS or the team. Often the initial survey (also called usability, safety, or windshield survey) has been completed in the first few days or weeks after the event, and is done by local officials. This initial survey usually results in a three-part distinction between “safe”, “restricted use”, and “unsafe”. Our assessment should be more detailed. Also, since it is likely that ICOMOS teams are not authorized or deployed under local or national government jurisdiction or responsible to report to the government, the ICOMOS damage assessments should not be used for governmental action such as the tagging of a structure to allow or deny entry without the independent review of the structure by the responsible governmental body. If unsafe conditions are identified in buildings which have not yet been inspected or dealt with by the responsible government, the ICOMOS team member should report this to that entity, and not take independent action, except to give informal advice. ICOMOS team members should particularly avoid independently retagging a building as in better condition than previously tagged by a government authorized inspector.

Assessment form fields

The following are explanations of the common data fields on the standard assessment forms.

PART 1: GENERAL DATA

(1.1) Building Identification: This information is essential for accurately locating the building later and for assuring proper dissemination of the findings. The physical address can be difficult to obtain in a disaster zone, so always include the latitude and longitude if the necessary equipment to do this is in hand. Otherwise, note side of the street the property is on by geographic direction, the street names of the nearest intersection, and numbers of properties or approximate distance to that intersection.

(1.2) Inspection Accuracy: This is the level of access to the building by the surveyor. Less access most likely means lower accuracy.

(1.3) Relation to other Buildings: The position of the subject building relative to adjacent structures is an important consideration in determining structural vulnerability. It also helps others in locating the building.

(1.4) Map Reference: Identify the grid or cell of the base map being used by the team. This is preferably an already-established map in general use. For specially made maps with arbitrary grids, keep a copy of the reference map on file at the field office and provide one to each team and take a digital photo of the map showing the property and its surrounds when at each building.

(1.5) Sketch and Notes of Building and Site: Draw a simple plan of the building, and sometimes also an elevation, section, and/or structural detail as deemed necessary, and annotate this or these to convey the general sense of proportion, number of stories, roof shape, etc. Use a different color to mark damage locations on the sketch.

(1.6) Architectural Style: Try to identify the style of the building. Mention the dominant and earliest style if style varies through additions and alterations. Use locally recognized names for the styles.

(1.7) Metrical Data: List the basic metrics for the building, including number of floors, etc. Estimate the age by listing an approximate year (e.g. c. 1870, or pre 1900) as closely as possible. If more than one major building campaign, try to list the major eras of work. State whether the building is occupied at the time of the assessment and the kind of occupancy (residential, retail, office, industrial, warehouse, etc.) and whether (if known) the occupant(s) are tenants or owners (or both).

(1.8) Soil and Foundation: Characterize the gross site morphology (shape of the land), and list any visible damage or suspected risk from ground subsidence (settlement), fissures, tilting, sliding etc.

(1.9) Roof: Characterize the roof structure first as thrusting or non-thrusting (gable framing without cross-ties is thrusting, a truss with intact bottom chord is non-thrusting). Describe the roofs also for porches and appurtenances, and identify if the roofs for these are structurally separate from the roof over the enclosed main building (of significance in terms of risk from future hurricanes).

Part 2: Construction details

(2.1) Building Shape: This is the plan regularity (or lack thereof) and is important for seismic behavior.

(2.2) Building structure types: *(Exterior, Interior, Floors)* These boxes allow choices for basic types of construction. Mark as many as appropriate for the main structure. Cross out or write in different selections as needed. (It is expected that more than one choice may be made.)

(2.3) Adequacy of Tying: Evaluate the extent and condition of lateral ties at floor-to-wall connections, across vaults and arches, etc.

(2.4) Further Actions: Recommend detailed evaluation if needed, barricades, shoring, bracing for safety.

(2.5) Damage to Structural Elements & Existing Measures: Mark all boxes that apply. The matrix combines damage level and extent, and the boxes are shaded to indicate vulnerability. Existing measures are those already in place at the time of the survey. If none, strike through this box with a diagonal line, or write “none.”

Adresse	Inspecteur:	Date:
Emplacement	Affiliation:	*jour/mois/année*

ICOMOS ÉVALUATION DES DOMMAGES APRÈS SÉISME – HAITI 2010

CATÉGORIE DES DOMMAGES	**0** EN BON ÉTAT	**1** DOMMAGES MINEURS/UTILISABLE	**2** DOMMAGES MODERES REPARABLES	**3** DOMMAGES GRAVES RÉPARABLES	**4** DETRUIT
MARQUAGE PRECEDENT					

IDENTIFICATION DU BÂTIMENT

Adresse	
Quartier	
Municipalité	
Province	
Nom du bâtiment	
Propriétaire	
Latitude	**Longitude**

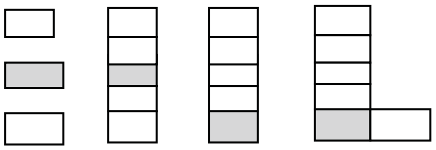
PRECISION DE L'INSPECTION

Extérieur seulement **Complet**

Non inspecté

Raison:

RAPPORT AUX AUTRE BÂTIMENTS



Isolé **Enclavé** **Extrémité** **En angle**

CARTE DE RÉFÉRENCE

DESSINS ET COMMENTAIRES DU BÂTIMENT ET DU SITE

Style Architectural:

3 DONNEES GEOMETRIQUES

Total des étages	**Hauteur d'un étage à l'autre (*m*)**		**Surface de plancher (*m²*)**		**Âge**	**Usage/destination**		**Occupé?**	
	1		**1**			**Domicile**			
	2		**2**			**Bureau**			
	3		**3**			**Assemblée**			
	4		**4**			**Industriel**			
	5+		**5+**			**Autre**			

Adresse	Inspecteur:	Date:
Emplacement	Affiliation:	*jour/mois/année*

SOLS ET FONDATIONS							
Morphologie du site				**Dommages (présents ou possibles) - glissement - liquéfaction - fissures**			
Sommet	**Pente forte**	**Pente douce**	**Niveau**	**Absent**	**Dû au séisme**	**Aggravée**	**Préexistant**

TOITURE	**Instable**	**Stable**	**Charpente du toit**: *à décrire*
Lourd	▓	▒	
Léger	▒		

FORME BÂTIMENT		**Façade**	
Plan		**Irrégulier**	**Régulier**
1	**Irrégulier**	▓	▒
2	**Régulier**	▒	

STRUCTURE EXTERIEURE			
Maçonnerie	Pierres	Briques	Tuiles
Ossature béton	Remplissage: briques tuiles pierres parpaings autre		
Ossature légère bois	Bardage horizontale	Bardage diagonale	Bardage métallique
	Contreventée/non contreventée		
Charpente bois	Colombage: *briques pierres terre*		
Ossature métallique	Revêtement métallique	Revêtement bois	Autre

STRUCTURE INTERIEURE			
Maçonnerie	Pierres	Briques	Tuiles
Ossature béton	Poteaux	Remplissage :	
Ossature légère bois	Plâtre	Couverture bois	Murs secs
Charpente bois	Poteaux	Revêtement	Autre
Ossature métallique	Poteaux	Contreventée	Autre
Autre			

TYPE DE PLANCHER	**OSSATURE**		
RAIDISSEUR	**Bois**	**Métal**	**Béton**
Béton			
Planches de bois			
Voûtes *tôle ou briques*			
Autre			

ACTIONS A PREVOIR:

Inspection détaillée:

Barricades

Etaiement vertical

Etaiement latéral

Cerclage

ADEQUATION DES LIAISONS *décrire*

DOMMAGES AUX ELEMENTS STRUCTURELS

Niveau des dommages et étendue / Composants structurels		**DOMMAGES**									
		Sévères			**Modérés**			**Mineurs**			**Nuls**
		> 2/3	1/3 – 2/3	< 1/3	> 2/3	1/3 – 2/3	< 1/3	> 2/3	1/3 – 2/3	< 1/3	
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	K
1	**Structure verticale**	▓	▓	▒	▒	░	░				
2	**Structure horizontale**	▓	▓	▒	▒	░	░				
3	**Toiture**	▓	▓	▒	▒	░	░				
4	**Bardage/façades**	▓	▓	▒	▒	░	░				
5	**Escaliers**	▓	▓	▒	▒	░	░				
6	**Dégâts préexistants**	▓	▓	▓	▒	▒	▒	░	░		

MESURES D'URGENCE EXISTANTES

Aucune	**Enlèvement/ nettoyage**	**Tirants**	**Réparations**	**Etaiement**	**Barricades**
A	**B**	**C**	**D**	**E**	**F**

ICOMOS FICHE D'EVALUATION DES DOMMAGES APRES SEISME – HAITI 2010

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Address	Surveyor:	Date:
Location	Affiliation:	*day/month/year*

ICOMOS POST-EARTHQUAKE DAMAGE ASSESSMENT – HAITI 2010

Category of Damage	**0** UNDAMAGED	**1** MINOR DAMAGE USABLE	**2** MODERATE DAMAGE REPAIRABLE	**3** SEVERE DAMAGE REPAIRABLE	**4** DESTROYED
PREVIOUS TAG					

BUILDING IDENTIFICATION

Address	
District	
Municipality	
Province	
Building name	
Owner name	

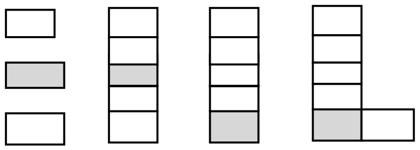
Latitude	**Longitude**

INSPECTION ACCURACY

From Outside Only **Complete**

Not Inspected
Reason:

RELATION TO OTHER BUILDINGS



Isolated **Internal** **End** **Corner**

MAP REFERENCE

SKETCH and NOTES of BUILDING and SITE

Architectural Style:

3 GEOMETRICAL DATA

Total Stories	**Floor-to-floor height (*m*)**		**Floor Area (*m*)**		**Age**	**Use**		**Occupied?**	
	1		**1**			**Dwelling**			
	2		**2**			**Business**			
	3		**3**			**Assembly**			
	4		**4**			**Industrial**			
	5+ (avg)		**5+ (avg)**			**Other**			

Address	Surveyor:	Date:
Location	Affiliation:	*day/month/year*

SOIL & FOUNDATION							
Site Morphology				**Damage (present or possible)** __landslide __liquefaction __Fissures			
Peak	**High Slope**	**Mild slope**	**Level**	**Absent**	**Produced by earthquake**	**Worsened**	**Pre-existent**

ROOF	**Thrusting**	**Non-thrusting**	**Framing Type:** *describe*
Heavy			
Light			

BUILDING SHAPE		**Elevation**	
Plan		**Irregular**	**Regular**
1	**Irregular**		
2	**Regular**		

EXTERIOR STRUCTURE *mark all that apply*			
Masonry walls	Stone	Brick	Block/tile
Concrete Frame	Infill: *brick tile stone block other*		
Light Wood frame	Horizontal sheathing	Diagonal sheathing	Metal sheathing
	Braced/unbraced		
Timber Frame	Colombage: *brick stone other*		
Iron/steel frame	Metal sheathing	Wood sheathing	Other
Other			

INTERIOR STRUCTURE *mark all that apply*			
Masonry walls	Stone	Brick	Block/tile
Concrete Frame	Columns	Infill:	
Light Wood frame	Plaster	Wood covering	Drywall
Timber Frame	Columns	Sheathed	Other
Iron/steel frame	Columns	Braced	Other
Other			

FLOOR TYPE	**FRAMING**		
DIAPHRAGM	**Timber**	**Iron**	**Concrete**
Concrete			
Wood planks			
Vaults *corrugated or brick*			
Other			

ADEQUACY OF TYING *describe*

FURTHER ACTIONS:

Detailed Evaluation:

Barricades

Vertical shoring

Lateral Bracing

Banding

DAMAGE TO STRUCTURAL ELEMENTS

		DAMAGE									
	Damage level and extent	**Severe**			**Moderate**			**Minor**			
		> 2/3	1/3 – 2/3	< 1/3	> 2/3	1/3 – 2/3	< 1/3	> 2/3	1/3 – 2/3	< 1/3	**Null**
	Structural Component	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	K
1	**Vertical Structure**										
2	**Horizontal Structure**										
3	**Roof**										
4	**Cladding**										
5	**Stairs**										
6	**Pre-existing damage**										

EXISTING EMERGENCY MEASURES

None	**Removal**	**Ties**	**Repairs**	**Shoring**	**Barricades**
A	**B**	**C**	**D**	**E**	**F**

ICOMOS POST-EARTHQUAKE DAMAGE ASSESSMENT FORM – HAITI 2010

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Appendix B
ICOMOS Post-Earthquake Emergency Protection and Mitigation Strategies

From the Methodology for Building Assessment and Mitigation developed by the International Council on Monuments and Sites (ICOMOS) exclusively for use in Haiti. Principal authors of the methodology were team members Stephen Kelley and Patrick Sparks.

Part 1: Immediate Mitigation Measures

- Putting up notice/marking the building stating that it is a heritage building and should not be demolished. Any signage should be coordinated with ISPAN.
- Gutters or drain pipes might be clogged with debris. It will be necessary to clear them, or perhaps to make temporary arrangements to drain off the water.
- Temporary covering with light covering material like plastic sheets fastened through ropes, nails/anchoring hooks would be helpful in preventing further damage especially during rains.
- The vulnerability of the damaged building may significantly increase over time especially after a series of aftershocks. Therefore where possible, it is useful to put monitoring equipment like "telltales" to monitor the cracks.
- Salvage of movable architectural fragments or collections to safe places would help in preventing further damage. This should be supplemented by identification and securing of temporary storage and access to laboratory for immediate conservation treatment.
- It is important to take measures for protection against looting of architectural fragments/collections.

Part 2: Short-Term Mitigation Strategies

There are numerous strategies that can be used to mitigate damage to the building. The strategies discussed below are not utilized in isolation but are used as a complement to one another as dictated by specific circumstances (Figure 138, following page).

Ground supported shoring consists of numerous timber or steel members leaning diagonally against a vertical wall to counteract the overturning action. It is relatively easy to assemble and typically does not require lifting equipment. The following disadvantages are noted:

- Requires considerable quantities of timber, steel, or other shoring materials
- Depending on the complexity, shoring may require a significant amount of time for assembly
- Can hinder circulation around the street and building
- Can constitute additional mass against the building which can be dynamically activated by aftershock tremors

The strapping (or belting) system acts as a corset to prevent the damaged walls from collapsing outward. Straps used have traditionally been steel cables. In the recent L'Aquila earthquake, polyester straps were used and are the same as those used in ports to handle heavy packages. The use of the ratchet allows for securing the strap at the appropriate strain. The layout of the straps must be done with great care using various timber sections to distribute the load on the walls. Whenever possible, it is very useful to bind the building together at the most critical levels, where there is also support for the wall from the interior, and thus also underlying structure to connect the strap at mid-points along the walls. This is generally at the tops of walls and at the floor levels. Polyester straps are superior to steel cable, which lacks flexibility in the corners, and is often more economical. Several layers of straps can be used to build additional tensile capacity. NOTE: In the event of partial collapse, it will often be necessary to restore the physical continuity of the wall before the straps are fitted. This is done by either filling the gaps or replacing collapsed parts with braces or horizontal shores or by temporarily rebuilding the ruined wall.

Bracing or walling the openings. Openings are weak points in a structure even during normal times. After an earthquake, cracks around them become a potential factor for collapse. Therefore to supplement other mitigation strategies, such as strapping, openings should be braced with timber balks in order to make the walls as homogenous as possible. Alternatively, it might be simpler to wall up all the openings systematically with bricks bound by weak mortar to allow for ease of later removal.

Dismantling and safe keeping. Fragile architectural elements which have been severely shaken, especially small-scale decorative features, will often have to be dismantled and the materials stored in a safe place. The operation should be amply documented by photography; the dismantled components (building stones in particular) should be numbered before removal and the numbers recorded in a notebook. The numbering should be robust enough to not be faded or rubbed off during storage and transit, but not leave a permanent stain on exposed unpainted surfaces. The components should be stored in a logical order to facilitate reassembly. Dismantling such structures is more difficult where the masonry is of brick, especially if the bricks are covered with plaster molding or sculpture. Ordinary brickwork does not normally need to be numbered, as photographs will provide the necessary information. The aim should be to remove architecturally distinctive components as nearly as possible in one piece, consisting of several bricks still bonded by their mortar.

Figure 138 Examples of shoring constructed after the two recent earthquakes in Italy demonstrate different solutions to the important problem of stabilizing heritage structures to avoid emergency demolition for public safety. The two photos on this page show an unreinforced masonry building damaged in the 2002 Molise earthquake shored entirely with polyester straps, thus eliminating the need to block the street with diagonal braces. Shoring has been installed in the window openings—an important part of any system as it gives the damaged masonry wall structural continuity across openings.

Protection of the building using tarpaulins. Tarpaulins and rope are typically used to protect building interiors from rainwater after hurricane damage. Such a mitigation strategy must be used only with the greatest caution as tarpaulins can act as a sail and cause further damage during high winds when used in conjunction with a structure that has already been structurally compromised.

Protection of non-movable objects. Temporary protection must sometimes be provided for non-movable objects of heritage value like altars, groups of sculptures etc. In the initial phase, sandbag protection may be considered. Thereafter effective protection against falls of overhanging masonry may be provided by a shelter stoutly built of timber or metal with adequate bracing and designed to resist crushing.

Removal and sorting of debris. Once the damaged buildings have been temporarily stabilized, it becomes much less dangerous to enter them or work near them. Only afterwards, debris of the collapsed upper parts should be sorted. However this work can be started earlier in case of heritage buildings that have been completely destroyed and wherever the structures still standing presented no danger to the workers or, conversely, where accumulated debris place the monument at further risk.

In all cases, the debris should be sorted as it is removed. Storage space should be set aside for the storage of each category: rubble, rough stone, whole bricks, dressed stone, reusable roofing materials, beams, joists and structural timbers, joinery, valuable small items e.g. bits of plaster with mural painting which it may be thought possible to reassemble later on, hardware, art objects and collectors' items.

Appendix C

Institutional Contacts

World Monuments Fund (WMF)
350 Fifth Ave. Suite 2412
New York, NY 10118, USA
Tel. +1 646 424 9594
www.wmf.org

Fondation Connaissance et Liberté (FOKAL)
143, Avenue Christophe
B.P. 2720
Port-au-Prince, Haiti
Tel: +509 224 1509
www.fokal.org

Institut de Sauvegarde du Patrimoine National (ISPAN)
Angle des rues Chériez et ML King
Port-au-Prince, Haiti
Tel: +509 3844 0889

Haitian Education and Leadership Program (HELP)
PO Box 1532
New York, NY 10159
Tel: 646-485-8667
www.haitianeducation.org

International Council of Monuments and Sites (ICOMOS)
ICOMOS International Secretariat
49-51, rue de la fédération
75015 Paris, France
Tel. +33 (0)1 45 67 67 70
www.icomos.org

Prince Claus Fund (PCF)
Herengracht 603
1017 CE Amsterdam, The Netherlands
Tel: +31 (0)20 344 9160
www.princeclausfund.org

Pictometry International Corp.
100 Town Centre Drive, Suite A
Rochester, NY 14623, USA
Tel. +1 585 486 0093
www.pictometry.com

GIS Corps of the Urban and Regional Information Systems Association (URISA)
701 Lee Street, Suite 680
Des Plaines, IL 60016, USA
Tel. +1 847 824 6300
www.giscorps.org & www.URISA.org

Figure 139 Left to right Martin Hammer, Stephen Kelley, Randolph Langenbach, Kevin Rowell, Patrick Sparks.

Appendix D
Author Bios

Martin Hammer is an architect in private practice in Berkeley, California. He has designed over 160 residential, commercial, and institutional projects. He has also participated in numerous building forensic investigations. Martin has been involved with the design, testing, engineering, and construction of straw bale buildings since 1995 and has experience with rammed earth, passive solar, photo-voltaics, rainwater catchment, greywater, and other sustainable building practices. He is a contributing author of the book *Design of Straw Bale Buildings*, and is co-authoring a *Strawbale Building Tutorial* for seismically active areas of the developing world for the World Housing Encyclopedia (www.world-housing.net). Mr. Hammer helped introduce straw bale construction to earthquake-affected Pakistan with the organization Pakistan Straw Bale and Appropriate Building (www.paksbab.org). Martin traveled to Haiti in March 2010 with a reconnaissance team from the Earthquake Engineering Research Institute (www.eeri.org), and is currently representing Builders Without Borders in Haiti, working on many facets of sustainable reconstruction.

Olsen jean Julien After studying architecture in Haiti, and Conservation of Monuments and Cultural Properties in Dominican Republic, he traveled to United States for the Post-Graduate Certificate Program in Conservation of Historic Buildings and Archaeological Sites (Columbia University, New York, USA) where he worked at the Columbia University Cultural Media Center. In 2004, he coordinated the Haiti Program at Smithsonian Folklife Festival in Washington DC. Engineer Architect, he is the principal of PHÉNIXIENCE, an architectural and engineering firm, teaches architectural conservation at the State University of Haiti and has served as Minister of Culture and Communication of Haiti (2008-2009). After the earthquake, he is working on preserving Haiti's built and movable heritage as manager of the Haiti Cultural Recovery Project (www.haiti.si.edu) a joint project of the Haitian government, the Smithsonian Institution, UNESCO, and the Fondation Connaissance et Liberté (FOKAL).

Stephen Kelley, Architect and Structural Engineer for Wiss Janney and Elstner, Chicago & co-President of ICOMOS Scientific Committee ISCARSAH. He has undertaken consultation work in the past for World Monuments Fund on other projects. Principal: Wiss, Janney, Elstner Associates, Inc. Fellow: Association for Preservation Technology. Fellow: US/ICOMOS. Editor: *Standards for Preservation and Rehabilitation*. Co-Editor: *Wood Structures: A Global Forum on the Treatment, Conservation and Repair of Cultural Heritage*; *Service Life of Rehabilitated Buildings and Other Structures*. Contributing Author: *Historic Preservation Project Planning & Estimating*; *Historic Building Facades, the Manual for Maintenance and Rehabilitation*; *Twentieth Century Building Materials*.

Randolph Langenbach, Conservator, Documentary Photographer, Retired Senior Analyst at the Federal Emergency Management Agency, and Emeritus Professor. He also has undertaken consultation work in the past for World Monuments Fund, specifically on the Bam Earthquake in Iran. He has been a consultant to UNESCO in Turkey, Iran, Georgia, and India, and is the author and photographer for the UNESCO book *Don't Tear It Down! Preserving the Earthquake Resistant Vernacular Architecture of Kashmir*. In 2002 he was awarded the National Endowment for the Arts Rome Prize Fellowship for his work on the subject of earthquakes and traditional construction. (www.conservationtech.com & www.traditional-is-modern.net). After the earthquake he established a new website on the subject: www.haiti-patrimoine.org.

Kevin Rowell has devoted himself to the study of sustainability, working extensively on international development, particularly in Asia and Latin America. In 2005 he cofounded the Natural Builders (www.thenaturalbuilders.com), a contracting company that works around the world doing cutting-edge work in green building and development, as well as large scale art installations. His passion for natural materials and their use in construction has shown through his work with groups such as World Monuments Fund in preserving traditional architecture, and the United Nations where he has facilitated interagency dialogues about the use of local materials in construction for development.

Patrick Sparks, Structural Engineer, and president of Sparks Engineering, Inc. in Austin, Texas. He specializes in the evaluation and rehabilitation of historic structures. He has evaluated hundreds of historic buildings in the wake of major Hurricanes Ivan, Katrina, and Ike. After Katrina, Mr. Sparks developed the assessment criteria and trained and led the team of engineers for FEMA's triage of critically damaged historic buildings on the coast of Mississippi. He is a co-founder of the Preservation Engineering Technical Committee of the Association for Preservation Technology, a Professional Fellow of the Center for Heritage Conservation at Texas A&M University, and is an expert member of ISCARSAH. (www.sparksengineering.com)

About the World Monuments Fund

Since 1965, World Monuments Fund has worked with local communities, governments, and affinity organizations to preserve cultural heritage around the globe. WMF has engaged in over 600 projects in more than 90 countries. Through five core programs: Cultural Legacy, Capacity Building, Advocacy, Education and Training, and Disaster Recovery, WMF seeks to advance innovation in the field and to ensure sustainable stewardship of the world's most treasured places. For additional information about WMF and its programs, please visit www.wmf.org

Figure 140*:* Daniel Elie (ISPAN) and Dinu Bumbaru (ICOMOS) at 32 Lamartiniere, built by former president Tancrede Auguste.

PHOTO CREDITS

Norma Barbacci: Figures 5, 6, 132 right, 140

Conor Bohan: Figure124 bottom

Martin Hammer: Figures 3, 4, 16, 18, 19 top & middle, 20, 21, 22, 23, 38, 39, 48, 49, 50, 52, 53, 54, 57, 59, 60, 67, 68, 70, 72, 77, 82, 106, 112 top, 113, 116, 117, 131, 135

Stephen Kelley: Figures 23, 24, 26, 27, 28, 31, 37, 40, 42, 47, 51, 55, 56, 58, 61, 62, 69, 71, 74, 75, 78, 79, 80, 86, 87, 89, 88, 93, 102, 110, 115, 129

Randolph Langenbach: Figures 1, 2, 7, 11, 15, 17, 19 bottom, 25, 29, 32, 34, 35, 36, 41, 44, 45, 63, 65, 69, 73, 83, 90, 94, 95, 96, 97, 98, 99, 100, 101, 107, 108, 109, 112 bottom, 114, 120, 121, 122,124 top, 126, 128, 130, 132 left, 133, 134, 136 left, 138, 141

Kevin Rowell: Figures 8, 13, 43, 64, 91, 92, 111, 136 right, 137

Miriam Shipp: Figure 139

Patrick Sparks: 30, 33, 46, 66, 76, 81, 85, 84, 103, 104, 105, 118, 119, 123, 125, 127

Pictometry: Figure 9, 10

Figure 141 *back cover* A splendid mansion of masonry construction on Rue 4 Pacot occupied at the time of the earthquake by Doctors without Borders. The house generally suffered only a moderate amount of damage, but the back masonry wall separated from the frame at the third-floor level. This may have been caused by the later construction of a bathroom with a raised concrete floor.

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