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TECLA Housing Post-Earthquake Damage Assessment
Habitat for Humanity Haiti
September 2021

Oxelia (pictured above) is the owner of a TECLA designed house in Corail. Following the earthquake, she told Habitat for Humanity Haiti, "We were all too afraid to go back into the house because you could still feel aftershocks. But now it has been days, and I see that my neighbors' houses have a lot of cracks, but mine is fine."

Habitat for Humanity Haiti - TECLA Housing Solution

Examining Habitat for Humanity Haiti's TECLA houses after the August 2021 earthquake

Introduction

On August 14th at 8:30 am local time, a 7.2 magnitude earthquake struck the southwestern coast of Haiti, causing large-scale damage across the country's southern peninsula. According to the Haitian Civil Protection Agency, the death toll surpassed 2,200 with more than 12,200 people injured. Approximately 53,000 homes were destroyed and more than 77,000 sustained damage.

The housing sector in the municipalities of Corail, Beaumont and Pestel, including the Caimite Islands, was severely affected by the earthquake. In these three communes, 50,000 houses were completely destroyed and 77,000 more were damaged. Additionally, public buildings, schools, and churches suffered significant damage or were destroyed. As a result, some 650,000 people – 40% of the area entire population of 1.6 million—have been left in need of shelter assistance.

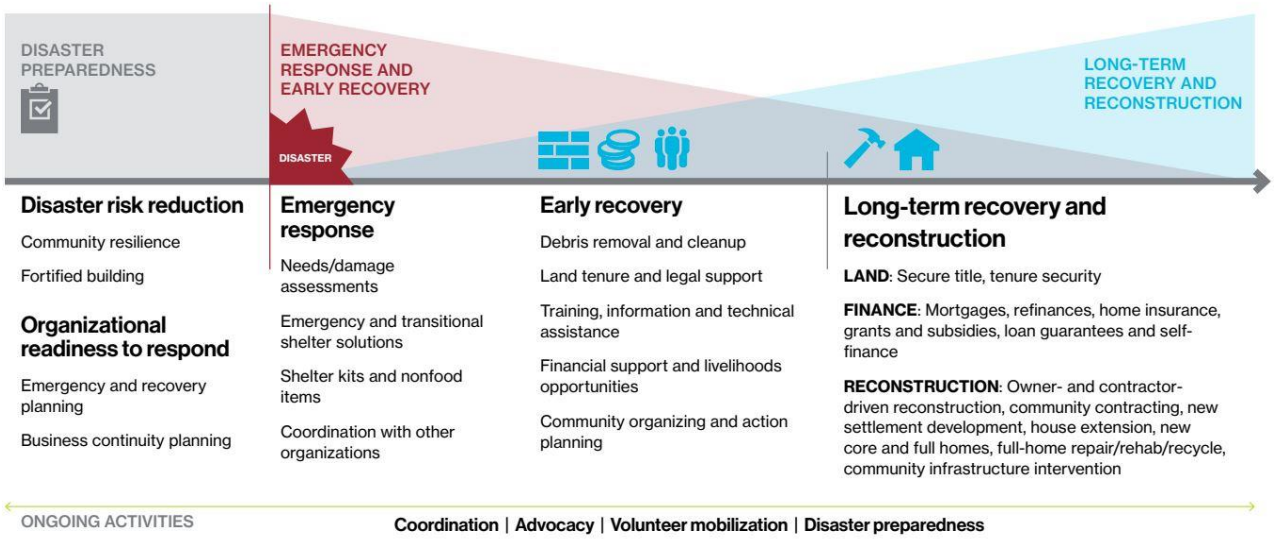
During the destruction caused by the earthquake, 296 homes in the area, that were constructed by Habitat for Humanity Haiti (HFHH) utilizing vernacular architecture were able to withstand the effects of the earthquake, with only 2% of the homes with this typology suffering major damage and requiring the intervention of a qualified mason to implement repairs.

HFHH has an operational office supporting the three impacted departments and has been implementing projects in the affected areas for the past four years. Over this period of time, HFHH has worked in partnership with OXFAM, Christian Aid/KORAL, IOM and CESVI with funding from ECHO, CERF/OCHA, ADH and AARP, to build 315 new homes and repair 1,500 damaged ones in response to the impacts of Hurricane Matthew in 2016.

The housing reconstruction and repair projects implemented by HFHH in the south of the country post Hurricane Matthew were inspired by the local vernacular architecture, which is a very common construction typology in the rural areas of Haiti. HFHH employed a strategy of promoting local participation, increased use of locally available materials, preserving the traditional culture and, most importantly, capitalization of local knowledge. The construction site was used as a "laboratory" class to train local builders and homeowners and raise household awareness on safe construction. The methodology used by HFHH was also intentional to positively influence the general perception towards vernacular architecture by both the local communities in the area and the Haitian housing sector.

Pathways to Permanence

Pathways to Permanence is Habitat for Humanity's global strategy for disaster risk reduction and response and is widely recognized by the global shelter and settlements sector. Pathways to Permanence calls for the reduction of vulnerability and supporting disaster-affected families and communities using holistic programmatic interventions that enable incremental progress toward the achievement of permanent, durable shelter and settlements. HFHH uses the Pathways to Permanence approach guide emergency response, early recovery, and long-term reconstruction activities.



Both damage and safety assessments as well as core and full housing solutions are key interventions within the Pathways to Permanence methodology.

TECLA Typology Design

HFHH offers a house design known as the Technique de Construction Locale Améliorée - Improved Local Construction Techniques (TECLA) model. This intervention aims to increase the resilience of Haitian families living in rural areas.

The TECLA vernacular house design is not an off-the-shelf architectural design. Rather, it is a specific configuration to a geographical region and adaptive to the living conditions of Haiti's rural areas population and its unique cultural heritage. This vernacular housing solution is built to account for the surrounding environment, available materials, and the climate landscape, including wind and sun patterns as well as prevalent or existing vegetation. The vernacular house relies on logical design ideas rooted in community life and household daily activities. It is a valuable addition to the built environment and the rural areas' cultural heritage.

The full TECLA house is approximately 45m² in size, and consists of a multifunctional room, two bedrooms and a gallery or

porch, a signature of Caribbean housing typologies. The gallery or porch located on the main façade represents approximately 9% of the total area of the full house. The access to the house includes a ramp to facilitate mobility for persons with disabilities.

The foundation of the house is made of a continuous concrete beam on top of mixed masonry (stone and cement). It has a built-in anchor steel bar 3/8 to anchor the bottom rail of the elevation with the foundation, which allows the whole house to move as a monolithic block.

The wall structure consists of wood frames, braced transversally with small stone masonry panels, so that they can take lateral loads in both orthogonal directions. Utilizing metal straps (e.g., hurricane straps) all joints are properly reinforced. In addition, the design and calculation of the bracing elements (shear walls) together with the constructional provisions (the regularity of the building) play a major role in the overall behavior of the structure to meet the requirements of non-collapse and damage limitation.

The four-sided roof, which covers the multi-function room consists of a rigid wooden structure, using two trusses lengthwise, braced together, and reinforced in the joint with plywood plaques. Also, a wooden on pan structure covers the two bedroom and the porch. Corrugated galvanized iron (CGI) sheets 44mm are used in all the roof structure, properly nailed and tied with 4 branches twisted wire to the elevation structure. This roof configuration is the most appropriate to resist the effects of high winds.

Wooden doors and windows complement the solution and finishing paint is applied to the exterior and interior of the home following a colorful Haitian palette. In addition, a rainwater collection system with a reservoir and faucet as well as a dry pit toilet complete the work.

As an added characteristic, the TECLA design allows for a back-engineered smaller solution (core house) of approximately 24m², in accordance with the progressive building concept. In that case, it corresponds to the multifunctional room and the gallery/porch built alone. Nevertheless, the extension points are built on the foundation, facilitating the addition of the two bedrooms when the family can. The whole drawing is then given to the family. This is important in disaster response contexts where demand for housing provision increases exponentially in the affected areas. By delivering a smaller solution, disaster-affected families can rapidly access permanent shelter and resources can stretch to reach more families.

The TECLA house design has been approved by the relevant Haitian authorities, namely the Unité des Construction de Logements et de Bâtiments Public (UCLBP) and the Ministère de Travaux Public, Transport et Communications (MTPTC).

Post-Earthquake Assessments

Following the August 14 earthquake, in collaboration with local authorities, HFHH launched a rapid evaluation of the TECLA houses built by Habitat for Humanity Haiti in the August 2021 earthquake affected areas: Pestel, Corail and Beaumont communes.

The objectives of the rapid housing evaluation were:

- To ensure the safety of the families by determining that the houses were safe to be inhabited by homeowners following the earthquake.
- To determine how the HFHH TECLA model houses responded to the earthquake and analyze the seismic behavior of the units.
- To identify and document any weaknesses in the TECLA design and gather lessons learned to inform future improvements in reconstruction and repairs.

Methodology

Following the earthquake, HFHH immediately accounted for all staff in the impacted area. HFHH then started to assess the impact of the earthquake in the affected areas and working to contact homeowners in the TECLA homes built by HFHH.

A specific team of HFHHH engineers was dispatched to conduct the TECLA house assessments in the departments of Gran-Anse, Sud and Les Nippes. The assessment was conducted utilizing a combination of tools:

- Physical Inspection
- Observation
- Individual Interviews (homeowners and local authorities)

The *physical inspection* consisted of a visual structural assessment performed by HFHH engineers to confirm the structural soundness of the TECLA houses. Key components such as the foundation, joints, beams, trusses, or columns/posts were analyzed. Criteria stated in the ATC-20 post-earthquake safety evaluation of buildings field manual was used as a reference tool. The assessment conducted by HFHH's team of engineers considered the TECLA homes following ASCE code 7-10 for minimum design loads with a projected wind of 205 mph for an exposure class D site as well as earthquake magnitude 7.2 which hit the southern peninsula.

The team implemented observation in the inspected communities to briefly gather information on other existing housing typologies and their seismic behavior beyond the TECLA mode. This was done for comparative purposes on the impacts by the earthquake.

Individual interviews with the families occupying the houses sought to gather information on first-hand assessments of the potential and visible damage that the family could see. The team also sought to understand the behavior of the houses at the time of the earthquake. Due to the limited access of some localities, the team could not visit all houses built during the response to Hurricane Matthew, and thus they decided to talk to the authorities to find out about the condition of the houses built within their respective communities. HFHH also sought to consider the local authorities' judgement and reactions on the quality of the houses.

The data collection was conducted through a digital based system, the Kobo toolbox, enabling exact and real-time information collection on the houses as they were being assessed by the engineers. Kobo also allowed HFHH to continuously track the information collected on the houses affected in case of further changes. The assessment results are also supported with evidence such as pictures and first-person testimonies.

Following internationally accepted definitions, the HFHH technical team agreed on classifying the level of the damages into five (5) categories:

1. **No impact or damage**:
   The “no damage " category includes the houses that stood firm and have not suffered any structural damage, with no cracks or broken components.

House of Etienne Tarline, built in Baie Trinette, Pestel (Grand'Anse)

2. **Minor impact or damage**: The “minor damage" category includes the houses that have instances of:
    a. Stone masonry collapsed in one (1) to three (3) triangles from the braced panels
    b. Showing minor cracks
    c. Having the stone masonry unsealed on the bracing.

    Such damages can be repaired within one day by one of the local masons previously trained by HFHH during the Hurricane Matthew response. Families with basic construction skills could also ensure such repair.


3. **Moderate impact or damage**: The “moderate damage" category includes:
    a. Houses that have one (1) to three (3) braced panels broken
    b. The stone masonry collapsed in some of the braced triangles

    Such repair requires skilled masons; most likely the ones trained during the previous Hurricane Matthew disaster response project, using the TECLA techniques and most of the collapsed masonry elements as most of the filling materials are recyclable.


House of Christiane Lucien in Lassale, Pestel Grande' Anse

4. **Severe impact or damage**: The “severe damage" category includes:
    a. Houses that suffered moderate damages AND one or more main posts, as well as intermediary post were broken by the effects of seismic lateral forces, causing the whole wall to bend or collapse.

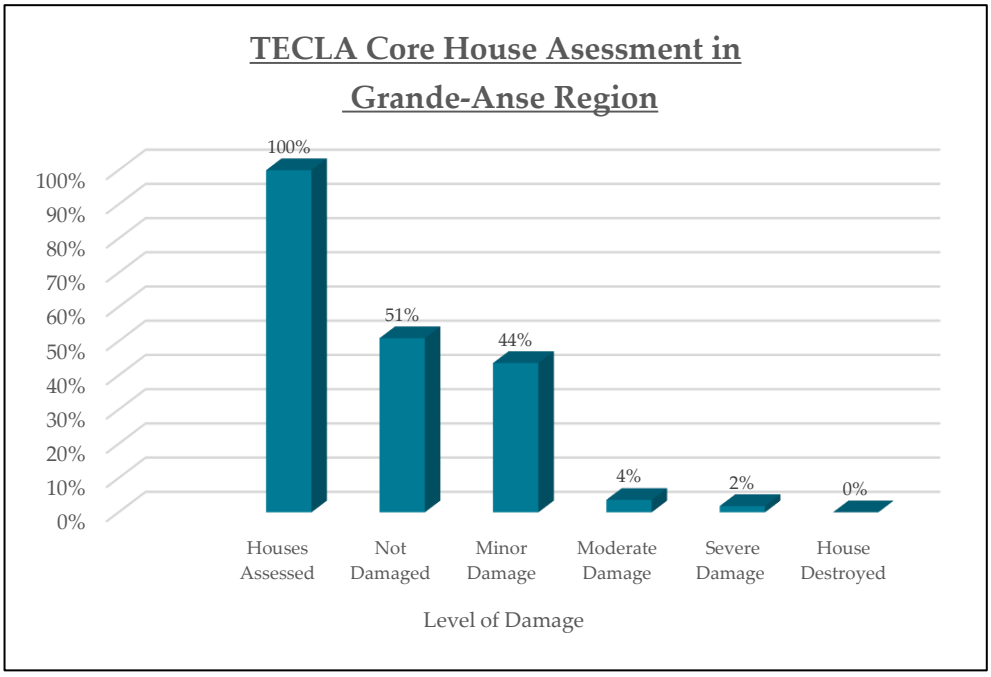
House of Maude Fremont in Cagousse, Pestel, Grande 'Anse

5. **House destroyed**: This is the case where the house totally or partially collapsed by major failure of structural elements, which we didn't observe.

Key Assessment Results

The rapid evaluation of the TECLA houses built by Habitat for Humanity Haiti in the Grand 'Anse region that comprises the communes of Pestel, Corail and Beaumont has concluded that:

- **100%** of the houses built by HFHH were able to withstand the August 14 earthquake. **No deaths or injuries were reported from people living in the houses.**
- **51%** of the houses did not sustain any damage. The overall structure stood firm, and all the key components, such as the foundation, joints, beams, trusses, walls, roof, floor, and columns/posts were intact. No cracks were identified.
- **44%** of the houses assessed had minor damage, with the stone masonry collapsing in one (1) to three (3) triangles from the braced panel or showing minor cracks or having the stone masonry unsealed on the bracing. However, the architecture of TECLA houses was designed to react to earthquakes in this way. In the event of an earthquake, the masonry filling the triangles formed by the braces could fall, and then be easily repaired by a local technician or a member of the household.
- **4%** of these houses have moderate damages, with one (1) to three (3) braced panels broken, and the stone masonry collapsed in some of the braced triangles. Such repairs will require skilled masons. However, most of the filling materials are recyclable, and even some of the wood can be reused.
- **2%** of these houses have severe damages. This means that the homes had moderate damages plus one or several mains post as well as intermediary post broken, causing a whole wall to bend or collapse.
- **0%** of the homes were destroyed.



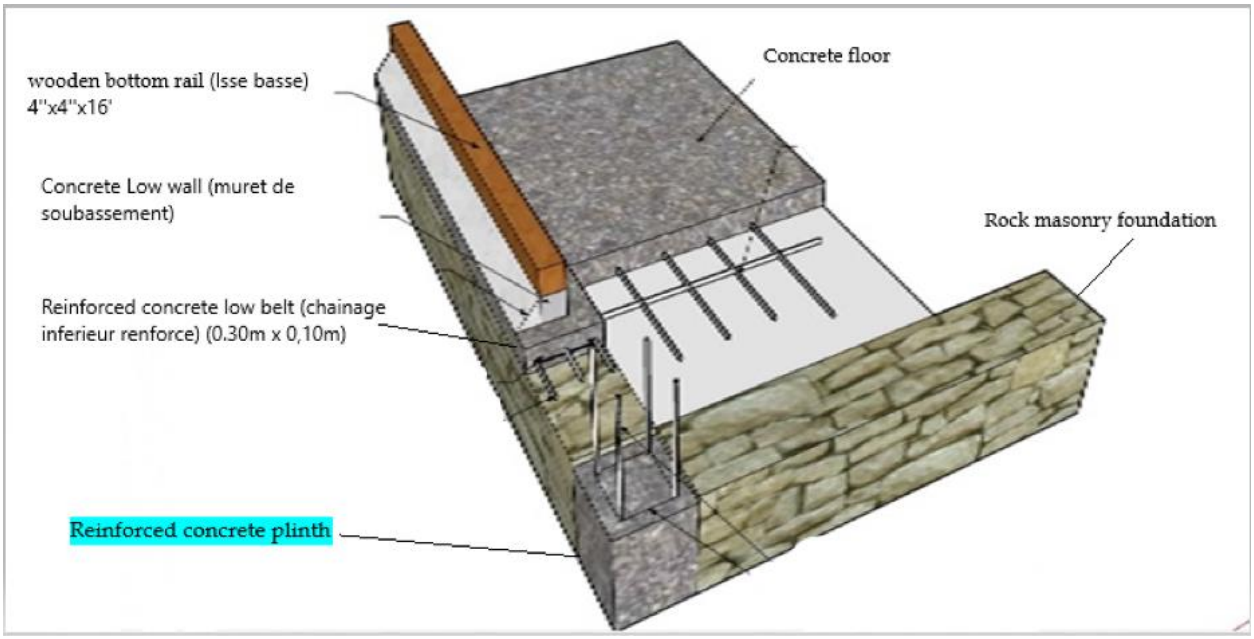
Lessons Learned and Recommendations

Following the earthquake and the rapid evaluation of TECLA homes, a task force has been activated to understand and address the observations done and propose appropriate reinforcement techniques and measures.

Foundation and floor

Although only 3 to 5 core houses presented such damages, we think it is important to propose solutions which will be applied case by case, according to the ground conditions

- **Observations**
  - Major cracks and detachment at the corners in the foundation masonry (low wall).
  - Major cracks in the concrete floor
- **Causes**
  - Ground pounding motion during the earthquake
  - eismic waves passing underground in the surrounding
- **Suggested improvements**
  - Addition of a reinforced concrete belt (lower chainage) 0,30m x 0,10m on the top of the concrete masonry foundation
  - Addition of 0.30m x 0.30m reinforced concrete pedestals in the corners of the masonry
  - Reduction of the distance of the keys in the masonry to a maximum of 0.80m instead of 1.20m



Proposed reinforcement of the foundation and floor

Elevation walls

A total of 6 houses over all 3 communes presented different types of damages in the elevation walls. Once again, we think it worth it to suggest adequate solutions to address these situations.

Observations:

- Breakage of the bottom rail and/or detachment of the intermediate posts in some places.
- Detachment and falling of panels above door and window lintels
- Detachment and falling of panels: stonework with bracing.

Causes

- Loss of resilience of wood due to rotting caused by moisture well before the earthquake
- Insufficient anchoring (number of nails) of stone masonry on the lintel elements of doors and windows
- Insufficient anchoring (number of nails) of the stone masonry on the laths constituting the cross bracing (St. Andrew's Cross)

Suggested improvements

- Better preparation or treatment of the wood in general, but especially of the bottom rail and posts: use of zinc chromate and paint or other treatment method
- Covering the bottom rail with plastic on the upper and outer sides, plus iron mesh to facilitate plastering.

- Increasing the height of the low wall and spreading a drainage layer on the slope to facilitate rainwater runoff on the ground outside the foot of the foundation
- Increasing the anchorage by adding additional nails in the crossbars
- Adding welded mesh or a 5cm x 5cm grid binding net on the inside of the panels to limit human damage

Designing / architecture

Almost all affected houses presented some weakness in the rear wall.

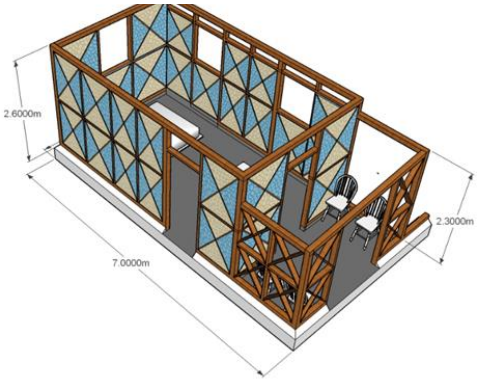
Observations

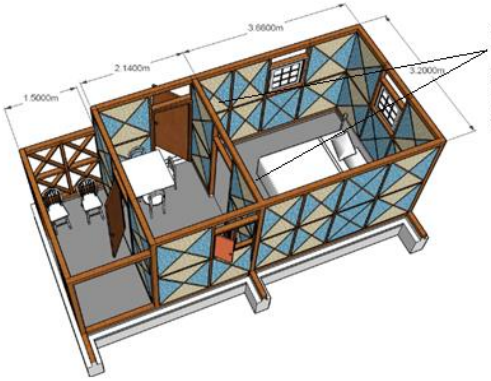
- The rear facade of the houses is usually more affected than the others

- **Cause**
  - Irregularity in the distribution of the wall panels across the width

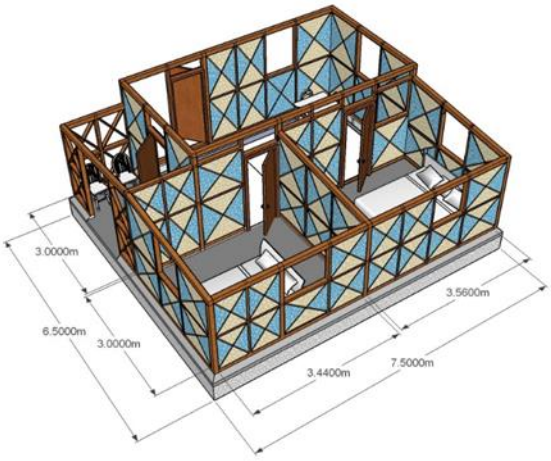
- **Proposed improvement**
  - Addition of two (2) new interior panels in the width direction, for a better redistribution of the forces

Core House's initial design





2 intermediariy panels added to ensure equal distribution of the load all along the lateral and rear walls. Thes panels will be removed for the extension. The materials can be re-uses.



Conclusion

Overall, the TECLA housing solution has shown itself to be very promising due to the design's resilience against multiple hazards and construction technique utilizing local practices and cultures, which are integral in the rural areas of Haiti. Sustainability is ensured using locally available materials and labor, which allows families the opportunity to build incrementally from the core to the full house design, continually improving their homes.

The seismic behavior of the TECLA housing solution is remarkable, as proven by their performance under the 7.2 magnitude solicitation of the past earthquake. No human life was lost in these homes and 98% of them survived the earthquake with damage that can easily be repaired. Even the 2% of homes that sustained severe damage allowed for their occupants to safely flee outside without harm. Thus, the TECLA design is a disaster resilient, culturally appropriate, and sustainable housing solution for rural areas in Haiti and should be promoted as such.

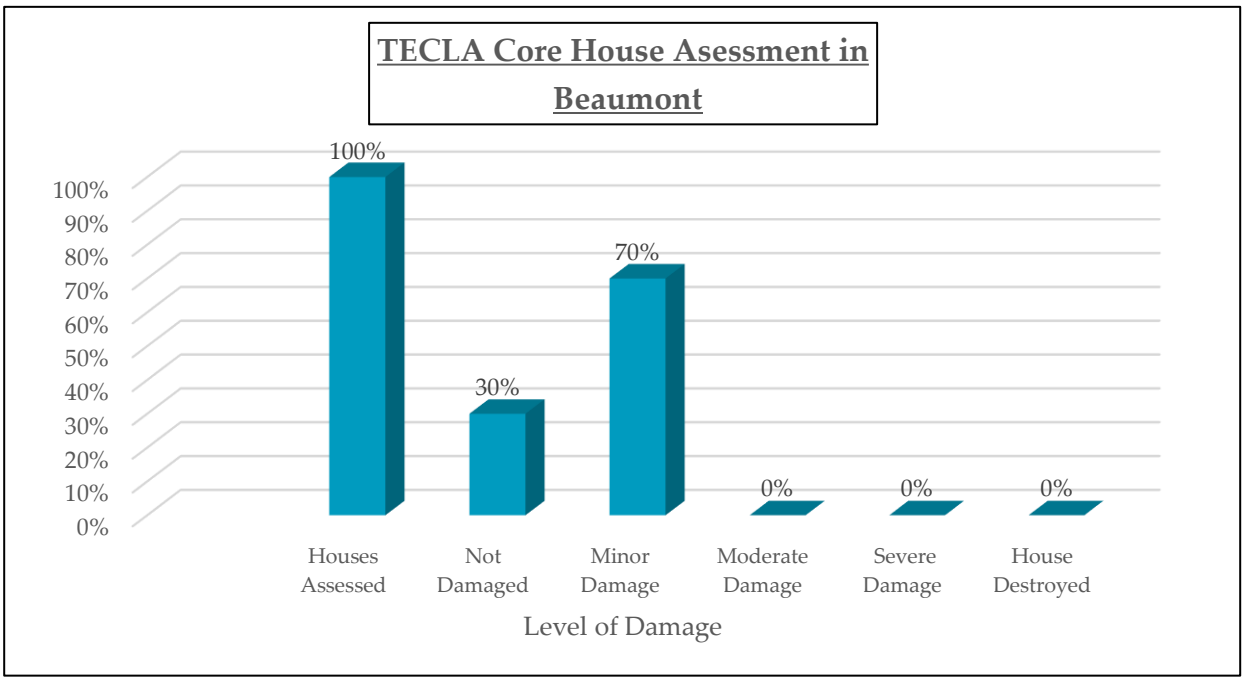
The 2021, August 14th's earthquake constitute an important test for the TECLA building concept used by HFHH as a disaster mitigation mean, within the BBS concept, to strengthen communities 'resilience. The positive findings of this evaluation based on observations of houses built by HFHH require more technical perspective to really determine the strength of the concept itself, which provided such positive behavior, and other conditions such as quality of materials and quality of labor. Therefore, HFHH is open to wider survey and analysis with other partner implementers, as well as key stakeholders in the control of seismic and meteorological areas.

Annex 1: Assessment Results by Municipality

The three departments affected by the earthquake, Grand'Anse, Sud and Les Nippes, did not suffer proportional impacts to the quake. Within each department, some areas were hit harder than others. However, the TECLA houses build by HFHH have shown impressive resilience to the intense earthquake. The below summaries of assessments by municipalities demonstrate the resilience levels of the TECLA model built across the region.

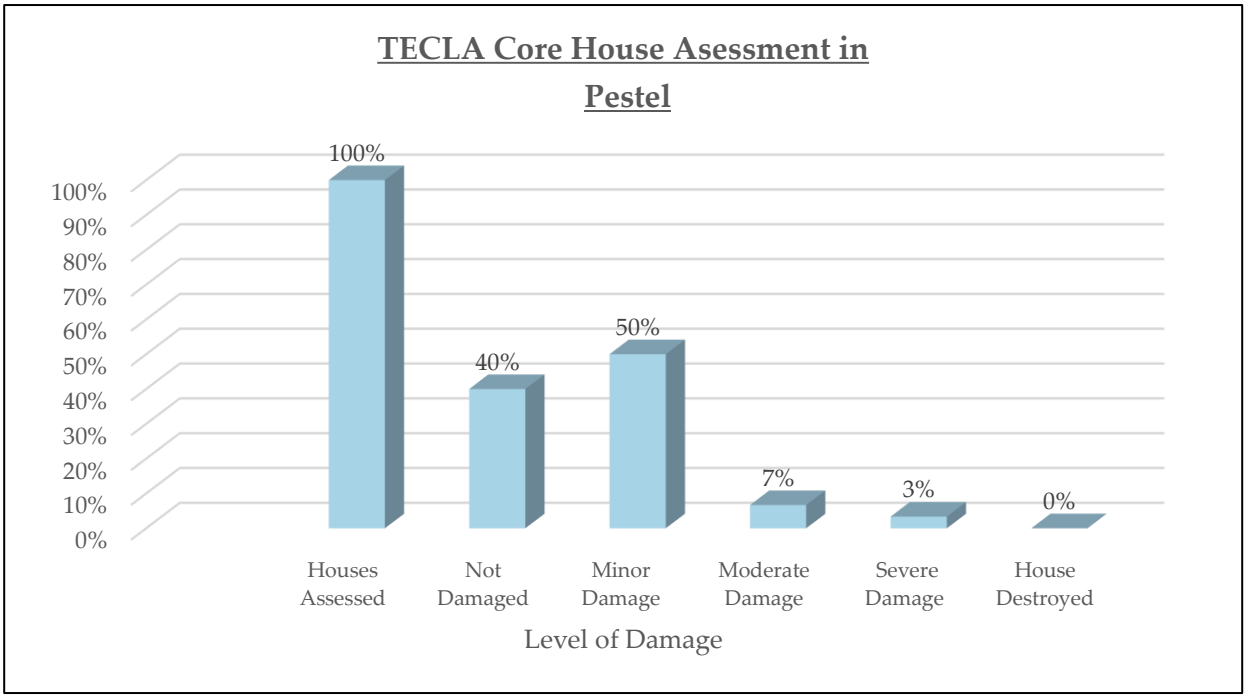
BEAUMONT

1. **100%** of the houses built by HFHH were able to withstand the August 14 earthquake. No death or injuries were reported from people living in the houses.
2. **30%** of the houses had no damage. The overall structures stood firm, with no damage to the roof or the floor.
3. **70%** of the houses assessed had minor damage that could be rapidly repaired by the local masons previously trained by HFHH.
4. None of them (**0%)** were moderately or severely damaged or destroyed.



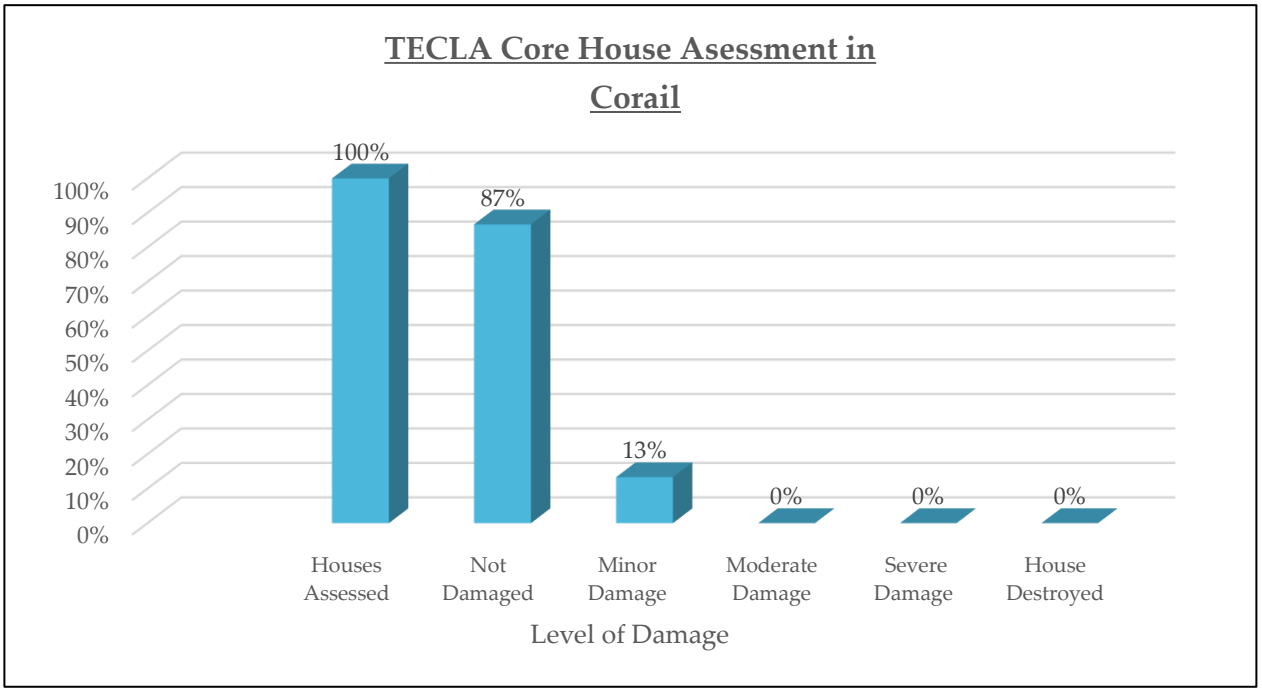
PESTEL

1. **100%** of the houses built by HFHH were able to withstand the August 14 earthquake. No death or injuries were reported from people living in the houses
2. **40%** of the houses had no damage. The overall housing structures did not suffer any type of damages.
5. **50%** of the houses assessed had minor damage that could be rapidly repaired by the local masons previously trained by HFHH.
3. **7%** of the homes had moderate damages which will require repairs by local, skilled masons who had been previously trained on TECLA techniques.
4. **3%** of the homes were severely damaged, suffering moderate damages and one or more main posts, as well as intermediary post broken, causing the whole wall bend or collapse.
5. None **(0%)** were destroyed



CORAIL

1. **100%** of the houses built by HFHH were able to withstand the August 14 earthquake. No death or injuries were reported from people living in the houses,
2. **87%** of the houses had no damage. The overall housing structures did not suffer any type of damages.
3. **13%** of the houses had minor damage that could be rapidly repaired by the local masons previously trained by HFHH.
4. None of them **(0%)** were moderately or severely damaged or destroyed.



Annex 2: Sample Pictures of HFHH TECLA Core House