

## Overview

Two devastating events occurred in the Philippines towards the end of 2013: a M7.1 earthquake on the island of Bohol on October 15, 2013, and typhoon Yolanda, which affected several islands on November 8, 2013.

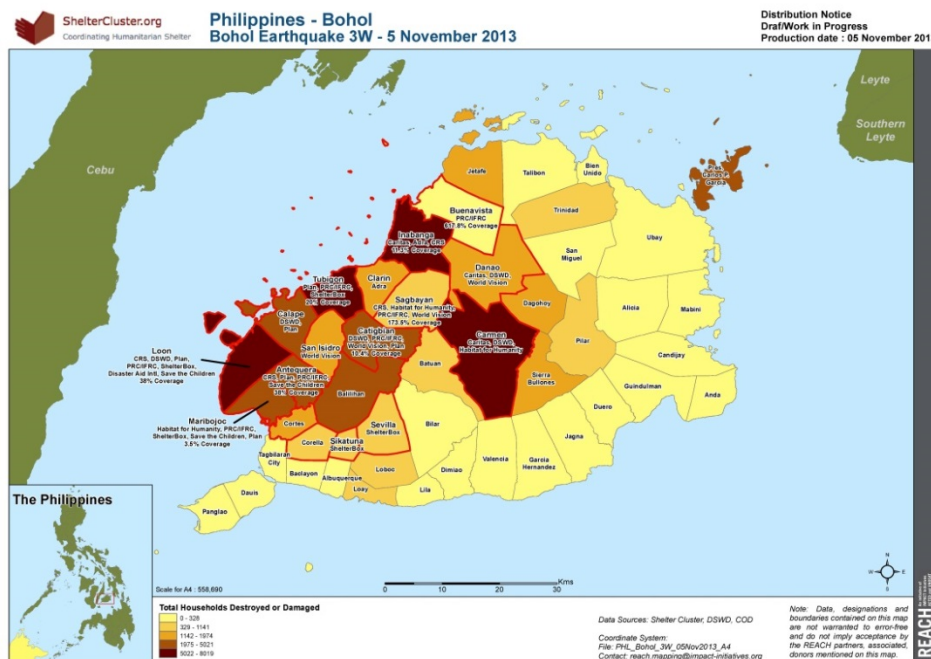


Figure 1. Map of housing damage on Bohol due to 15 October, 2013 earthquake

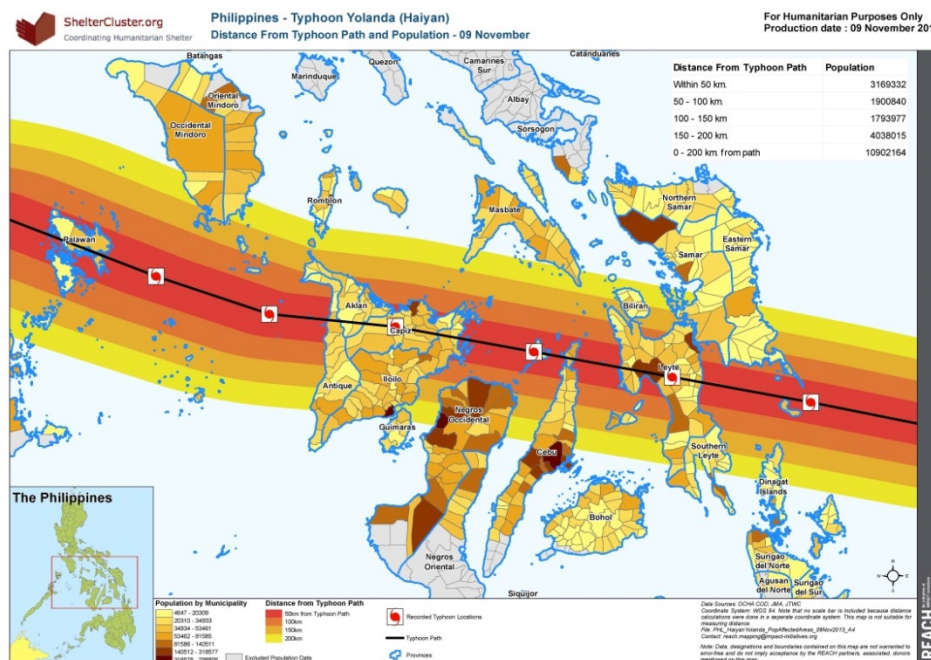


Figure 2. Map of path of Typhoon Yolanda and Philippines population density

The M7.1 Central Visayas earthquake hit near the city of Catigbian, Bohol Island in the Philippines on October 15, 2013. According to the National Disaster Risk Reduction and Management Council (NDRRMC), the earthquake killed 222 people and injured 976. 671,103 families, or 3,221,248 people, have been affected. Over 73,000 houses have been damaged, with 14,512 houses considered completely destroyed and 58,490 partially damaged. The International Federation of the Red Cross (IFRC) reports in its 22 November, 2013 Emergency Appeal and Operation Update that some families have started to construct makeshift houses using salvaged material, though the majority of those with damaged houses remain in temporary shelters or are living with host families.

An estimated 14.4 million people have been affected by Typhoon Yolanda, which hit several islands in the Philippines on November 8, 2013. Yolanda was the strongest typhoon in the Philippines in recorded history, with maximum sustained winds of 145 mph (235 kph) and gusts of up to 196 mph (315 kph), although it should be noted that this is the speed at which the instrumentation failed, and local estimates of wind speed are as high as 230 mph. According to the NDRRMC, the current death toll stands at 6,201, with another 1,785 people still missing. The Department of Social Welfare and Development (DSWD) estimates that the number of displaced people peaked at around 3.62 million, of whom an estimated 224,177 were living in 1,104 evacuation centers (UNOCHA SITREP#19, 28 November 2013). Over 1.1 million houses have been damaged, which is five times the number of houses damaged by the 2010 earthquake in Haiti.



**Figure 3.** Typhoon damage on Leyte



**Figure 4.** Earthquake damage on Bohol

As the typhoon zone moves through the emergency phase, assistance for rebuilding homes is becoming one of the top requests from affected populations. In both disaster areas, the Philippines government, Philippines Red Cross, IFRC, and international aid and relief agencies are providing emergency and temporary building assistance in the form of tarps, shelter kits, and other supplies. Assessments are underway and shelter standards and policies are being developed.

Build Change staff Gordon Goodell, Director of Engineering, and Ben Biddick, Lead Design Engineer, made field observations during reconnaissance visits to the earthquake-and typhoon-affected areas. 6-8 December, 2013 were spent in the typhoon zone, on Leyte and southern Samar, and based in Tacloban, Leyte. 8-21 December, 2013 were spent in the Bohol earthquake zone. The visits were made possible by a grant from the Argosy Foundation and funding from the IFRC, acting as advisors for the Philippines Shelter Cluster.



Through the course of the evaluation, a number of overall lessons about safe construction in the Philippines were learned. These are listed together here as recommendations and highlighted individually throughout this document. The recommendations are derived from the most common failure mechanisms observed, with the hypothesis that rebuilding using the systems and techniques local people already know will be the most cost effective approach. The recommendations are an attempt to highlight the prevailing deficiencies in local building practice that must be corrected in order to build safely in the future.

### **Recommendations for Masonry Structures**

1. Don't use masonry in the gable wall. It's too heavy. Build a hipped roof or a lightweight gable instead.
2. Use strong concrete blocks. Don't use blocks that break when dropped on the flat side on hard earth from chest height. Find a seller that makes stronger blocks.
3. Wet concrete blocks before adding them to walls, and plaster the house to make it stronger.
4. Connect the roof to the ring beam with straps or brackets.
5. Connect the masonry structure using a ring beam on top of walls, a plinth beam at the foundation, and tie columns between them.
6. Use 40cm overlaps to connect rebar, not short laps or short hooks.
7. Connect beams and columns together by continuing rebar through the joints. Use rebar stirrups with rotated hooks around column and beam rebar.
8. Use rebar dowels or masonry tooting to connect masonry walls to columns. Build the walls before pouring the columns and ring beam.
9. Use reinforced concrete lintels above windows and doors.
10. Don't use limestone, coral, or beach sand as aggregates to make concrete or concrete blocks.

### **Recommendations for Timber Structures**

11. Use diagonal wind bracing between trusses.
12. Use diagonal bracing to strengthen column-beam connections.
13. Connect truss members with straps or gusset plates.
14. Connect all wood framing members to each other.
15. Connect the roof to the walls with straps or brackets.
16. Anchor timber posts to the foundation with post brackets.
17. Ensure the foundation is deep and heavy enough to counteract the uplift force of wind.

Guided by these recommendations, this document provides an overview of the common housing types in the Philippines, followed by structural damage assessments from both the Typhoon and the earthquake. Corresponding photos are included. The document then examines the condition of construction materials and their supply chains in the Philippines, local design and construction skills, and the provisions and enforcement of the Philippines Building Code. It concludes with a discussion of the country's prospects for rebuilding and two posters prepared by Build Change with tips for building back safely.

### **Philippines Housing Types**

Houses in the Philippines were affected differently by the earthquake and the typhoon. Most of the housing types found were better suited to resist either wind or seismic load, but serious construction defects resulted in very few houses that are adequate for both. Filipinos generally live in houses made of light timber framing, masonry, or a combination of the two – all of which are vulnerable to natural disaster. Housing types in the Philippines include<sup>1</sup>:

1. Nipa hut. A Filipino icon, these huts are raised on hardwood stilts and constructed from bamboo and other light wood materials, with thatched roofs. The name refers to an architectural style rather than a specific building material or system.



**Figure 5.** Nipa hut on Bohol (example 1)



**Figure 6.** Nipa hut on Bohol (example 2)



**Figure 7.** Timber frame house with amakan (woven bamboo mat) walls under construction on Bohol

<sup>1</sup> Most of these housing types are derived from “Post-Earthquake Shelter Assessment: Bohol Province, Region VII, Philippines: Provisional Interim Report.” Philippines Shelter Cluster, 11 Nov 2013, p. 11-13. <[http://www.reach-initiative.org/wp-content/uploads/2013/11/Bohol\\_Earthquake\\_shelter\\_assessment\\_Provisional-Interim-Report.pdf](http://www.reach-initiative.org/wp-content/uploads/2013/11/Bohol_Earthquake_shelter_assessment_Provisional-Interim-Report.pdf)>.

2. Timber house. Also raised on wooden stilts, these houses use heavier timber than bamboo for their walls, and light timber framing with either thatch or corrugated galvanized iron (CGI) for their roofs.



**Figure 8.** Timber house on Bohol (example 1)



**Figure 9.** Timber house on Bohol (example 2)



**Figure 10.** Example of a raising technique for a timber house on Bohol



**Figure 11.** Example of thatch roof framing using mixed materials on Bohol

3. One-story timber with masonry skirt wall house. These houses have foundations of concrete posts, low masonry skirt walls with timber wall framing above, and roofs of light timber framing and CGI.



**Figure 12.** One-story timber with masonry skirt wall house on Bohol (example 1)



**Figure 13.** One-story timber with masonry skirt wall house on Bohol (example 2)



**Figure 14.** One-story timber with masonry skirt wall house on Bohol (example 3)

4. One-story masonry house. These houses use masonry for both the foundation and the walls, with either timber framing and CGI or concrete slabs for the roof.



**Figure 15.** One-story masonry house on Bohol (example 1)



**Figure 16.** One-story masonry house on Bohol (example 2)

5. One- or two-story house with timber frame and masonry infill. These houses have a heavy timber frame and masonry infill wall panels, with a light timber and CGI roof.



**Figure 17.** Heavy timber frame house with masonry infill panels on Bohol



**Figure 18.** Detail of a heavy timber frame house with masonry infill panels on Bohol

6. Two-story house with masonry foundation and walls of masonry and timber framing. These houses have a concrete masonry foundation that supports two stories, with a ground level of concrete masonry walls and a second level of light-framed wooden walls, topped with a timber and CGI roof. Floor framing for the upper floor is generally of wood, although occasionally concrete slabs are used.



**Figure 19.** Two-story masonry and timber framed house on Bohol

7. Two-story masonry house. These houses use concrete masonry for their foundations and walls on both stories, usually with a light timber and CGI roof.



**Figure 20.** Two-story masonry house on Leyte



### **Structural Damage Assessment**

#### *Leyte and Samar (Typhoon Damage)*

The Typhoon caused widespread damage in Leyte and Samar. Failure modes for extreme wind events are different than for seismic events. Out-of-plane failure becomes more significant because winds push directly on the weak axis of wall panels. Where the wall panels themselves do not fail, structural elements must be connected well enough to transfer these forces to elements that are strong in the direction of the wind force, typically shearwalls. The houses surveyed in the Philippines tend to be of simple design – square or rectangular – which is helpful for wind or seismic loads, but many structures failed because they didn't have a sufficient number or layout of resisting elements (shearwalls) to transfer the forces to the ground.

For all of the various failure modes encountered, the deficiencies in housing construction can be categorized according to the **Build Change 3 Cs**: Configuration, Connections, and Construction and materials quality.

- Configuration: Layouts should be simple, square (or close to square), and symmetric, and avoid long spans between cross walls, which will ensure adequate out-of-plane support for walls and adequate shearwall density. Heavy roofs on weak walls should also be avoided.
- Connections: All parts of the structure must be connected together for it to resist earthquakes and strong winds. This includes tying the roof to the walls, the wall panels to the frame, the frame elements to each other, and the entire house to the foundation.
- Construction and materials quality: Construction materials such as concrete blocks, concrete, rebar, and structural lumber must be strong enough to support the loads imposed upon them. Construction quality or workmanship must be of high enough quality to ensure that these materials are assembled properly into structural systems that can safely transfer the loads imposed.

1. **Timber houses, both one- and two-story**, are almost all entirely destroyed, having performed very poorly in strong wind. The very light construction systems used by the poorest populations, such as nipa and other bamboo huts, were blown away completely, as these structures generally had no foundation at all. Most non-timber buildings used timber and CGI for their roofs, which are also almost all completely destroyed or blown away.



**Figure 21.** Destroyed timber house on Leyte



**Figure 22.** Intact masonry house on Leyte with destroyed timber roof

→ **Recommendation 14:** Connect all wood framing members to each other.

→ **Recommendation 17:** Ensure the foundation is deep and heavy enough to counteract the uplift force of wind.

2. **Houses, both one- and two-story, relying on a reinforced concrete (RC) frame system with infill walls** performed poorly; in general only the frames are left, with the buildings unusable and often leaning hazardously. It should be noted that many larger RC frame structures, such as commercial and public structures, performed well in the typhoon, indicating that the permitting and code enforcement process in the Philippines can work quite well, but is not sufficiently applied to housing.



**Figure 23.** Damaged RC frame house on Leyte



**Figure 24.** Destroyed RC frame structure on Leyte with only frame remaining

3. **Confined masonry structures** performed relatively well in the strong winds, in spite of the mediocre quality of the masonry. About twenty percent of buildings were confined masonry, though this is a difficult estimate as there is a lot of variation between completely unreinforced masonry (URM) and well-confined masonry (CM). For all masonry construction, window and

door openings are typically unconfined. Out-of-plane failure was found in almost all buildings without a ring beam. Buildings with a ring beam exhibited much greater capacity and first failed out-of-plane at the unconfined openings. Failure did not typically occur at the wall-column joint, which is common in many other countries, because builders in the Philippines tend to use mortar bed dowels to connect walls to columns. Most connections between reinforced concrete elements are made with hooks that are too short, and have therefore failed. Global wall overturning due to a lack of foundation connections was frequently observed. Deformed rebar is much more common than smooth rebar in the Philippines, but unfortunately many failures of RC confining elements were observed as a result of insufficient bar lap lengths, often only 2" or 3". RC slab roofs also fared well. It is not common to see concrete slab roofs on these houses, although on nicer, more expensive houses they are more common, especially in sloped configurations. Because the majority of the wind force on roofs is uplift, the heavier concrete roofs would be expected to perform better. (As will be seen in the earthquake section below, however, houses with these heavy roofs did not perform well under seismic load, where the roof force is sideways and must be transferred to the walls below.)



**Figure 25.** One-story confined masonry house on Leyte that survived the typhoon



**Figure 26.** Two-story confined masonry house on Leyte that survived the typhoon (although it lost its wood framed roof)



**Figure 27.** Destroyed masonry house on Leyte (example 1)



**Figure 28.** Destroyed masonry house on Leyte (example 2)



**Figure 29.** Destroyed masonry house on Leyte with only a few confining elements remaining

### *Bohol (Earthquake Damage)*

The earthquake damaged both Bohol's timber and masonry structures, though for different reasons and to different extents. Houses on Bohol are roughly split between light-framed timber and concrete block masonry, along with many mixed systems that combine these two.

1. **Masonry houses, both one- and two-story**, are most commonly an inappropriate and dangerous mixture of URM, under-reinforced masonry, and poorly confined masonry. Rebar is commonly constructed with insufficient lap lengths. Column and beam connections are generally made with short hooks, which failed easily in the earthquake.



**Figure 30.** Masonry house destroyed by the earthquake on Bohol



**Figure 31.** Collapsed masonry gable on Bohol

→ **Recommendation 1:** Don't use masonry in the gable wall. It's too heavy. Build a hipped roof or a lightweight gable instead.

→ **Recommendation 9:** Use reinforced concrete lintels above windows and doors.



**Figure 32.** Earthquake damage, masonry house on Bohol



**Figure 33.** Inadequate rebar lap length on Bohol

→ **Recommendation 6:** Use 40cm overlaps to connect #3 rebar, not short laps or short hooks.



**Figure 34.** Out-of-plane ringbeam failure from earthquake on Bohol. The span of the ring beam is too great without a connected perpendicular wall to break it up, and the ring beam has failed at its corner joint. Note that some block walls are lightly reinforced vertically in the cell voids, which are then grouted. In many block houses all cells, even unreinforced ones, are grouted, which adds to seismic mass without adding strength.



**Figure 35.** Masonry wall failure on Bohol. Note the lack of connection between perpendicular walls.

→ **Recommendation 5:** Connect the structure using a ring beam on top of walls, a plinth beam at the foundation, and tie columns between them.



**Figure 36.** Earthquake damage on Bohol showing poor masonry construction.



**Figure 37.** Stirrups kept this column on Bohol confined, but the short hooks were not enough to connect to the adjacent RC element.



**Figure 38.** Inadequate roof connection on Bohol.



**Figure 39.** Roof framing must be firmly connected to the ring beam with brackets or straps that pass under the longitudinal ring beam reinforcement. Bending the vertical column bars over trusses or rafters is common but insufficient.

→ **Recommendation 4:** Connect the roof to the ring beam with straps or brackets.

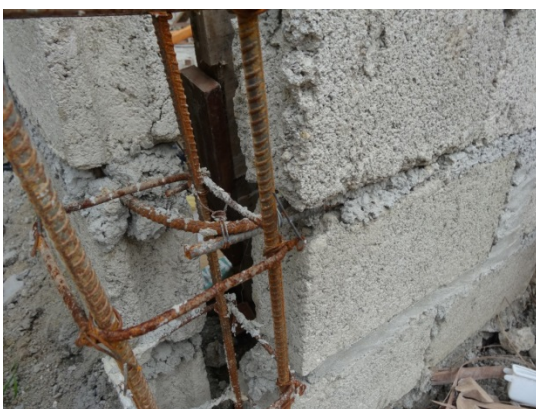


**Figure 40.** In this house under construction on Bohol, the longitudinal bars of intersecting ring beam segments are not connected at all. This extremely dangerous practice is common.



**Figure 41.** Rebar column under construction on Bohol. The ends of the stirrups are not hooked 135 degrees nor are they long enough nor are they rotated. These stirrups will blow apart under seismic load and allow the concrete core to crumble.

→ **Recommendation 7:** Connect beams and columns together by continuing rebar through the joints. Use rebar stirrups with rotated hooks around column and beam rebar.



**Figure 42.** Confined masonry building under construction on Bohol using earthquake-resistant construction technique of wall dowel extending into column joint.

→ **Recommendation 8:** Use rebar dowels or masonry tothing to connect masonry walls to columns. Build the walls before pouring the columns and ring beam.

2. **Timber houses, both one- and two-story**, exhibit poor connections, which translates into inadequate load paths. Purlin-truss connections, roof-plate connections, and wall-foundation connections are universally insufficient, typically being made with a single nail. Foundations are often lacking, or where present, are too shallow.

→ **Recommendation 13:** Connect truss members with straps or gusset plates.



**Figure 43.** Timber-framed house under construction on Bohol. There is some diagonal bracing for the lower level, but not in the walls above.



**Figure 44.** Timber house damaged by the Bohol earthquake. This is a typical “soft story” failure, where the open part below is not adequately braced to transfer the lateral seismic load from the story above.

→ **Recommendation 11:** Use diagonal wind bracing between trusses.



**Figure 45.** Insufficient nailing of a roof-to-wall connection on Bohol



**Figure 46.** Inadequate connection of timber frame to concrete foundation on Bohol, for both uplift and lateral forces

→ **Recommendation 15:** Connect the roof to the walls with straps or brackets.



**Figure 47.** A more meticulous but still completely inadequate connection of timber frame to concrete foundation on Bohol. Brackets should be hooked to the column rebar and cast into the foundation pier, then bolted or heavily nailed to the wood column.



**Figure 48.** A better idea for the connection of timber frame to concrete foundation than in Figures 46 and 47, but insufficiently nailed to the wood column.

→ **Recommendation 16:** Anchor timber posts to the foundation with post brackets.

3. Other houses had a **hybrid system of timber and masonry**, such as timber frames with six-to-eight inch diameter log columns and ring beam with concrete block masonry infill walls. Because of the incompatibility in ductility between masonry and wood (wood can accommodate a lot more movement in an earthquake, whereas URM is brittle), in most of these structures the infill walls failed while the post and beam structure remained supporting the roof or often even a second floor. Infill URM panels will not give lateral strength to a timber frame. Under seismic load they will explode and fail well before the timber frame reaches its deflection limit. The timber frame should be well-braced with diagonal wood bracing in all directions.

→ **Recommendation 12:** Use diagonal bracing to strengthen column-beam connections.



**Figure 49.** Wood post with masonry infill on Bohol



**Figure 50.** Wood post with masonry infill showing earthquake damage on Bohol

4. For the poorest and most at-risk populations, houses are frequently 3-sided rooms built of bamboo. Here, too, connections and load path are completely inadequate. Foundations are nonexistent, and connections typically consist of one nail, with a few exceptions of lashed wire or twine. The lashed connections performed much better, as nails tend to split the bamboo.



**Figure 51.** Bamboo and timber hut on Bohol with connections of single nails through braces made of bamboo split longitudinally

### **Construction Materials and Supply Chain**

In Bohol, local timber materials are excellent, including abundant palm trees for scaffolding and formwork, and mahogany and other suitable structural lumber such as Gmelina, mostly milled by chainsaw, for buildings. Walls are typically covered in woven bamboo mats, which are both beautiful and functional (though there is some growing sentiment that “modern plywood,” usually a quarter of an inch thick, is better. This stems from a desire for modernization, though people who already have plywood-sheathed houses do not like them because they are not well enough ventilated).



**Figure 52.** Timber on Bohol



**Figure 53.** Timber at a roadside materials supply shop on Bohol



**Figure 54.** Fresh timber from coconut trees downed by Yolanda is available for construction on Leyte. This is all that is left of what was a forest. Collection, milling, and reuse of this downed timber should be encouraged and supported. The typhoon zone should be trading coconut lumber for mahogany from Bohol.



**Figure 55.** Thatched roof panels at a roadside materials vendor on Bohol



**Figure 56.** “Amakan” woven bamboo mat on Bohol

Masonry materials quality, however, is substandard. Concrete blocks are locally made in hand-filled four-inch-wide molds with aggregates of limestone, coral, and seashells, and are weak and unsuitable for structural use. Although good quality deformed Grade 40 rebar is almost universally used, concrete and concrete blocks suffer from a lack of sufficient cement, poor aggregates, and inadequate curing. For larger projects where building codes are enforced, quality aggregates are imported from neighboring volcanic islands, but for poorer populations the cost of these housing materials is prohibitive.



**Figure 57.** Workers making concrete blocks on Bohol. Note that the blocks are curing in the sun. They will be sold the next day.



**Figure 58.** Concrete block mold on Bohol. Mechanical vibration of the blocks is common, but is not as important as proper materials and curing, which are not common.



**Figure 59.** Concrete blocks on Bohol. Note the tan color, a combination of poor quality aggregates and insufficient cement ratio.



**Figure 60.** Concrete blocks on Bohol



**Figure 61.** Poor quality concrete blocks on Samar. These tend to break when picked up.



**Figure 62.** Deformed Gr40 rebar for building on Bohol

→ **Recommendation 2:** Use strong concrete blocks. Don't use blocks that break when dropped on the flat side on hard earth from chest height. Find a seller that makes stronger blocks.



**Figure 63.** Local aggregates on Bohol



**Figure 64.** Imported aggregates on Bohol



**Figure 65.** Bohol aggregates. Note the light limestone color – this is mostly seashells.



**Figure 66.** Seashell pulled from a pile of Bohol aggregate at a supplier's yard

→ **Recommendation 10:** Don't use limestone, coral, or beach sand as aggregates to make concrete or concrete blocks.

In many areas roadside building supply stands carry the essentials of cement, local lumber, nails, and roofing, but very little else. In the Provincial capital of Tagbilaran, building supply stores are large and well-stocked, including imported lumber and plywood, fasteners, and a huge assortment of tools, including power tools. Transport runs smoothly, but there is no network of distributors of quality building materials beyond the big city. Again, there seems to be an all-or-nothing situation between the supply of materials for buildings that fall within the jurisdiction of municipal building code enforcement and all the small residential projects that follow no standards at all.



**Figure 67.** Cement on Bohol (example 1)



**Figure 68.** Cement on Bohol (example 2)

### **Local Design and Construction Skills**

Aside from structural connections, carpentry skills in Bohol are generally excellent, with joinery commonly notched and housed. On the other hand, masonry skills are poor on Bohol as in the rest of the Philippines, with consistent examples of high-quality, safe masonry or concrete construction found only in commercial and public buildings or higher-end residential construction.



**Figure 69.** Light timber frame house under construction on Bohol



**Figure 70.** Light timber trusses on Bohol



**Figure 71.** Light timber roof frame on Bohol



**Figure 72.** Timber roof connections on Bohol



**Figure 73.** Timber connection on Bohol. Note that the connection is well notched for additional strength for gravity loads, but that this will not help for wind uplift. For uplift there is only one nail.



**Figure 74.** Timber connection on Bohol. This type of connection is typical, and is insufficient in every direction.



**Figure 75.** Poor masonry work on Bohol. Note the absence of mortar in the vertical joints.



**Figure 76.** Inadequate masonry wall connections on Bohol. Each wall intersection should have a column with horizontal rebar dowels tying walls to the column.

→ **Recommendation 3:** Wet concrete blocks before adding them to walls, and plaster the house to make it stronger.

### **Philippines Building Code Provisions and Enforcement**

The National Structural Code of the Philippines (“Structural Code”), last updated in 2010, is an all-in-one code for loads, concrete, steel, and masonry – though it does not include information on confined masonry. It is in English with metric units, and each section is a portion of the corresponding United States code, meaning that it is based on the *ASCE/SEI 7-10*. However, the Philippines code is geared toward larger buildings – not the smaller kind of structures in which most of its inhabitants live and sleep. Attempts to apply the Structural Code directly to small residential projects will result in buildings that are prohibitively expensive to build. However, the fact that a useable code exists and is enforced for larger projects is encouraging. With a simplified residential code like the International Residential Code (IRC) in the United States or system-specific adopted design guidelines as exist in many countries, the same mechanisms and agencies could be used to ensure that housing in the Philippines is built safely.



## **Discussion**

The unfortunate coincidence of two distinct and devastating disasters taking place so close together geographically and chronologically presents a unique opportunity to compare their outcomes and preconditions and examine the adequacy of design load provisions in the Philippines Structural Code. Using the wind provisions of the Structural Code, and amplifying the design wind for proximity to open water gives a design value of about 200 mph—adequate for the winds encountered even in this “storm of the century” type event. Similarly, the seismic acceleration values specified in the Structural Code are sufficient for an earthquake with the ground accelerations recorded in the Bohol event.

In the earthquake on Bohol, timber structures fared overwhelmingly better than masonry structures. However, the opposite is true for buildings that encountered Typhoon Yolanda, as the higher dead load of masonry contributed to resist the extremely high winds. In planning for the next event, which could be a typhoon or an earthquake, this puts us in a difficult position for the permanent reconstruction effort. Rebuilding with the weight of masonry is tempting to resist typhoons, but the quality of masonry materials and construction are generally not sufficient to transfer the design loads of an earthquake safely. Both systems *can* be built safely, to resist both wind and seismic load. The question should be, “What deficiencies have to be corrected in each system in order to make it safe? The first C, Configuration, is easily addressed for both systems. For the other two C’s, Connections and Construction and materials quality, masonry construction in the Philippines suffers from serious deficiencies in connections, materials quality, and construction quality. Light timber construction, on the other hand, suffers only from lack of knowledge of proper load path for the various loads and the ability to connect elements properly to accommodate those loads by providing viable load path from roof to foundation.

To address the deficiencies in masonry construction, intervention is required in the raw materials supply chain (aggregates), building materials production (concrete blocks, concrete), building materials supply chain (roof connection straps and brackets), construction skillset (builder training), and code enforcement institutions. The deficiencies in light timber frame construction, however, can be addressed more easily. Building material supply chain issues must still be addressed for straps, brackets, and other connectors, and code enforcement will still be required, but the majority of the deficiencies can be addressed and corrected through builder training.

Though the Bohol earthquake and Typhoon Yolanda have devastated the Philippines and decimated its housing stock, the country is still disposed to rebound successfully and mitigate damage and loss of life when the next disaster strikes, due to a number of factors. As discussed above, timber building materials are abundant in the Philippines, and the quality is excellent. Other materials, such as rebar, roofing, and connection elements are widely available, and transportation is generally good. That carpentry skills are excellent suggests a strong foundation for further skill-building in both carpentry and in masonry, where it is currently deficient. In addition, since the Philippines Structural Code is sufficient in its loading provisions and based on ASCE 7 methodology, it is well-suited to accommodate derivative codes and guidelines, such as simplified guidelines for confined masonry, light timber, and other common Filipino housing types. Also, interaction with Filipino design professionals, architects, and engineers indicates that the system of higher technical education functions well, so that expertise exists not only for design but for training and knowledge-building as well. For these reasons, and with the appropriate next steps, the Philippines is poised to rebound from its recent disasters stronger than before.

## 5 February 2014 Update

Since the original publication of this report, Build Change also sent a team to the island of Bantayan, in the North Central Visayas. Findings here were different because although this island received the full wind effect of Typhoon Yolanda, it was sheltered from the storm surge that resulted in tsunami-like waves of up to 7 meters in height on Leyte and Samar. This makes it easier to differentiate the kinds of damage that were caused by the surge from the damage that was caused by wind.

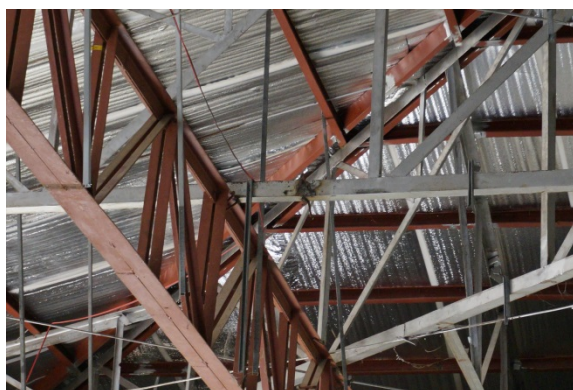
Unlike Leyte and Samar, on Bantayan there are many damaged buildings left standing that could be retrofitted and put back into safe service. 24,000 housing units are damaged or destroyed, along with many schools. People are now beginning to rebuild, so there is an urgent need for technical assistance from engineers. This would include simplified design and construction guidelines for residential construction, training of builders, retrofit design of housing and schools, review of new school design, and construction supervision and inspection.

Schools in particular were widely found to be structurally deficient in the Philippines. A huge number of school buildings are based off of a national government design, which is structurally flawed. Responsibility for construction, though, rests with provincial or municipal governments, and is typically very poor. Frequently this is due to limited local government budget and resources for construction, and municipal engineers who are untrained in design and construction quality.

In addition to the specific and general deficiencies with masonry, timber, and bamboo construction mentioned earlier in this report, many damaged structures on Bantayan, including many schools, had roofs made of light gauge steel framing with CGI sheets. Consistent with the problems found above with the second C, Connections, the welds connecting steel rafters to purlins and purlins to trusses were inadequate, most commonly due to poor craftsmanship. Training for welders should be added to the list of recovery needs, as steel roof framing is a viable, locally sourced building technology for reconstruction. Build Change expects the situation found on Bantayan to be similar for many of the islands of the inner Visayas that were in the Yolanda track, where there is heavy wind damage but little damage from the storm surge.



**Figure 77.** School building on Bantayan showing wind damage to the gable wall. This is unsafe and may result in failure and collapse in the next disaster event.



**Figure 78.** Example of poor welding techniques in the steel framing and CGI roof of a school building on Bantayan.

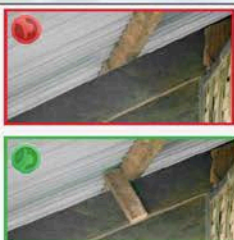
## You **CAN** Keep Your Family Safe In Future Earthquakes and Typhoons



For wood construction, follow these 7 tips to make your house safer in earthquakes and more resistant to typhoons.

**1.**

Connect all wood framing members **strongly** to each other to improve typhoon resistance. Nails are cheap!



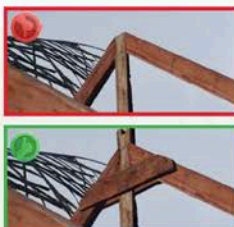
**2.**

Use **diagonal wind bracing** between trusses.



**3.**

Truss members should be connected with **straps** or **gusset plates** to have strength in strong winds.



**4.**

Connect the roof strongly to the walls with **straps** or **brackets**.



**5.**

Use **diagonal bracing** to strengthen column-beam connections.



**6.**

Anchor the posts to foundations with **post brackets**.



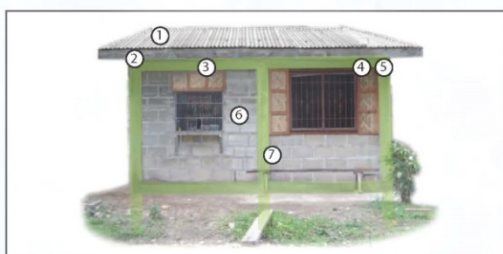
**7.**

Foundations must be **deep** and/or **heavy** to counteract the uplift force of the wind.

## You **CAN** Keep Your Family Safe In Future Earthquakes and Typhoons



For masonry construction, follow these 7 tips to make your house safer in earthquakes and more resistant to typhoons.



**1.**

Build a **hipped roof** or a **lightweight gable**. Masonry gables are heavy and can collapse in an earthquake.



**2.**

Connect the roof strongly to the ring beam with **straps or brackets**, or else it could blow away in a typhoon!



**3.**

Connect the building using a **ring beam** on top of walls, a **plinth beam** at the foundation, and **tie columns** between them.



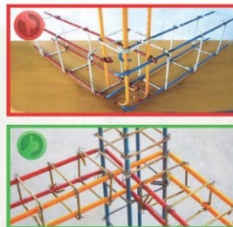
**4.**

Overlap rebar by at least **40 rebar diameters**; short overlaps and hooks are not strong!



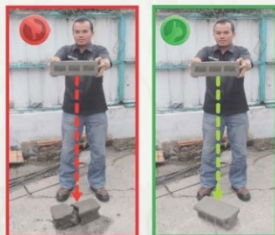
**5.**

Connect beams and columns together by **continuing rebar through the joints**. Use rebar stirrups with rotated hooks around column and beam rebar.



**6.**

Use **strong blocks**. If the blocks break when dropped, find another seller that makes stronger blocks. Wet the blocks before adding to the wall and add plaster to the walls.



**7.**

Connect the walls to the columns with **rebar dowels** or masonry tooting. Build the walls **before** pouring the columns and ring beam.

