APPENDIX I: CASE STUDY: HAITI

The 23m² house of Cademus Brunet in the informal neighborhood of Villa Rosa, Canapé Vert, Port-au-Prince, was largely destroyed by the magnitude 7.0 earthquake on 12 January, 2012. The original slab roof collapsed along with the upper portion of most of the four walls. His family was displaced into a tent camp. He thought about staying in the house under tarps with his family, but his neighbor’s partially collapsed two-story house towered over it, threatening to collapse further.

Along with many of his neighbors, he was selected as a beneficiary of a reconstruction program being implemented by Cordaid with technical consulting and assistance by Build Change. A team of Build Change-trained and -employed Haitian engineers began the process with a homeowner survey and a seismic evaluation of the remaining structure. Some reconstruction had already been done by the homeowner, but the work had not proceeded very far before running out of funds and the work varied in quality. Much of the existing structure was reusable, although there were several deficiencies found. The recent (post-earthquake) work varied in quality. The blocklaying had been done reasonably well. Although the homeowner had paid for rebar and concrete tie columns because he knew these were important elements, they had been so

Figure 1. The house of Cademus Brunet, as it looked as the retrofit began.

Figure 2. A Build Change engineer conducting a homeowner survey.
poorly executed due to lack of knowledge that the building had to be considered unreinforced masonry (URM). This is common in Haiti and elsewhere. Money is wasted, where there is very little to spare, on elements that are essential but fall short on at least one of the critical three Cs: Configuration, Connections, or Construction quality.

Among other things, such as the obvious missing roof and the dangerous condition of his neighbor’s house, the seismic evaluation also identified that a new ring beam would have to be added to confine the tops of the walls, and walls or buttresses would have to be added to support walls that were too long for the out-of-plane design forces perpendicular to the walls. Construction details for the ring beam addition were part of the standard Build Change retrofit methodology, but a new detail would have to be created for the buttresses, as they were not originally part of the retrofit methodology but were encountered when homeowners in small spaces did not want to add interior walls, in the living room for example.

As unique situations such as this arose, “new” or “non-standard” details were incorporated into the retrofit methodology, field tested, and reused. The scale of the program required a ready-to-use library of typical retrofit solution details that could be applied quickly, with conservative assumptions so that they would be applicable for most conditions. The occasional addition of new details, however, gave the team of Haitian engineers experience in
problem-solving, applying engineering principles and code requirements, and construction documentation.

We realized during this process of developing new details that the computer-assisted drafting (CAD) skills of the Haitian engineers were significantly below our expectations, even with the understanding that they had had almost no access to computers during their civil engineering coursework. In response to this, we created a 40-hour introduction to 2D AutoCAD course (using a standard AutoCAD training text) which a senior architect on our staff taught to the technical staff, requiring those in the field to come back to the office 2-4 hours per day until it was accomplished. This program was so successful and so appreciated by our staff that we eventually did the same thing to raise their level of competence in using Excel as a calculation tool.

A sketch plan of the existing structure was made and dimensioned on site, and after returning to the Build Change office the evaluation team transformed the sketch into an existing structure plan (Figure 6). The existing plan was used to calculate existing

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**Figure 6.** Existing plan.
shearwall density, which was compared to the required minimum. The engineers determined that for the size of the existing structure the existing exterior walls, once rehabilitated, were sufficient to carry the lateral forces safely to the foundation.

They then turned their attention to the defects found in the seismic evaluation, addressing each deficiency identified in the evaluation checklist. The addition of the ring beam was straightforward, a standard detail that was already drawn and used extensively for URM houses. The addition of a ring beam was one step in the conversion of a URM house to confined masonry. Unlike the addition of columns without a ring beam (a common, but misguided, practice in Haiti), which adds very little to the strength or ductility of the structural system and therefore structure, the addition of a ring beam, even without properly configured, connected, and constructed columns, adds significantly to the overall performance of the structure. There need be only enough columns to hold the ring beam down for seismic and wind vertical forces. In cases where there is sufficient existing shearwall density for a URM house, or where the addition of a wall could provide the required amount (and is architecturally acceptable to the homeowner), the complete conversion to combined masonry may be a more expensive option. However, in cases where much retrofit work would be needed for the URM structure the confined masonry conversion may be more economical, because of the permitted reduction in required seismic loading due to the greater ductility and reserve strength of the properly confined structure.

Build Change decided before the program began, even before the retrofit methodology was formalized, to add a ring beam where possible to every masonry house that didn’t have one, as part of the retrofit. It has been debated within and without Build Change whether donor dollars would be better spent simply adding a ring beam to every structure and saving the expense of the full evaluation, analysis, and design process. There is a good argument to be made here, particularly from the cost-benefit perspective of the donor, but the argument is a problematic one.

As an engineering firm Build Change cannot be satisfied with an “85% solution,” designing houses to be better than they were.
without proving that they meet code requirements for life safety performance. We have an obligation to design to withstand building code-specified loads; this is ethical behavior required of an engineer. The building codes and the structural engineering community do not accept the idea that a building must remain standing just long enough for people to get out safely.

In Haiti, there is an added dimension to the question, as discussed in the main text. We are working in Haiti because of the overwhelming loss of life during the last earthquake; if we are not willing to design everything we (re)build to meet code-specified life safety performance goals, what are we doing? It is through this approach, the example it sets, and the augmentation of local design and construction capacity that results from it, that we hope to change local construction practice permanently.

Where the owner was willing to add transverse walls to support the long walls out-of-plane, standard details could be used. However, for the living room a buttress scheme was devised by the engineers with guidance from the lead engineer. The hand-drawn details were added to the design package (standardization and incorporation into the CAD detail library came after a particular solution showed up a few times) and the retrofit plan was drawn (Figure 10). The retrofit plan and corresponding structural details are the primary construction documents from which the retrofit would be built. We found that homeowners had very little capacity
to understand construction documents, so each change to the house was carefully explained to the homeowner before he signed his acceptance on the plan.

During the construction, supervising engineers helped the builder understand the plans and details. We learned that we needed to spend more time during the builder training explaining the procedures and specific details involved so that the builders had an accurate idea of what they were agreeing to build. This reduced disagreement later, promoted understanding, and eased the acceptance and adoption of our retrofit solutions. We created a step-by-step Retrofit Picture Guide showing many of the more common or misunderstood details. Due to the visually/graphically oriented nature of the Picture Guide, it became an invaluable resource in the process.

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8 The Picture Guide was produced in English, French, and Haitian Creole. The English version is available at www.buildchange.org/USAIDPrimers.html.
field, and we started giving it out to the builders at the builder trainings.

Finally the engineers prepared a scope of work and an engineer’s estimate of cost, which we refer to as the bill of quantities (BOQ)\(^9\). We maintain and continually update price lists for materials and labor from various sources: other organizations that are building, job sites (homeowners, builders), and materials suppliers and outlets, particularly in the purchase of the materials we need for the practical elements of our training courses. In a reconstruction program based on grants, the BOQ becomes more important than in many countries, where the contractor will do his own materials take-off and bid. The builder may not have the skills to do this, so the BOQ becomes the de facto take-off and bid for the project. This means that the materials list on the last page is what the homeowner is actually going to buy, and the price on the last line is probably the grant that the donor is going to provide, either directly or through some combination of grant, loan, and homeowner matching.

\(^9\) Appendix II contains complete BOQ input and output in English.
In Figure 11 the length of new wall is entered. Intermediate sheets calculate materials quantities per square or linear meter for each detail, and they are totaled and divided according to the details that are required to be accomplished with each installment of funding on the output page (Figure 12). The current labor and materials price list is a separate sheet in the BOQ spreadsheet which is referenced in the calculations and can be updated at any time. There is also a manual input page, where the quantities of materials required for works that are not a standard retrofit detail, such as the buttresses in this case, can be calculated by hand and entered directly. Once a new detail gets used enough to be added to the list of standard details we add it to the automated input page so that inputting the quantity by linear or square meter will generate all required materials and labor automatically.

Once the BOQ was ready the engineers prepared the complete design package\(^\text{10}\). The design package was reviewed, approved, and signed by the lead engineer and then presented to the homeowner in his home, where the proposed works could be explained clearly.

\(^{10}\) The complete design package for Cademus Brunet’s retrofit is available at [www.buildchange.org/USAIDPrimers.html](http://www.buildchange.org/USAIDPrimers.html).
so that even someone who doesn’t read construction documents could understand, approve, and sign the plans. It was then up to the homeowner to submit his application for grant to the donor, usually through a neighborhood committee. The homeowner was required to take the half-day homeowner training, conducted by Build Change engineers for groups of about 20 homeowners, to learn how to buy good quality materials, select a contractor, and be involved in the supervision of his project.

Once the donor notified us that the grant was approved and ready for delivery to the homeowner, a Build Change supervising engineer was assigned to the project. He contacted the homeowner immediately to discuss the scope of work involved again and to advise the homeowner in interpreting the BOQ and purchasing materials. The supervisor checked the contractor selected by the homeowner against our list of trained builders and either approved the selection or gave the homeowner instructions for how the contractor could sign up for the next Build Change builder training in the neighborhood.

Once the danger from the neighbor’s house was remedied, the first installment of the grant was delivered, the homeowner and builder were trained, and the materials for the first installment were on site, construction began. A Build Change supervisor was responsible for up to twelve projects in close proximity simultaneously under way. After the morning’s team meeting at the main office the supervisor would spend the entire day in the field, where we also maintained a field office, with his backpack full of: laptop, camera, Retrofit Picture Guide, Guide de Bonnes Pratiques... (the government-issued confined masonry construction guidelines), construction documents for his jobs, and Quality Control (QC) checklists for each job. He spent each day circulating among his job sites answering questions, providing on-the-job training, and documenting that minimum quality specifications had been met.

As the work was completed for each installment, the supervisor submitted his QC checklists with supporting photos to the project manager so that a request for next installment could be processed. This was submitted to the donor with supporting documentation and, upon verification and acceptance, the next installment was given to the homeowner to pay the contractor for the work done.
and to buy materials for the next phase, and the work continued. It was important to streamline this process; we found that if there was too much delay at a given site the contractor would move his crew to a different job and the homeowner might have a difficult time getting him back.
The QC checklist is specific and detailed. The example in Figure 15 ensures that every step in building the new ring beam, from concrete mixing to proper curing, is done correctly. Note that the completed checklist is signed by the homeowner, the builder, the supervisor, and the lead engineer who reviews it. In this case the ring beam was built correctly with the engineer’s supervision. If she returns to the job site to find something done incorrectly, there is space on the form to note it and record her recommendation to the builder and homeowner. If they refuse to correct it, she takes a photo and submits the documentation as non-compliant, which stops the delivery of the next installment. Finally, there is space to note that the correction has been made, take another photo, and restart the process.

### Figure 15. The QC checklist for the addition of a ring beam on Cademus Brunet’s house.

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Date</th>
<th>Photo</th>
<th>Engineer’s Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mixing concrete</td>
<td>3/11</td>
<td><img src="attachment" alt="Photo" /></td>
<td>[Signature]</td>
</tr>
<tr>
<td>2</td>
<td>Pouring concrete</td>
<td>3/12</td>
<td><img src="attachment" alt="Photo" /></td>
<td>[Signature]</td>
</tr>
<tr>
<td>3</td>
<td>Setting formwork</td>
<td>3/13</td>
<td><img src="attachment" alt="Photo" /></td>
<td>[Signature]</td>
</tr>
<tr>
<td>4</td>
<td>Curing concrete</td>
<td>3/14</td>
<td><img src="attachment" alt="Photo" /></td>
<td>[Signature]</td>
</tr>
<tr>
<td>5</td>
<td>Inspecting</td>
<td>3/15</td>
<td><img src="attachment" alt="Photo" /></td>
<td>[Signature]</td>
</tr>
</tbody>
</table>

#### Figure 16. On-the-job training, demonstrating proper concrete mixing technique

Appendix III shows a complete ring beam QC checklist in English.
While this allowed us to document that the retrofit had been done properly and that the finished house was seismically resistant, the process of sorting photos became cumbersome for the supervisors. Build Change is now piloting a program to put the QC checklists on tablets so the supervisors can fill them out and take the supporting photos electronically. This allows the upload to our database to happen automatically when they return to the office. This methodology allows us to streamline many aspects of the retrofit program, including homeowner surveys and retrofit evaluations, which can be put on tablets to eliminate paper, input error, and administrative time. The tablets also allow a convenient way for supervisors to have construction documents, construction guidelines and building codes, and materials supplier and builder databases (including records of any Build Change training they have received) in the field.

Once all the work for the final installment was completed, the supervisor submitted the supporting documentation and the house was marked finished. We found it useful to withhold a final installment of 5-10% or the final labor payment as incentive to complete the house. Withholding the final labor payment worked better if all parties agreed, because requiring the homeowner to advance any money for materials proved problematic. In some programs this final payment was provided by the donor as a “finishing bonus,” which the homeowner could keep or put toward finish plaster, paint, or interior fixtures. The amounts were small, and it proved well worth the investment for the donor to incentivize the completion of as many houses as possible.

The estimated cost of the complete retrofit of Cademus Brunet’s house, from the engineer’s estimate of cost which was submitted to Cordaid in the BOQ, was $3,682. Cordaid funded the project at its maximum grant size of $3,500. In addition to funding the $182 gap in required structural work, the homeowner invested more of his own funds after the structural work was complete for decorative finishing plaster, paint, and electrical wiring. Homeowners often do not keep close track of these amounts, make in-kind contributions of materials or labor, and/or are hesitant to disclose their own contribution amounts to our engineers, but we estimate that in addition to the $182 M. Brunet contributed approximately $200 of his money to the project, bringing his personal contribution to

Figure 17. QC documentation: The ring beam formwork, rebar, stirrups, and roof framing hold-down straps have been laid out correctly.
about ten percent of the grant amount. In a country such as Haiti, where economic means are scarce, this demonstrates a significant leveraging effect provided by the funding of the donor. Very few households were able to commit funds for items such as decorative plaster and paint immediately after the structural retrofit was complete, but as we continued work in adjacent neighborhoods we returned to areas we had worked in earlier to find that homeowners were gradually making these cosmetic improvements with their own funds, taking pride in their houses, and improving the overall appearance and livability of their neighborhoods. After about a year we even began to see homeowners making significant additions to their houses, usually by adding another story, copying the techniques they had learned during the retrofit of the building below. The results usually were not perfect, but are far safer than the buildings that had tried to withstand the earthquake of 2010.

Figure 18. Cademus Brunet’s retrofitted house. The fancy plaster details and doors were not part of the structural retrofit, and so not included in the grant from Cordaid. They were paid for by the homeowner, who began to take pride in his home again. He also added interior electrical wiring at his own expense.