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SEISMIC RETROFIT OF HOUSING IN POST-DISASTER SITUATIONS – BASIC ENGINEERING PRINCIPLES FOR DEVELOPMENT PROFESSIONALS:

A PRIMER

DRAFT

January 2014

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ACRONYMS

A&E	Architecture and Engineering
ASCE	American Society of Civil Engineers
ATC	Applied Technology Council
CAD	Computer-Assisted Drafting (& Design, formerly referred to as CADD)
CBO	Community-Based Organization
EERI	Earthquake Engineering Research Institute
FIDIC	Fédération Internationale des Ingénieurs-Conseils (International Federation of Consulting Engineers)
FEMA	Federal Emergency Management Agency
IMR	Information Monitoring & Reporting
NGO	Non-governmental organization
NZSEE	New Zealand Society for Earthquake Engineering
QA/QC	Quality assurance/quality control
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

This Primer introduces engineering and development professionals to the basic steps in the process of planning and executing post-disaster seismic retrofit of housing projects funded by the United States Agency for International Development (USAID). It is intended to provide USAID officers and host country officials with the steps, principles, and best practices that need to be taken to carry out safe and effective housing retrofit in a post-disaster situation. It provides a road map for developing a project through planning, evaluation, design, and implementation and builds on two earlier USAID Primers, "Basic Engineering and Construction Management: A Primer" and "Building Back Housing in Post-Disaster Situations – Basic Engineering Principles for Development Professionals: A Primer." It also accompanies the newly released Primer, "Site and Retaining Wall Hazard Mitigation in Post-Disaster Situations: A Primer,"[1] which focuses in part on the retrofit of existing retaining walls.

This Primer addresses various phases of the planning, evaluation, design, and implementation process and the various deliverables and milestones usually included as part of the process. The document also discusses the role and responsibilities of the USAID project manager, including interactions with the affected community(ies), partners, local officials, and other involved organizations.

The Primer addresses several objectives:

- Greatly reduce deaths, injuries, and economic losses caused by housing collapses due to natural disasters in developing countries
- Permanently change building code enforcement and/or construction practices so that houses built in the absence of external funding and technical support are substantively more resistant to collapse during and after disaster situations
- Build local capacity through training of builders, homeowners, engineers, and government officials

[1] The USAID Primers referenced in this document are available at www.buildchange.org/USAIDPrimers.html .

- Change construction practices permanently by building local skills and stimulating local demand

Compared with the construction of new housing, retrofitting is fast and economical, and it provides a way to address existing damaged structures that may be salvageable but that are unsafe for occupation in their current condition. Quite often in post-disaster settings in the developing world these damaged structures will continue to be occupied, creating a life safety hazard during aftershocks and further seismic events. A post-disaster retrofit program also provides an ideal platform to build local capacity across the construction sector, including engineers, builders, materials producers, and inspectors.

OVERVIEW

PRINCIPLES AND STRATEGIES

Post-disaster seismic retrofit of housing presents an opportunity not only to rebuild safe housing for the affected population but also to change construction practice permanently so that local builders, engineers, and homeowners build safe houses in the future. These objectives are addressed here by applying the following principles and strategies:

- **Local Solutions** – Use detailed housing subsector studies to determine the most cost-effective ways of rebuilding disaster-resistant houses using materials and skills that are available through the local private sector.
- **Technical Excellence** – Leverage the knowledge and skills of the best engineers and architects in the world – both in the US and the developing world – to ensure that the very best designs and design thinking are applied to the reconstruction efforts while sticking to a carefully compiled list of criteria for local sustainability and acceptance.
- **Equality** – Empower the homeowners to participate in the design and manage their own construction, with technical assistance.
- **Local Capacity** – Build local capacity by hiring and working with local engineers, architects, builders, universities, and governments, and by training vocational or trade school students.
- **Job Creation** – Work with local masons, carpenters, and homeowners to incorporate disaster-resistant building techniques that are culturally accepted and easy to adopt with limited training and education.
- **Economic Growth** – Kickstart the local economy by purchasing locally available materials and products.
- **Bridging the Gap** – Learn and spread best practices from post-disaster housing reconstruction programs so that the many other agencies involved in these efforts build better houses and leave in place more sustainable local impacts.

> "While it is unlikely that engineers, builders, and homeowners will be familiar with seismic retrofit procedures and techniques, which are a specialty niche of structural engineering in the developed world, these skills can be transferred successfully to local engineers and builders, giving them more sustainable reconstruction tools for the future."

A project's success over the longer term requires knowledge, skills, and abilities on the part of those implementing and managing it. However, many professionals in the developing world have not yet internalized the core competencies that those in more advanced economies take for granted. For this reason, USAID incorporates capacity building activities into many of its engineering projects. While it is unlikely that engineers, builders, and homeowners will be familiar with seismic retrofit procedures and techniques, which are a specialty niche of structural engineering in the developed world, these skills can be transferred successfully to local engineers and builders, giving them more sustainable reconstruction tools for the future.

RATIONALE FOR SEISMIC RETROFITTING AS POST-DISASTER HOUSING

The focus of this Primer is on the seismic retrofit of existing housing using the homeowner-driven reconstruction model. Homeowner-driven reconstruction is a post-disaster housing reconstruction model that is gaining in usage and popularity worldwide. It has been successfully implemented after recent earthquakes in India, Indonesia, China, and Haiti. More specifically, homeowner-driven reconstruction of new housing was the reconstruction model of choice by government agencies overseeing reconstruction following the 2001 Gujarat, India earthquake, the 2007 and 2009 West Sumatra, Indonesia earthquakes, and the 2008 Sichuan, China earthquake.[2] It can be a lower cost, higher impact model than donor-driven reconstruction and can produce safe homes, satisfied homeowners, and sustainable change in construction practice.

Homeowners are empowered to make their own choices, which results in greater satisfaction and buy-in, an increased willingness to invest more in disaster preparedness, and a reduction in dependency.

Homeowners drive the process themselves, making decisions with the retrofit evaluation and design team about how they want to reconstruct their houses. They usually do not build the houses themselves, but rather hire small scale, local contractors to do the construction. Financing is provided directly to the homeowner or to small groups of homeowners in the form of cash grants, materials vouchers, and/or small loans. Although the community or small group model has been

[2] The Government of Haiti's National Housing and Habitat Policy, released in October 2013, promotes the participation of homeowners in the construction process to select housing solutions that meet their needs. Visit http://uclbp.gouv.ht/download/pnlh-resume-executif.pdf for the executive summary. Though there is no official housing *reconstruction* policy for Haiti, homeowner-driven approaches to reconstruction are being promoted and used by many agencies there.

used successfully, caution is advised in this approach. Homeowners take more responsibility for managing their own projects when they receive a subsidy on an individual basis. This increases the level of personal responsibility, making homeowners fully aware that if they do not receive the next installment of funding it is because of their decisions – not anyone else cheating them. Homeowners also resolve land title issues themselves, again making it their responsibility as a condition of the grant, rather than having them complain about waiting while an implementing partner wades into this potential quagmire.

"While nobody wants a homeowner to make the same mistake twice, we cannot stop him from doing it with his own money. We should, however, stop him from doing it with donated money."

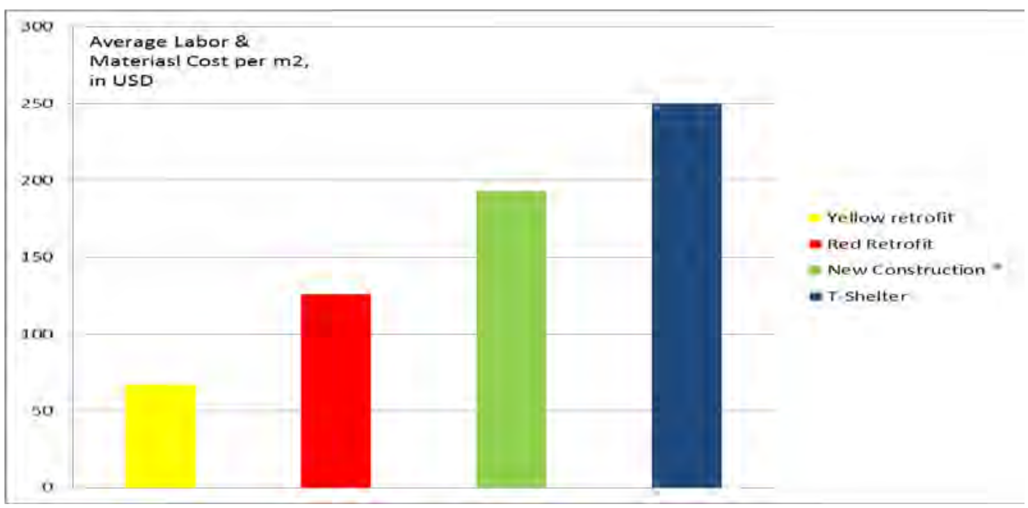
For these reason, this approach is most effective when the government provides some enforcement and/or the provision of grant or loan financing is contingent upon meeting minimum standards for good construction quality. In other words, financing should be provided in installments, with checks on construction quality. This puts the donor in the position it wants to be in, donating money to reconstruct, but only with the assurance that people will build back better. While nobody wants a homeowner to make the same mistake twice, we cannot stop him from doing it with his own money. We should, however, stop him from doing it with donated money.

The homeowner-driven model of reconstruction is described more extensively in the USAID Primer "Building Back Housing in Post-Disaster Situations – Basic Engineering Principles for Development Professionals: A Primer." Because a seismic retrofit program addresses existing houses, and the homeowner will therefore want to be involved in the design of his retrofitted house, the homeowner-driven model is most appropriate and effective. A retrofit program can be operated successfully on the donor- or contractor-driven model, too, as long as the program is structured in such a way to involve the homeowner sufficiently to assure his or her buy-in for the plan. Seismic retrofit programs also do not have to be limited to single-family housing. In the retrofit of schools, hospitals, multi-family housing, and commercial buildings, the homeowner may be a proprietor or owner and the funding scheme may be very different.

In post-disaster settings, seismic retrofit of housing can be an early response strategy. Permanent reconstruction of new housing presents many challenges which are obviated by retrofitting. Land title issues are less difficult or almost nonexistent, because the homeowner is most often still living in his damaged house and there are no competing claims to title. Design issues such as layout are less challenging, as the retrofitted structure will be a repaired and strengthened version of the same house that the homeowner and his family lived in before. There are even fewer rubble removal challenges, as the homeowner usually has cleared already any rubble himself to make his damaged house more livable. Thus a retrofit program can begin much more quickly and efficiently than a program of new housing construction.

Seismic retrofit of housing can also replace some portion of temporary or transitional shelter ("T-Shelter") construction because the evaluation, design, and construction requires far less time than that of new housing, displacing the homeowner and his family for a much shorter time. T-Shelter funding typically comes from the initial post-disaster humanitarian stream of funding, thus any portion of T-Shelter construction replaced by retrofitting provides a head start for permanent reconstruction long before the formal permanent reconstruction phase begins. Experience in Haiti following the January 12, 2010 earthquake, shown in Table 1, reveals that the cost of retrofitting can be less than half that of new housing or T-Shelter construction. Furthermore, money spent on retrofitting can be used to build local capacity and pay for local materials and labor, whereas eighty percent of the money spent on T-Shelters in Haiti was spent overseas for materials and transportation.[3]

Figure 1. Average Cost per Square Meter of Retrofitted Yellow- and Red-Tagged Houses Compared to New Construction and T-Shelter in the Greater Port-au-Prince area of Haiti, 2011-2012



(Sources: Build Change for new construction and retrofitting; Priscilla Phelps and UCLBP for T-Shelter[4])

[3] Adrian, Jean-Christophe; "Urban Resilience"; http://www.urd.org/Urban-Resilience?artpage=2-4

[4] According to Priscilla Phelps, housing adviser to the now-defunct Interim Haiti Recovery Commission and one of the chief authors of *Safer Homes, Stronger Communities: A Handbook for Reconstructing After Natural Disasters*, which was compiled by the World Bank just before the earthquake, over $500 million has been spent on T-Shelters in Haiti: (http://www.nytimes.com/2012/08/16/world/americas/years-after-haiti-quake-safe-housing-is-dream-for-multitudes.html). According to UCLBP, the Shelter Cluster co-operation between NGOs and the Haitian government, 110,964 T-Shelters had been built by November 2012. $500 million / 110.964 = $4500 per T-Shelter. $4500 / 18m^2 = $250/m^2.

> "The inventory we are interested in is only safe housing. In fact, unsafe housing is worse than no housing at all."

An early retrofit program adds quickly to the stock of safe housing. It is a dangerous mistake to think that retrofitting does not add to available housing stock; this quick conclusion makes the claim that retrofitting only deals with existing housing stock. That is true, but this housing is unsafe. Thus, not only should it not be counted in the inventory of available housing, but it should really be counted as a negative. The inventory we are interested in is only safe housing. In fact, unsafe housing is worse than no housing at all. It is, after all, unsafe buildings that kill people in an earthquake. The brutal reality is that tents do not kill, and from a seismic hazard standpoint people would be safer living in tents than in unsafe houses.

HISTORICAL AND TECHNICAL BASIS OF SEISMIC RETROFITTING

Prior to the introduction of modern seismic building codes in more developed countries in the 1960s and 1970s, many buildings were built without adequate detailing, reinforcement, or ductility to withstand the loading of major seismic events and perform to the level of life safety. The incidence of major events near urban centers prompted research and the publication of technical guidance for the seismic evaluation and retrofit of existing inadequate structures so they could be rehabilitated to perform to the level of the new seismic codes. Early pioneers in this work were the American Society of Civil Engineers (ASCE), working with the US Federal Emergency Management Agency (FEMA) and the National Earthquake Hazards Reduction Program, and the New Zealand Society for Earthquake Engineering (NZSEE). This work continues today as we learn more about seismic loading and structural system response. The 1994 Northridge, California earthquake, for example, caused many failures of welded steel frame connections that were previously thought to have adequate ductility and light wood frame connections that were previously thought to have adequate strength.

In much of the underdeveloped world there is a lack of seismic code guidance for building design and construction and insufficient training of engineers and architects in seismic design principles. Worldwide the most common construction system is unreinforced or under-reinforced masonry, whether brick, stone, adobe, or concrete block. Unreinforced masonry is particularly susceptible to seismic damage and failure because it lacks ductility and exhibits brittle, often explosive failure modes. Some

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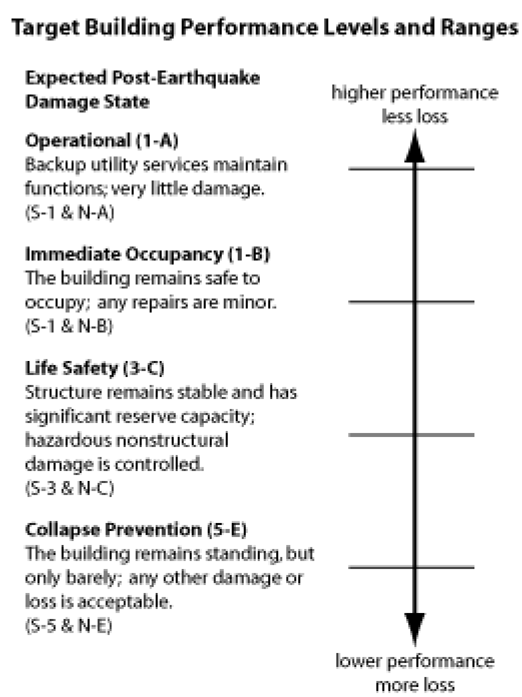
This estimate is conservative, despite NGO claims that T-Shelters cost between $2,000 and $3,000. Elsewhere Phelps posits that the real cost is probably between $6,000 and $10,000 (http://www.thenation.com/article/170929/ngo-republic-haiti).

American cities, such as San Francisco, California and Seattle, Washington, offer incentives to encourage building owners to perform voluntary seismic retrofits of old unreinforced masonry buildings.

In the early 1980s FEMA began a project to research and produce guidelines for the seismic evaluation and upgrading of existing buildings. This work resulted in *FEMA 356, Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, which was published in 1997. The work continued and was eventually split into two documents, *ASCE 31, Seismic Evaluation of Existing Buildings*, and *ASCE 41, Seismic Rehabilitation of Existing Buildings*. Both have been adopted by reference into the International Building Code. These two documents have recently been re-combined into an expanded *ASCE 41-13*, *Seismic Evaluation and Retrofit of Existing Structures*, the publication of which is forthcoming, and *ASCE 31* has been discontinued.

These guides give procedural options of varying complexity for the evaluation, analysis, and retrofit design of existing buildings. Unlike most building codes, which are prescriptive (defining what is allowed and what is not allowed), these are performance standards. They provide multiple solution paths to achieving the same objective, which is that the retrofitted building will meet a pre-selected performance class. *ASCE 41* defines these classes this way:

Figure 2. *ASCE 41* Performance Levels for Structural and Non-Structural Building Elements (Courtesy of *ASCE 41*, 2005)



This approach gives significant flexibility to the engineers designing retrofit solutions as a means of building back post-disaster in countries where substandard construction has magnified the tragedy of a recent earthquake and where reconstruction budgets are usually extremely limited. If performance criteria are not specified by local building codes, USAID typically specifies the immediate occupancy performance level for buildings designated as emergency shelters and the life safety performance level for residential construction. Reconstructing to a specified performance level for a given code-specified earthquake loading assures the performance of the rehabilitated structure during a future earthquake. This is the essential difference between retrofit and repair. While repair is a form of building rehabilitation, it is focused on repairing the damage from the most recent earthquake. Seismic retrofit focuses on saving lives in future seismic events.

ADVANTAGES OF SEISMIC RETROFIT AS POST-DISASTER RECONSTRUCTION

A reconstruction program centered around seismic retrofitting of the existing damaged but useable housing stock provides significant advantages in terms of safety, homeowner satisfaction, cost, and sustainability. While each of the most common alternatives – repair, T-Shelter, and new construction – can provide some of these benefits, a seismic retrofit program maximizes the benefits. This is particularly true when paired with a homeowner-driven reconstruction approach.

A seismic retrofit program can:

Increase Safety.

- Buildings are rebuilt to a code-prescribed level of seismic performance.
- Local engineers and builders are trained to design and construct retrofit solutions. This approach promotes an understanding of the key weak points in the existing construction practice that led to the catastrophic loss. These skills will be used in the future to design and build safer structures.
- Existing structures that are standing but unsafe (and often inhabited) are systematically and efficiently addressed and made safe.

Increase Homeowner Satisfaction.

- Retrofitted houses are improved, safer versions of the houses that the same families lived in before the earthquake – the ones the homeowners chose to build or buy originally.
- Neighborhood character is retained. At the end of a retrofit program in a neighborhood it is a safer, spruced-up version of its former self, not a mass-produced neighborhood where all houses look almost the same.
- Families are displaced for much less time while their houses are being retrofitted than with other solutions.
- Homeowners do not have to struggle with land ownership issues. This is often a challenge imposed on homeowners by aid organizations. It is generally not an issue in countries with strong government, such as in China after the 2008 Sichuan Province earthquake. In Indonesia, however, it was a large, even debilitating issue when the non-governmental organizations (NGOs) made it into one, such as in Aceh in 2005. In West Sumatra in 2007 and 2009, common sense tactics to allow homeowners to verify property ownership, such as affidavits signed by neighbors, were employed to reduce the burden. In a retrofit program homeowners are easier to identify and these same common sense strategies work very well.

Reduce Cost.

- As shown in Table 1 above, retrofitting is significantly cheaper in terms of materials and labor than the other options, providing more safe floor space per dollar spent.
- Parts of houses that are intact and structurally sound can be part of the retrofitted structure, rather than being torn down to make way for a new house.
- Because a retrofit program can be started early in the relief process, even while rubble is being cleared, money that would have been spent on temporary solutions can be allocated earlier to permanent solutions.

Increase Sustainability.

- Retrofitting can be done with local materials and labor, putting resources back into the local economy.
- Building materials can be reused or recycled, reducing the overall cost per house.

- The transfer of skills to and among builders, engineers, and materials producers creates a larger, more specialized, more employable workforce. Thus the transfer of capacity from reconstruction assistance to the local workforce becomes a self-perpetuating transfer which eventually does not depend upon foreign inputs.
- Homeowners take pride in their retrofitted houses and are inspired to commit their own funds toward improvement and maintenance.
- Houses can be retrofitted to support an additional story, which puts rental properties back on the market.

Decrease Institutional Risk.

- Designing to a recognized code standard is the correct way for foreign engineers and organizations to conduct themselves in post-disaster situations. This approach removes the burden of deciding for themselves what is "good enough" for a given country. It also sets a good example of the professionalism required of construction sector actors in countries that often need that as much as they needs good schools, good building codes, and good building materials and skills.

DRAWBACKS TO SEISMIC RETROFIT AS POST-DISASTER RECONSTRUCTION

The disadvantages to retrofitting are felt at the level of the partners who are implementing the program more than by the homeowner. They can be overcome through careful program design, so should be considered carefully before the start of the program. The extra effort and therefore cost are warranted, however, because the major disadvantages stem from an intensified effort to build local capacity as a lasting legacy of the program.

A seismic retrofit program may:

Increase Cost.

- The process is more design-intensive than other approaches, as each house is treated uniquely. Staff must be trained and paid to do this work on an ongoing basis. Even though the cost of materials and labor is significantly cheaper than for other approaches, this must be balanced with the potential for increased design cost.
- A higher caliber staff, of both foreign and local engineers, must be paid to do this work than would be required to repeat the designs of one or a few qualified foreign engineers. In most cases the local

engineering workforce will not be sufficiently qualified, and foreign structural engineers familiar with *ASCE 41-13* must be employed to train and mentor them and provide technical supervision.

Result in Some Unfinished Houses.

- Some houses will not be disaster-resistant at the end of the program. If the financial subsidy and the homeowner's funds are not sufficient to complete the house according to the retrofit design, the homeowner and builder may not produce a disaster-resistant house. In addition, corruption or lack of will may reduce construction quality. It may be difficult to convince a homeowner to spend the subsidy on the structural elements required when he may have other priorities, such as enlarging his house or improving the finishes.

- Houses may be less attractive for photographs. Because limited funds must be used first for required structural improvements, there may not be enough for finishes such as tile and paint. Thus, it may be difficult to obtain picture-perfect images of houses for reports and PR materials.

Increase Risk for the Implementing Partners.

- Undertaking a process that is based on designing to a building code standard increases the perceived risk to partners. However, this is normal and exceptions should not be made just because the project is taking place in the developing world. The program must be conducted so that design work culminates in review by qualified engineering staff.

- NGOs that work across a broad spectrum of humanitarian aid may not have the structural engineering expertise required to implement a retrofit program and may have to hire an engineering consultant.

KEY ELEMENTS OF A SUCCESSFUL RETROFIT PROGRAM

A homeowner-driven retrofit program is most effective when the essential technical, financial, and social components are in place.

Technical: Earthquake-resistant construction will become common only if the right technology is locally available, widely known, and culturally accepted.

- Technology Choice: It is easier and more effective to make improvements to existing buildings and building methods rather than introduce something new. When given the choice, homeowners will choose what they are already familiar with. The opportunity exists to

"Provision of financing must be contingent on applying minimum construction standards. This is best done in stages, so that the homeowner must meet milestones in compliance with the construction documents in order to receive the next stage of funding."

work with the homeowner to build better using locally available materials and techniques.

- Standards: A clear, complete, *ASCE 41-13*-derived, government-endorsed guideline for the specific adaptation of retrofit methodology to local practice and conditions, consisting of evaluation, analysis, and design procedures and solution detail drawings, is required before the program begins. Government-produced, -adopted, or -endorsed seismic loading criteria must be established in advance.

- Capacity: Builders, engineers, architects, building materials suppliers, and inspectors must be trained.

Financial: Homeowners must have access to sufficient funds to rebuild safely and completely.

- Access to Capital: Homeowners must have sufficient funding in the form of grants, loans, or materials vouchers.

- Incentives: Provision of financing must be contingent on applying minimum construction standards. This is best done in stages, so that the homeowner must meet milestones in compliance with the construction documents in order to receive the next stage of funding and continue the work.

- Subsidies: Subsidies or price controls on certain building materials may be required to meet funding goals.

Social: Someone has to want the house to be earthquake-resistant.

- Motivation: Demand for safe housing must be created among homeowners through information campaigns and coupling financing with building standard compliance.

- Acceptance: People from different cultures have their own ideas about what a house should be. They will accept structural requirements if their ideas about layout of interior and exterior spaces, orientation to light/wind/view, privacy, and security are respected.

- Enforcement: Building standards must be enforced by government officials, donors, or a third party.

THE ACTORS IN A RETROFIT PROGRAM

THE ROLES OF IMPLEMENTING PARTNERS

Key roles must be filled in order to execute a homeowner-driven housing retrofit program: technical consultant(s) for design and construction supervision, and implementing partner(s) for homeowner selection and fund distribution.

It is possible and recommended that the same organization be used as the technical consultant for design and construction. The technical consultant or consultant team could be an Architecture and Engineering (A&E) firm, a specialized non-profit organization or social enterprise, a team of local experts from the academic and business sector, or any combination of the above. In more developed countries there is often a perception that, while improving efficiency and reducing cost, the design-build model suggested here does not provide for independent design error checking in the field. Implementing partners must openly acknowledge that this is a potential avenue for corruption. Periodic independent qualified auditing of the compliance of finished houses should be included in the program. This will be discussed further in the section about retrofit project implementation.

Despite these concerns, the design-build model offers extremely valuable benefits. A capacity-building approach to design means that by definition the designers will be inexperienced and hopefully the volume of work will be high. Design errors will occur and will occasionally get through the review process. Having well-trained supervision in the field that can catch an error on the job site and communicate directly with the designer about it is an invaluable tool of last resort. If incorporated into a formal process of review, revision, and reissue of construction documents it does not have to be excessively onerous and teaches good professional habits and ethics. If this step is not taken formally, either the finished house will not match the construction documents and its safety will not be documented, or worse, the error cannot be fixed in the field and the finished house may not be safe.

Similarly, it is very difficult to train seismic retrofit evaluators and designers without rotating them through the field supervision process.

"Invaluable lessons are learned in the field, both individually and institutionally, about the constructability and general feasibility of various design solutions."

Invaluable lessons are learned in the field, both individually and institutionally, about the constructability and general feasibility of various design solutions. There is a feedback loop available from the field that not only should not be missed or ignored, but for the organization should be incorporated into a continuous learning process that prompts ongoing revision to the way evaluation, design, and construction are carried out.

The implementing partners for design and construction should be different from the implementing partner for homeowner selection and fund distribution. Separating these roles preserves the consultant relationship between the homeowner and technical consultant; the technical consultant is seen as a trusted advisor rather than a source of funding, which facilitates a better dialogue with the homeowner about safe construction. Plus, this separation better mirrors the contracting requirements and separation of roles of the Fédération Internationale des Ingénieurs-Conseils (FIDIC, International Federation of Consulting Engineers).

Additional partners may be needed for other activities which are necessary prior to retrofit activities but are outside the scope of this Primer. Those activities include but are not limited to the following:

- Site cleanup
- Property rights and land titles
- Community mapping and planning, with plot boundaries identified
- Infrastructure planning and implementation
- Banking and access to capital

Options for selection of and contracting with the technical consultants and implementing partners are covered in two earlier USAID Primers: "Basic Host Country Construction Contracting for Development Professionals: A Primer," and "Basic Engineering and Construction Management: A Primer."

THE STAKEHOLDERS IN A POST-DISASTER HOUSING RETROFIT PROGRAM

There are a number of stakeholders involved in post-earthquake housing retrofit. It is important to define clearly the role of each stakeholder group and leverage the core competencies of each. The major stakeholder groups and their roles are identified in this section.

Donor (in this case USAID):

- Provide funding for technical assistance and other work
- Manage disbursement of financial subsidy to homeowner or community group for materials and labor, or oversee the distribution of funding by an implementing partner

Government (relevant ministries, municipal engineers, and building inspectors):

- Adopt consensus-based code guidance for required loadings, including seismic loading, for building construction
- Produce or adopt consensus-based, clear, easy-to-implement building standards and guidelines
- Provide certification programs or licensure regulations for builders, engineers, and government officials
- Provide plan review and permitting services and building inspections to ensure compliance with approved construction documents
- Manage disbursement of financial subsidy to homeowner or community group

Homeowners:

- Participate in the design process and approve final designs
- Procure the building materials
- Hire the contractor
- Oversee construction
- Pay for building materials and pay the contractor

Community Groups:

- Select homeowners who qualify for the program
- Assist with gathering homeowners for informational meetings and resolving disputes
- Assist with public awareness outreach campaigns
- Assist in resolution of land rights and property boundary issues
- Identify local builders, building materials suppliers, and other stakeholders

Technical Assistance Providers (engineers and architects who provide support in developing the building standards and direct technical assistance to homeowners during reconstruction):

- Develop evaluation, analysis, design, construction, and materials guidelines, and related resources and tools
- Support the government in building code and guideline development, adoption, and enforcement
- Provide training and capacity building to homeowners, builders, engineers, building materials producers, and government officials
- Guide the homeowner through the design, builder selection, and construction process
- Supervise construction and provide on-the-job training to builders as needed

NGOs/Community-Based Organizations (CBOs): work with community groups and homeowners to:

- Clear debris
- Resolve land tenure issues
- Implement infrastructure projects
- Do civil works such as building retaining walls that protect more than one house
- Approve final list of homeowners who qualify for the program
- Manage disbursement of financial subsidy to homeowner or community group

Private Sector Enterprises and Institutions:

- Provide construction contracting and labor
- Provide building materials, material transportation, and equipment rentals
- Provide financial products such as loans, micro loans, and insurance

United States Agency for International Development:

USAID is usually the sponsor of the housing project, and in the case of homeowner-driven housing retrofit, it contracts directly with engineering and construction companies as a technical assistance provider and implementing partner to distribute funds to homeowners.

PRE-EVALUATION ACTIVITIES

In the wake of a disaster, several activities must take place before reconstruction or retrofitting of permanent housing can begin:

1. Assess the country for political stability and safety of teams on the ground.
2. Confirm that higher-priority items are being addressed first: water, food, medical treatment, sanitation, maintenance of the peace.
3. Assess safety and tag affected buildings using the methodology of the US Applied Technology Council (ATC) *ATC-20, Post-Earthquake Damage and Safety Evaluation of Buildings*.[5]

   Rapid safety assessments allow for a quick inventory of damaged buildings and facilitate the quick return of some homeowners to undamaged, safe buildings. An ATC-20 type survey was used successfully following the 2010 earthquake in Haiti.
4. Recruit and train local engineering staff to implement the rapid assessment procedure at scale.
5. Confirm that rubble removal operations are being addressed.
6. Use post-earthquake reconnaissance and forensic engineering to understand causes of collapse.

   A post-earthquake environment presents an ideal laboratory in which to learn why some buildings collapsed and others did not. Forensic engineering studies are regularly performed by professional engineers, technical assistance providers, and research institutes such as the Earthquake Engineering Research Institute (EERI) to document lessons learned and make recommendations for safe rebuilding. Identifying causes of collapse can help shape and inform reconstruction guidelines, especially in situations in which building codes or guidelines are not available.

[5] ATC-20 is a rapid method for evaluating building safety for immediate reoccupation after earthquakes. Implementation results in tagging buildings as follows: INSPECTED (apparently safe, green placard); LIMITED ENTRY (yellow placard); or UNSAFE (red placard). More information is available at https://www.atcouncil.org/index.php/component/mijoshop/product/36-procedures-for-postearthquake-safety-evaluation-of-buildings-addendum.

Please visit www.buildchange.org/USAIDPrimers.html for a summary of causes of collapse for confined masonry buildings in Indonesia.

7. Assess the potential for other hazards.

   Additional studies may be needed to quantify the likelihood and magnitude of future disasters, including:

   - Earthquakes
   - Tsunamis
   - Hurricanes, cyclones, or high winds
   - Floods
   - Landslides
   - Climate extremes

8. Perform housing, materials, and labor subsector studies.

   It is easier and more sustainable to make minor low- or no-cost improvements to existing ways of building than it is to introduce a completely new technology or reintroduce a traditional building method that is no longer common. A retrofit program should be based upon design solutions that can be understood, learned, and implemented by the local workforce using local materials.

   Housing subsector studies address the following questions:

   - **Housing**: How are houses commonly built? What systems and techniques are used? Do homeowners build themselves or hire local builders? Or are housing units built by the government or through the commercial private sector? Have common architectural, cultural, and climate preferences changed as a result of the disaster?
   - **Materials**: What materials are used, of what quality, where are they produced, how much do they cost, and will the production be able to meet demand? Who buys the materials (homeowners, builders, contractors)?
   - **Labor**: What is the skill level of local builders? What tools and techniques do they use? What tools and technologies are locally available? What retrofit solutions will the local workforce be capable of implementing once trained? How much do they earn?

The most effective way of obtaining the above information is through direct interviews and surveying of various stakeholder groups, such as homeowners, builders, building materials producers, and municipal officials. The Emergency Market Mapping and Analysis (EMMA) Toolkit[6] has become a popular method of rapidly assessing the market for reconstruction after a disaster.

9. Determine which building standards apply.

   Determine if relevant and adequate building codes and standards exist in the project country. Codes may not exist, or the codes may not be relevant to the most common structural system used for housing. For example, in many developing countries, building codes for multi-story buildings may exist, but applying these codes to one- or two-story single family homes may result in overly conservative designs and construction guidelines which lack important details on essential techniques to build an earthquake-resistant structure.

   Work with government officials toward the adoption of codes, standards, and guidelines if necessary, foremost for required live loading (seismic, wind, snow, etc) requirements for reconstruction. The codes and standards used should meet the standards applicable in the country in which the project is located. If such standards are not available or are not adequate, regional or international standards can be used. US standards are typically used on USAID projects; these usually exceed the requirements of local codes and standards, which will help ensure that retrofitted houses are safe, but may add to the cost of the project. Specific to retrofitting, the government of the project country should endorse the use of *ASCE 41-13* or a retrofit guideline derived from this standard.

   In the case of incomplete or inapplicable building codes, the best design solution may be a mix of international building codes, existing simple design and construction guidelines, and qualified engineering judgment to arrive at a solution that is sufficiently safe yet affordable, sustainable, and can be implemented in the local context.

10. Evaluate location options.

    In choosing a project area for a retrofit project, neighborhoods must be considered as a whole. If it appears that a large percentage of houses in the neighborhood will not meet seismic safety criteria

[6] More information is available at www.emma-toolkit.org.

during the evaluation process then an area might be slated for relocation rather than retrofit. Examples of conditions that might warrant such an approach are areas with an extremely high water table, liquefiable soils, excessively steep slopes, or in close proximity to a known seismic fault.

There is a good argument to be made for retrofitting homes in areas that would not be deemed suitable for a new construction project. While the local government may know that certain areas are not safe for residential construction, it may not have the capacity to enforce zoning ordinances or no-(re)build edicts. In this case the most at-risk populations may stay in the most risk-prone zones in houses that are damaged and unsafe. These are the most difficult and expensive neighborhoods to address, but should be considered if technically feasible. For steep existing neighborhoods, for example, a solution that was used successfully in Haiti is to retrofit existing retaining walls and add new walls to protect houses that can be retrofitted. This process is documented in the USAID Primer, "Site and Retaining Wall Hazard Mitigation in Post-Disaster Situation: A Primer."

11. Clarify objectives and performance criteria.

    At this stage, the project team, in consultation with project country government officials, must decide on performance objectives and priorities. Questions to be addressed include:

    - Should damaged houses be retrofitted? If so, to what extent should retrofitting displace T-Shelter construction and/or new housing construction?

    - Should there be standardized criteria for which houses should be retrofitted, which should be rebuilt, and which should be torn down and not be reconstructed? Or should these decisions be left to the technical consulting partner and its engineering staff to decide during the evaluation process?

      If decisions about which houses can be retrofitted successfully are made by the technical consultant on a case-by-case basis, depending on the structural assessment and the projected retrofit budget compared to the cost of new construction, the cost savings associated with retrofitting can be maximized. In Haiti after the 2010 earthquake it was assumed by many that all houses tagged red ("Unsafe") in the ATC-20 assessment process would have to be torn down and rebuilt, and all houses tagged yellow ("Limited Entry") could be retrofitted. This was never the intent of ATC-20, which says in its Appendix A, "It is very important to understand that the ‘red tag’ Unsafe posting does not automatically mean that the property has been condemned or will require demolition."

In fact, many red-tagged houses were successfully retrofitted in Haiti – in some neighborhoods, as many as fifty percent. At the opposite end of the spectrum, many yellow-tagged houses were not retrofitted, often because much that was undamaged was still not structurally adequate to meet life safety criteria. In addition, many buildings that were mostly undamaged by the earthquake and were tagged green ("Inspected") in the ATC-20 process escaped damage by luck of geography and geology, and actually needed or still need to be retrofitted. While not difficult to address from a technical standpoint, these houses are very difficult to address from a funding perspective.

- To what performance level should houses be retrofitted?

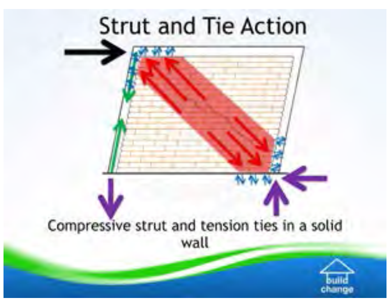
  A common and appropriate performance level for housing is life safety, which according to *ASCE 41*, Section 1.5 means "significant damage to the structure has occurred but some margin against either partial or total structural collapse remains. Some structural elements and components are severely damaged but this has not resulted in large falling debris hazards, either inside or outside the building. Injuries may occur during the earthquake; however, the overall risk of life-threatening injury as a result of structural damage is expected to be low. It should be possible to repair the structure; however, for economic reasons this may not be practical. Although the damaged structure is not an imminent collapse risk, it would be prudent to implement structural repairs or install temporary bracing prior to reoccupancy."

12. Adopt or create retrofit guidelines.

    Guidelines must include seismic evaluation checklists, analysis calculation procedures, and retrofit solution detail drawings, and be endorsed by the government of the project country. The guidelines should be derived from and compliant with *ASCE 41-13*, and simplified and adapted to the local context as identified in the forensic and sector studies discussed above. The process for the creation of such guidelines is beyond the scope of this Primer, but examples of the various components, which were used extensively in Haiti, can be found at www.buildchange.org/USAIDPrimers.html.[7]

13. Hire and train local staff in the retrofit procedure.

Retrofit training for the technical consultant's local staff is the foundation of the retrofit program. The only way a retrofit program can be implemented at scale successfully is with a large staff of well-trained engineers. This training takes weeks of classroom experience followed by weeks of supervised practical experience in a pilot phase, involving the first houses to be retrofitted in the program. Classroom training of engineers should be taught by structural engineers thoroughly experienced in seismic retrofitting and intimately familiar with the adopted guidelines. Many engineering firms and organizations have this teaching experience already from work after previous disasters. For information about finding training assistance, please visit www.buildchange.org/USAIDPrimers.html. Retrofit training for local engineering staff should include the following topics:



- Fundamentals of geologic hazard and seismicity
- Seismic loading and building response
- Structural system selection and performance
- Common building types found in the project area and their common structural deficiencies and failure modes
- Load path and connection design
- Common building materials used in the project area: quality, suitability, and testing procedures
- Fundamentals of seismic retrofitting
- The retrofit procedure for the project: evaluation, analysis, design, cost estimation, and construction quality assurance/quality control (QA/QC) methodology

[7] The complete Build Change/Degenkolb Engineers Seismic Evaluation and Retrofit Manual & Companion created for seismic retrofit of housing in Haiti is available at the link above. They contain the entire methodology used, including evaluation checklist, complete construction details, sample calculations, and sample existing retrofit plans. In 2011, prior to the start of program activities, they were approved for use by the Haitian Ministry of Public Works, and Build Change and Degenkolb trained 58 Ministry engineers in their use.

The Retrofit Guide produced by the Haitian Ministry of Public Works two years later, which includes a revised version of the Build Change/Degenkolb Manual as a technical appendix, is available at the same web page.

The basics of seismic engineering are covered as a review or for the common case in many countries that they are not part of the curriculum at local engineering schools. In many cases, a review of more basic engineering analysis tools may also be required. Classes should be well designed, participatory, and should include feedback for the instructors in the form of brief daily quizzes.

During the field training engineers should evaluate, design, and supervise the construction of houses themselves, supervised by the instructors. Small groups of students should give presentations at each stage to the larger group so that students can share lessons learned in the field. Another important aspect of the practical training is that time should be spent developing the engineers' own construction skills for the practical skills common to the housing type and construction methods used in the project location. This gives them the confidence to correct unsafe building practice found when working as site supervisors, with contractors who may be very resistant to changing the way they are used to doing things.

14. Other specific activities, such as conducting an environmental analysis, are required for any USAID project. These mandatory requirements are described in the USAID Primer "Basic Engineering and Construction Management: A Primer."

THE RETROFIT PROCESS: SEISMIC EVALUATION

Once a neighborhood has been selected for the retrofit program, the technical consultant's team begins to evaluate houses. There are four essential components of the evaluation:

- Homeowner Preference Survey
- Site Survey and Sketch
- Existing Building Survey and Sketch
- Seismic Evaluation

HOMEOWNER PREFERENCES SURVEY

The evaluation begins with a homeowner survey of information that is non-technical but important to the retrofit process. This survey collects much of the same data as in a housing subsector study, but is specific to each homeowner. The homeowner survey includes the following:

Table 1. Homeowner Preferences Survey Contents

General Data	– Homeowner name, address, ID – House address, GPS coordinates – Surveyor name, survey date
Homeowner Data	– Willingness to participate in the program – Family structure, number of family members, gender – Special needs, mobility issues – Land tenure status – Job and income – Willingness to share walls or live in multi-unit dwellings – Intention to expand horizontally or vertically
Homeowner Contribution	– **Design**: Does the homeowner want to be involved and have some control over the retrofit solutions used? For example, increasing shearwall length along a line of resistance can be accomplished by filling in an existing window or adding a length of new wall. The homeowner may have a strong preference based on the needs of the family. – **Construction**: Does the homeowner want to build himself, choose the contractor, supervise construction, or remain uninvolved? – **Materials contribution**: Does the homeowner

	have stockpiled or salvaged materials for use in construction? What type and how much? – **Construction inputs**: Can the homeowner provide water and/or electricity for use during construction? – **Funds contribution**: Can the homeowner contribute funds to provide finishes or build an addition to the home?

SITE SURVEY AND SKETCH

The engineer measures the building footprint and the plot and orients the house on a dimensioned sketch of the site. Any adjacent buildings, roads, or pathways and any utilities, drainage, septic systems, wells, trees, excavations, or other significant features are also noted on the sketch. Orientation to sun, prevailing wind, views, and cultural norms should also be noted. Photos of the site are taken. The site sketch and photos will be useful in planning the retrofit, but if it turns out after analysis that the house cannot be retrofitted the site sketch may be used to design the layout of a new house on the plot.

EXISTING BUILDING SURVEY AND SKETCH

The engineer measures the existing building and enters all information on a reasonably scaled sketch. This process is best accomplished by a team of two, and must be done carefully and accurately as the information is critical to the seismic capacity analysis of the existing structure and will be used as the basis for the existing and retrofit plans during the design process. All building elements are included: foundations (dimensions, depth), walls (length, height, thickness, opening dimensions and locations), floors and roofs (material, thickness, overhangs, opening), columns and beams (a rebar scanner such as the Hilti PS35 may be required to evaluate reinforcement), and stairs. Any obviously damaged or structurally deficient building elements are noted on the sketch. Interior and exterior photos are taken, including a photo of the overall structure (principal elevation) and photos of significant damage and structural deficiencies.

SEISMIC EVALUATION

The seismic evaluation compares the existing structure to a checklist of structural criteria grouped into categories. Each item is marked as Conforming, “C”; Not Conforming, “NC”; or Not Applicable, “NA.” A brief description of each item should be included, as well as space for brief notes about each item, as needed.[8] The specific evaluation requirements will vary based on location and structural systems, but the evaluation should include:

- Geologic Site Hazards (e.g., liquefaction, slope failure, site retaining walls, surface fault rupture)
- Foundations (e.g., construction, performance, degradation, resistance to wall overturning, structural continuity between foundation elements)
- Building System(s) (e.g., load path; materials; number, height, and tributary mass of stories; floor, roof, and wall systems)
- Building Configuration (e.g., shearwall density and distribution, vertical and horizontal irregularities or discontinuities, risk from adjacent buildings)
- Building Components (e.g., freestanding columns, unsupported beams, slab openings, stairs, parapets)

Deficiencies found during the seismic evaluation, which is to say items on the checklist marked "NC," will be addressed during the building analysis and retrofit design. There should also be space at the end of the checklist for the engineer to comment on any observed damage or deficiency not sufficiently covered by the checklist items. As local engineers become more experienced with the process they will begin to develop their own engineering judgment for the building types and structural systems encountered in the project area. If they see a problem that is rare or out-of-the-ordinary or unseen before in the project, they should be encouraged to address it by adding comments and photos and by working with technical mentors and supervisors to design a solution to the problem. The checklist is a valuable tool, but it cannot be exhaustive. Engineers in the field need to understand that they must study the house and understand how its elements function as a system and how well they will perform. Care should be taken in producing or choosing an evaluation checklist and in training the engineers in its use so that they do not become limited by the checklist.

One difficulty in the seismic evaluation process is the probable unwillingness of homeowners to allow any destructive investigation of their houses during the evaluation process. This is understandable and

[8] A complete seismic evaluation checklist for masonry construction in Haiti is available as Appendix D of the Build Change/Degenkolb Engineers Seismic Evaluation and Retrofit Manual at www.buildchange.org/USAIDPrimers/html .

should be addressed as part of the retrofit program design. Most checklist items will be visible without destructive investigation, but a few are not, and can cause expensive complications later on if not discovered before construction begins. An example of this sort of problem is the degradation of reinforcing bars inside structural concrete slabs by water infiltration. Often the homeowner will have plastered over any visible evidence of this degradation. The funding and implementing partners must decide in advance if destructive testing by the engineers, such as removing a portion of the plaster from the underside of a slab, will be allowed, and if so, how owners will be compensated to repair it if the item is found to be structurally adequate or the house is not deemed appropriate for a seismic retrofit for technical or budgetary reasons. This reimbursement expense can be small compared to the cost of having to replace a slab that was not found to be deficient during the evaluation and so was not included in the retrofit budget.

THE RETROFIT PROCESS: ANALYSIS AND DESIGN

Based on the information from the forensic and seismic evaluations, and if the homeowner is willing to participate in the retrofit program and the site and structure proposed are suitable for retrofit, a design package for the house is produced by the engineers. Continuity between the evaluation team and the designer is crucial. One of the engineers who did the seismic evaluation should carry the process through analysis and design, or important defects might be misinterpreted or lost. As good as pictures and sketches from the field are, the engineer who saw the structure in the field will have a level of understanding of the adequacy or inadequacy of building systems as a whole that will influence the design process. The retrofit design package contains the complete building evaluation checklist and homeowner preference survey and includes the following:

- Site Plan
- Existing Plan
- Retrofit Calculations and Hypothesis
- Retrofit Plan
- Retrofit Details
- Scope of Work
- Bill of Quantities (BOQ)

SITE PLAN AND EXISTING PLAN

The engineer begins the design process by making an accurate drawing of the existing site and structure from the sketches, photos, and notes gathered during the evaluation. Although drawings can be done in a Computer-Assisted Drafting (CAD) format, the one-off nature of retrofit design makes it more efficient to produce neat hand drawings that are reasonably scaled. All dimensions are included on the drawing, and form the basis for an engineering analysis of the existing structure. Separate drawings are made for the site and each level of the structure.

Grid lines are used to identify wall and column lines, and must be consistent at each level of the building in order to check vertical alignment of structural elements in the analysis of the structure. If drawings are done in CAD format, staff should be taught or refreshed how to overlay level layers to check for vertical discontinuities. If drawings are done by hand, scale must be consistent and a light table should be used in the analysis of multi-story buildings.

RETROFIT CALCULATIONS

For unreinforced masonry and confined masonry, analysis focuses on comparing existing competent shearwall density to that required for the seismic acceleration and resultant forces based on the seismic load of the structure. An example spreadsheet showing these calculations can be found at www.buildchange.org/USAIDPrimers.html.

In addition to shearwall density, the engineer checks the evaluation for deficiencies that must be remedied in the design in order to ensure a competent load path to carry the seismic forces generated safely to the foundation and ground. Each deficiency noted in the seismic evaluation is addressed. From the details created as part of the retrofit methodology for the program, the engineer selects the most efficient combination of remedies to address shearwall density requirements and correction of deficiencies.

RETROFIT PLAN AND DETAILS

This retrofit hypothesis is then transformed by the engineer into a retrofit design plan for each level of the structure. Typically the existing plan is copied and the retrofit plan is drawn on top, with remedies shown graphically in keyed or keynotes fashion with detailed call-outs to reference the structural details that will be provided with the design package. Construction documents must include materials specifications that correspond to the required strengths of materials used in the development of the retrofit techniques. Most details used will be standard for the program, although occasionally new details will be drawn to cover conditions previously unseen or unanticipated in the conception of the retrofit program methodology.[9]

New solutions to design challenges and the accompanying new details are an important aspect of the retrofit program, and the ability to

[9] Sample retrofit plans and structural details are available at www.buildchange.org/USAIDPrimers.html .

incorporate them quickly and effectively broadens the capacity of the staff and the program. Structural calculations supporting the decisions made for the new details should be kept electronically in anticipation of changes in both staff and local code requirements. Each new retrofit detail (solution) should be well-designed, well-documented, well-drawn, and well-understood by the engineering staff. This will require ongoing training by the senior engineering staff. Any such changes to the retrofit program will also be more successful if they are made with the input of the local staff.

> "In most countries where poor construction quality leads to large losses due to natural disasters, the construction sector is not trained in or familiar with the use of construction drawings."

In most countries where poor construction quality leads to large losses due to natural disasters, the construction sector is not trained in or familiar with the use of construction drawings. Local engineering staff may not have had access to computers for CAD drawing in school, or even to sets of proper construction drawings for reference. Builders may never have seen a set of construction documents. Without submittal drawings and/or a permit approval process, building inspectors my not even know how they are supposed to do their jobs. Thus, the detailing of structural drawings is of crucial importance to the retrofit program. Details should be extremely graphic and depend as little as possible on notation. In order to teach the process that permitting must be done based on design documents, building must be done according to design documents, and inspection must be done to insure compliance with design documents, the design documents must be understandable to all actors. This is true of all documents including contracts, but applies particularly and crucially to drawings and details. This is a prime opportunity to use the retrofit program for long-lasting capacity building that cuts across the entire construction sector.

SCOPE OF WORK AND BILL OF QUANTITIES

Once the retrofit plan is drawn and detailed, the engineer provides a list of the required scope of work and calculates a BOQ, which is an engineer's estimate of cost for the required materials and labor. This estimate should be as accurate as possible, including the most current materials and labor costs available, as it often forms the basis of the subsidy awarded to the homeowner by the donor and the contract for the work between the homeowner and contractor who will perform the work.

Developing a spreadsheet-based BOQ presents another opportunity for capacity building of local technical staff. Learning or practicing calculating quantities in spreadsheet format aids in the acquisition of basic tools for planning the construction process. Later in the program, when training builders, it will be seen that the inability to plan the process is at the root of many of the problems that lead to poor construction quality. Beginning this process early, with a well-conceived BOQ, kickstarts the process correctly. Inputs should be based on the number and dimensions of each detail (new foundation, new column, new wall, etc.), and outputs should be based on quantities of materials for each installment of funding, regardless of the details they are to be used for (volume of aggregate for all concrete and mortar to be used in the first installment for foundation, columns, etc.; volume of aggregate for all concrete and mortar to be used in the second installment for walls, beams, columns, etc....). If necessary and in addition to the common language of the implementing partners, outputs should be provided in the local language and currency. Examples of a retrofit BOQ from Haiti are available at www.buildchange.org/USAIDPrimers.html.

THE RETROFIT PROCESS: IMPLEMENTATION

Implementation of the retrofit design will depend on the model (homeowner-driven, donor-driven, etc.) adopted by the implementing partners and the funding source and distribution scheme. Regardless of the implement methodology employed, however, there are a number of key ingredients to the success of any retrofit project:

- Homeowner Training
- Builder Training
- Contracting, Scheduling, and Funding
- Site Supervision
- Public Outreach and Information
- Information Monitoring & Reporting
- Inspection and/or Program Evaluation

HOMEOWNER TRAINING

Before a retrofit design is implemented, homeowners receive training in the basics of safe construction and quality building materials selection. When provided with basic information such as relative proportions of cement, sand, and gravel required to achieve the specified concrete strength, homeowners can play an integral and valuable role in construction supervision. Sharing such knowledge with homeowners can build their confidence that their house will withstand the next earthquake, and contribute to long-term recovery from the traumatic effects of the disaster.

Suggested content for homeowner trainings includes the following:

- Why was your house damaged in the earthquake?
- Why were other buildings around yours not damaged in the earthquake?
- How likely are more earthquakes in your location?

- How can you make your house resist the next earthquake and other disasters?
- Design features to avoid and why
- Simple methods for evaluating materials quality
- Basics for concrete mixing, masonry work, and other relevant construction techniques
- Reading construction plans and details

Please visit www.buildchange.org/USAIDPrimers.html for examples of typical instructional materials for homeowners from China, and Haiti, and Indonesia.

BUILDER TRAINING

In addition, local builders receive training in earthquake-resistant design and construction, improving not only physical skills such as block laying and carpentry, but imparting an understanding of how a building performs as a system and the importance of all elements and the connections between them. Builder training begins in a formal setting where skills and concepts are taught in a group, and continues in the field where engineers provide on-site supervision and on-the-job training.

As some techniques in the retrofit program will be new to local builders, the builder training sessions should be used to explain how to accomplish them. Not only does this improve the capacity of the builders to adhere to the design documents in the field, it avoids many contractual pitfalls that may occur if the builder realizes too late how much labor is actually involved to execute a given detail. When he later finds himself in this situation he may write it off as a learning experience and do it correctly, but too often he will refuse to do it or do it wrong to save money, leading to an unacceptable construction defect which is often intentionally hidden from supervisors and inspectors. The builder training sessions are also the opportunity to explain how design drawings and details should be read and used. The builders must understand what is expected of them if they are to deliver earthquake resistant houses later on.

A system should be established to document the training and skill level of builders. This should include evidence of training attendance, performance on pre- and post-tests, and competency levels in the various skills taught at the training. A certification card should be presented, with room left for the certification of additional skills or skill improvement during on-the-job training as the builder retrofits houses during the project. This certification process can also be used to create a database of trained builders from which homeowners or even other organizations can choose qualified builders.

CONTRACTING, FUNDING, AND SCHEDULING

Builder or contractor selection is usually done by the homeowner with the oversight and advice of the technical consultants. Homeowners can choose to rebuild the house themselves; however, this choice is usually made only by homeowners who have construction experience or skilled builders in their families. It is more common for homeowners to hire a local builder.

Houses built through the informal construction sector in most project countries rarely have formal contracts in place between the homeowner and the builder. However, the post-disaster reconstruction environment provides an opportunity to take this step forward and implement a simple contract intended to protect the rights of both the builder and the homeowner. In many cases the implementing partner will choose to be a party to this contract. The technical consultant, however, should not be a party to this contract, allowing the preservation of the role of objective technical advisor.

Relevant government officials should be consulted to determine if such a contract already exists in practice in the project country. Short, simple contracts should include the following, as appropriate:

Table 2. Some Elements of Simple Contracts between Homeowners and Contractors

Owner name, address, and identification number
Contractor name, address, and identification number
Commitment to follow governing law
Project name
Project address
Building footprint area and number of stories
Type of contract (typically lump sum paid in installments)
Total price: specify materials and labor, labor only, or materials only; price usually includes contractor's fees, construction management, profit, and taxes
Payment schedule, including defects liability period
Construction schedule (start date, end date, number of days)
Force majeure clause; typically requires homeowner to pay for completed parts that meet quality specifications; contractor to cover loss of tools or equipment on

site
Homeowner commitment to pay the contractor according to the terms of the contract
Homeowner’s rights, such as the right to inspect the site and offer technical inputs
Contractor commitment to complete the construction works to acceptable quality and on schedule according to the terms of the contract, and duty to protect workers’ safety
Cancellation clause
Signatures of both parties

The project schedule is difficult to control in homeowner-driven reconstruction, as the pace is typically set by the homeowner and the contractor’s abilities and access to resources. Interruptions related to weather, holidays, cash flow, and work or family obligations for the homeowner can be common. However, interruptions can be minimized if funding is provided promptly.

Homeowner-driven reconstruction is most effective when the financing is provided in installments and is contingent upon meeting minimum standards for design, materials, and construction quality. As trained builders carry out the construction activities outlined in the retrofit plan, engineers provide quality assurance by verifying that work is done properly through a documentation system of checklists and photographs. Loan or subsidy disbursements are arranged in installments and the release of the next funding installment is dependent on successfully completing the work required for the previous funding installment and having that work documented and signed off formally to the funding partner by the quality assurance team. These checklists are also signed by the homeowner, ensuring his participation in and approval of the retrofit process. Without the leverage that can be applied through the funding scheme, the homeowner may be distracted from the retrofit plan, opting, for example, to create more unsafe space for his family with the funds available rather than retrofitting the existing space to make it safe.

Much greater detail on contracting, scheduling, and funding methods can be found in three of the USAID Primers mentioned previously: "Basic Host Country Construction Contracting for Development Professionals: a Primer," “Basic Engineering and Construction Management: A Primer," and "Building Back Housing in Post-Disaster Situations – Basic Engineering Principles for Development Professionals: A Primer."

SITE SUPERVISION

Construction supervision is necessary to authorize the release of the next funding installment for reconstruction and to achieve the objective of a disaster-resistant home. Construction supervision also provides an opportunity for on-the-job training of local building professionals. The level of construction supervision can vary from periodic inspection at crucial milestones to full-time site presence, depending on the complexity of the construction, the skills of the builders, and the level of government inspection. Construction supervision is best provided by in-country professionals and technicians, who usually require training but have been shown to evolve into competent supervisors. The assigned field personnel's integrity and attention to detail are very important. Oversight and mentorship by experienced mid- or senior-level professionals is essential.

A simple construction quality checklist should be developed and used in this process. The level of detail expected in the checklist depends on the donor's expectations, but must ensure that each retrofit detail constructed conforms to minimum standards that meet the retrofit design performance criteria.[10] For the addition of a new wall in confined masonry, for example, the checklist might include the following:

Table 3. Contents of a Construction Checklist Used for a Typical New Confined Masonry Wall in a Post-Disaster Environment

MATERIALS QUALITY
Quality of materials, such as sand, gravel, stone, water, cement, masonry units, reinforcement, and others as per specification
REINFORCED CONCRETE
Reinforcement diameter, strength, type, and condition as per specification
Reinforcement assembly as per specification
Concrete formwork installed correctly and using spacers to maintain cover of concrete over steel
Concrete mix proportion as specified
Concrete poured, compacted, and cured per specification
MASONRY WALL
Mortar mix proportion as specified
Masonry units meet specification and laid with proper bonding and staggered joints; joints completely filled with mortar
Masonry wall cured per specification
Wall plumb and level
Electrical and plumbing installed properly

[10] A sample QC checklist from Haiti is available at www.buildchange.org/USAIDPrimers.html.

Wall plastered and painted per specification

Along with the checklists, supervisors take photos to document that work has been done correctly. The checklists and accompanying photos are an audit-compliant way to document that the building was built according to the design documents and is therefore earthquake-resistant. Although once funding decisions have been made based on these documents it is hoped that they will not be consulted again, electronic versions for each house are kept by the technical consultant and other implementing partners as evidence that details that cannot be inspected once a building has been covered with finish materials were, in fact, executed correctly.

The time required by supervisors to complete, download, organize, and file checklists and photos so that they can be reviewed and stored should not be underestimated. Efficiencies in the program should be sought so that this crucial task can be done methodically and well, without being too onerous for staff who need to spend as much time as possible in the field, supervising. For this reason, organizations are now experimenting with computer tablet-based checklists that integrate field documentation with their Information Monitoring & Reporting (IMR) departments via cloud-based database solutions.

Documentation and funding approval constitutes half of the supervision process. The other half is on-the-job training of builders. Skills taught in the initial builder training will only be absorbed and incorporated if they are reinforced on the jobsite. If the funding scheme is set up carefully, builders have incentives not only to build safely, but to continue to improve any deficient skills with on-site trainers until the requirements can be met. It is imperative that the supervisors have a high skill level themselves. For the builders to trust them and to listen, the supervisors must earn their respect. This is done by showing rather than telling. Experience has shown that builders do not want to be told what to do by engineers, and that engineers want to tell builders what to do and not get their hands dirty. This approach works (with accompanying grumbling) in countries where code enforcement prevails. When this is not the case and one objective is to teach builders to build better, supervisors must be able to work with builders and show them how to do it right. Developing the practical skills of the engineering staff of the technical consultant to the point where this is possible must be considered as an overhead cost in the design of the retrofit program.

> "…builders do not want to be told what to do by engineers, and…engineers want to tell builders what to do and not get their hands dirty."

PUBLIC OUTREACH AND INFORMATION

A successful retrofit program includes not only the training of homeowners and builders, but if possible a wider information campaign should be conducted in the neighborhood to explain to others why buildings are being addressed the way they are, and what the key elements of a seismically resistant building are. In this way a retrofit program has impact potential beyond the buildings being retrofitted. Depending on the penetration and saturation of a given neighborhood for a retrofit project, outreach can help the program reach a critical tipping point, where earthquake-resistant features begin to be incorporated into buildings which are not part of the program and are not supervised by engineers.

Messages about safe building practice should be succinct, clear, and graphically oriented to appeal to populations with limited literacy skills. Posters, broadcast media, demonstration buildings, community resource centers, and information kiosks outside construction materials vendors have all been used successfully. Engineers, trainers, supervisors, and other staff of project partner organizations should act as ambassadors at all times while in the field and encourage homeowners and builders who are not part of the retrofit program to find more information about earthquake-resistant construction techniques and build more safely. Examples of outreach materials used in a Haiti retrofit program are available at www.buildchange.org/USAIDPrimers.html.

INFORMATION MONITORING & REPORTING

Once the homeowner agrees with the retrofit plan, the complete design package is submitted to the fund distribution implementing partner for the first installment payment. There is one set of drawings for the homeowner, one set for the contractor, and one set to attach to the contract with the contractor, if used.

All parties involved in the project are responsible for record-keeping:

- The ***design technical consultant*** will keep the design file and submit it to the fund distribution partner when the design is final and ready for construction. The design technical consultant will report on how the number of design packets completed compares to goals.
- The ***construction technical consultant*** will keep construction quality checklists and file them for installment payment requests. Though construction management is the responsibility of the contractor/builder, the construction technical consultant will keep a

daily record of the work performed, the weather conditions, and other information (for example, safety issues). The construction technical consultant will also note how the work is progressing relative to the schedule. An essential element of the construction technical consultant's files is a library of photographs which documents the construction progress and provides adequate documentation of compliance with construction quality standards. The construction technical consultant reports on completion status for which houses are successfully retrofitted according to design documents and can therefore be considered earthquake-resistant.

- The ***fund distribution implementing partner*** will keep records of funds distributed to the homeowners.
- The ***homeowner*** will maintain homeowner records, including the complete design package with structural, architectural, and detail drawings, the contract with the contractor, receipts for building materials purchased, and payments to contractors.
- The ***contractor/builder*** will also maintain contractor or builder records, such as the contract with the homeowner, the drawing package, the daily work log, reasons for delays, safety issues, receipts for building materials purchased, and payments to builders.
- The ***USAID project manager*** will maintain adequate records in order to be able to readily produce reports on the project's status, problems, and successes. The USAID project manager will rely primarily on reports from the technical consultant and fund distribution implementing partners. It is important that the USAID project manager make routine site visits and record observations, especially concerning problem areas. Photographs are important and should be part of the USAID project manager's files.

INSPECTION AND/OR PROGRAM EVALUATION

> "Independent evaluation of design and construction quality should be considered part of the retrofit program."

Independent evaluation of design and construction quality should be considered part of the retrofit program. Ideally this function will be assumed by the local code enforcement governing body, but this is rarely the case in underdeveloped countries, particularly for residential construction. There may be a training and capacity building opportunity in teaching local officials how to inspect buildings for compliance with construction documents at important milestones. There may also be a supporting role that implementing and technical partners can play for local governments to help them implement a complete building code enforcement program. Quite often even officials are not aware how the system works other countries. Partners in reconstruction should be very familiar with standard permit and inspection models that lead to safe, code-compliant buildings from other countries that can be held up and demonstrated as a model for new programs in project countries. Whenever working with officials on issues of licensing and permitting, partners should remain aware that this is a government function with a very large potential for corruption.

Evaluation can also be done by an outside contractor who is well versed in retrofitting and understands the obstacles and issues in the project country. Such a contractor might be difficult to find, but will be worth the effort for the level of peer review it can provide for the technical consultant. This process can be beneficial to everyone involved. A sampling technique, considering both design packages and retrofitted houses, should be used to evaluate both design performance and construction performance. Terms of reference for the consulting work must be carefully considered, as the task may not be as simple as checking for code compliance. There may be no code, so the evaluator may have to become familiar with the retrofit methodology adopted or created by the technical consultant. The donor may be interested in specific questions which it is not technically proficient to answer on its own, such as whether the technical consultant's builder training program is effective enough to achieve the required outcomes. Such questions may affect the timeframe of the evaluation, requiring multiple visits to single buildings or to successive buildings built by individual builders.

In addition to any third party inspection or evaluation, or particularly in the absence of it, the technical consultant should create a system of internal quality control. This is also part of the feedback loop that was discussed above in the section regarding implementing partners. An independent team of two can learn and teach a lot by spot-checking designs and construction sites and providing formal feedback to everyone involved. This team seems to work best when it consists of one expat mid-level supervising engineer and one local senior-level design engineer. This combination is the least likely to be viewed as "quality police" by local supervisory staff in the field and the most likely to return fair, objective, high quality information.

Such an internal evaluation team may be able to accomplish the following:

- Locate houses that have languished in the field and for one reason or another never been completed

- Verify "complete" status of houses that may be in question
- Identify trends such as supervisors who don't perform well, contractors who don't perform well, or even retrofit solutions that don't work well or are consistently not built correctly in the field
- Identify common misunderstanding or misapplication of retrofit details by engineers
- Hold brief weekly technical staff meetings to discuss problems seen in the field and possible solutions
- Identify corruption on the part of any of the project actors

Maximizing the opportunity to learn from project implementation is always worth the effort, although care must be taken not to hamper the implementation itself. In the pilot phase, constant evaluation is required if questions about approach and effectiveness are going to be answered in a way that leads to efficient and effective scale-up. In a scaled up program, dynamic feedback and quick response become crucial. Solutions that are not working as planned or project demands that were not seen at the outset must be accounted for immediately so that only a limited number of houses are affected by the error or lack of foresight. No retrofit program implementing partner wants to go back and re-retrofit houses which were not done right the first time, but it is better to fix one than one hundred. Without making a commitment to internal evaluation, feedback, and flexibility, the technical partner will become overwhelmed when errors emerge because of the large number of houses already affected, rather than having the capacity to use errors as opportunities to learn and improve the program quickly.

CONCLUSION

Seismic retrofit of existing structures post-disaster is a viable means of beginning both humanitarian assistance and permanent reconstruction quickly. A retrofit program can achieve multiple benefits in the short term and the longer term:

- Standing buildings that are unsafe and possibly occupied can be made safe and returned to the supply of viable housing stock quickly.
- The cost per square meter under safe roof can be less than half the cost of either T-Shelter or new construction.
- The program entails an early and ongoing investment in local capacity building of engineers, builders, and government officials, who will then have the skills required for later stages of reconstruction.
- The program uses local building materials and labor, stimulating the local economy.
- The design solutions respect cultural norms, homeowner preferences, and local building practices, making the completed housing more appealing and the gains in construction quality more sustainable.
- The program sets a good example of design and construction practice, modeling code-based design and construction procedures.
- The retrofit approach is scalable and applicable worldwide. Design solutions can be tailored or created for different building materials, systems, and environments.
- Retrofitted housing is earthquake-resistant to a code-prescribed life safety level, ensuring that the loss of life in the next disaster in the project location will be lessened by one family for each house retrofitted as part of the program.
- Retrofitting, combined with community outreach, focuses on the specific weak points in the local building practice, making it likely that this knowledge will spread beyond the houses involved specifically in the program.

A successful retrofit program depends upon several key factors: careful program design, informed choice or creation of the retrofit methodology, extensive training and mentoring of local staff, a qualified expat engineering supervisory staff, and the creation of evaluation feedback mechanisms to ensure that the program works well and continues to improve. With these components in place, retrofitting can begin early to relieve suffering and at the same time pave the way for later, more complex stages of the permanent reconstruction process.

APPENDICES

For all of the following Appendices to this Primer and additional resources, please visit www.buildchange.org/USAIDPrimers.html.

APPENDIX 1: CASE STUDY: HAITI

APPENDIX 2: SAMPLE RETROFIT BILL OF QUANTITIES (HAITI)

APPENDIX 3: SAMPLE RETROFIT CONSTRUCTION QC CHECKLISTS (HAITI)

APPENDIX 4: CASE STUDIES: NEPAL AND PERU

APPENDIX 5: SAMPLE INFORMATION OUTREACH CAMPAIGN MATERIALS (HAITI)

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