

10 HOUSING DESIGN AND CONSTRUCTION TECHNOLOGY

Guiding Principles for Housing Design and Construction Technology

- The housing designs and construction technologies (HDCTs) used in reconstruction (there may be several) should be selected by taking into consideration local building practices, desired standards, culture, and economic and climatic conditions.
- The HDCTs used in reconstruction may affect prices and supply in the building materials market; interventions may be needed.
- Local expertise is invaluable in selecting HDCTs, but if changes are needed to improve resilience, builders should be supported by training, and their expertise augmented by global knowledge and best practices.
- A structure's entire life span, from construction through maintenance to eventual demolition or reuse, should be considered in evaluating the suitability of technology options.
- Repairing and retrofitting partially damaged houses are legitimate alternatives to full reconstruction but deserve similar attention and assistance to improve their resilience.

This Chapter Is Especially Useful For:

- Lead disaster agency
- Local officials
- Agencies involved in reconstruction
- Project architects, engineers, and chartered surveyors
- Project managers
- Affected communities

Introduction

When a disaster affects housing, there are important choices to be made in the rebuilding effort related to the design and construction technology to be employed and whether to repair or retrofit housing as opposed to demolishing it. These choices must take into account environmental, economic, social, institutional, and technical factors. The size and scale of the project as well as the geographic concentration of the affected area also play a significant role in the decision-making process. Ignoring these factors or making the wrong decisions about them can significantly affect whether or not stakeholders are satisfied with the reconstruction and whether or not the resulting housing solution is sustainable.

This chapter is particularly relevant for stakeholders responsible for the design, construction, and retrofitting of houses. It covers the three principal subjects related to efforts to rebuild housing after a disaster: design, construction technology, and the decision whether to repair or retrofit versus demolish. The chapter provides guidance to help practitioners make decisions that result in the most appropriate solutions. All considerations and recommendations developed here are relevant for both urban and rural contexts, but they need to be adapted to the context to ensure the appropriateness of a given building technology in the urban or rural environment.

Key Decisions

1. The **lead disaster agency** should select and engage a multidisciplinary team of experts, which may include experts from outside the country, to analyze the disaster impact on common HDCTs and help select the HDCTs to be used in reconstruction.
2. The **lead disaster agency**, having decided on HDCTs for reconstruction, must ensure that they are fully integrated into the reconstruction policy, including the housing financial assistance scheme, and must determine how to ensure that the norms and standards are uniform across the disaster area.
3. The **lead disaster agency** must decide the conditions under which repairing or retrofitting will be promoted as an alternative to full reconstruction.
4. The **lead disaster agency** should decide on and implement a range of mechanisms to fully involve **local governments, local communities, and the building industry** in decision making regarding HDCTs and in implementation of reconstruction.
5. **Agencies involved in reconstruction** should decide how to conform to the HDCT standards set by the **lead disaster agency**, including those for repairing and retrofitting of partially damaged houses, if it is agreed that they are appropriate approaches.

6. **Agencies involved in reconstruction** should decide jointly how the choice of HDCTs affects the need for training and should cooperate to ensure that quality training is available.
7. **Agencies involved in reconstruction** should decide, while planning their programs, how to lower the environmental impact of reconstruction.
8. **Agencies involved in reconstruction** should decide how to manage the impact of design and technology on building materials market, if necessary.

Public Policies related to Housing Design and Construction Technology

Building codes, if they exist, are the principal public policy instrument that governs choices regarding HDCTs. Countries that have recently updated building codes may have incorporated into them emerging policy objectives, such as energy efficiency, reduction of the environmental impact of building materials and construction technologies, or use of universal design that makes buildings accessible to those with differential abilities (see box). Where building codes do not exist, or are not adequate, they can potentially be updated for purposes of carrying out reconstruction, although the time required for designing, consulting with the public on, approving, and developing regulations for implementation of building codes can easily hold up reconstruction schedules.

A more practical approach may be to establish standards and guidelines for safety, comfort, and environmental impact for use during the reconstruction and repair program, to adjust them as reconstruction and repair work proceeds, and to use them as the basis for establishing or updating the building codes once the reconstruction program is completed. Whether the decision is to update building codes or to develop standards and guidelines, it is critical to involve building industry professionals, such as architects, engineers, builders, and chartered surveyors when developing specifications and codes.¹

Universal Design

Universal design entails the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. The intent of universal design is to simplify life for everyone by making products, communications, and the built environment more usable by as many people as possible at little or no extra cost. Universal design benefits people of all ages and abilities.

Principle One: Equitable Use. The design is useful and marketable to people with diverse abilities.

Principle Two: Flexibility in Use. The design accommodates a wide range of individual preferences and abilities.

Principle Three: Simple and Intuitive Use. Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

Principle Four: Perceptible Information. The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

Principle Five: Tolerance for Error. The design minimizes hazards and the adverse consequences of accidental or unintended actions.

Principle Six: Low Physical Effort. The design can be used efficiently and comfortably and with a minimum of fatigue.

Principle Seven: Size and Space for Approach and Use. Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

Source: The Center for Universal Design, 1997, *The Principles of Universal Design*, Version 2.0. Raleigh, NC: North Carolina State University. Copyright © 1997 NC State University, The Center for Universal Design.

Technical Issues and Recommendations: Housing Design

Housing design involves the form, dimensions, orientation, natural lighting, ventilation, and spatial organization of dwellings. There is no "ready-made" solution for housing design in reconstruction. Careful and contextualized integration of many issues determine whether or not a rebuilt house's stakeholders, most importantly, its inhabitants, are satisfied. The table below contains several of the issues involved in housing design, how the issue is relevant, and recommendations for designing the most suitable option.

1. See Royal Institution of Chartered Surveyors (RICS), 2009, *The Built Environment Professions in Disaster Risk Reduction and Response Guide* (London: University of Winchester), http://www.rics.org/site/scripts/download_info.aspx?downloadID=829&fileID=991.
2. Gujarat State Disaster Management Authority (GSDMA), 2003, *Guidelines for Construction of Compressed Stabilized Earthen Wall Buildings* (Gujarat: GSDMA), <http://www.gsdma.org>.
3. See International Code Council, "Codes and Standards," <http://www.iccsafe.org/cs/>.
4. Paul Gut and Dieter Ackerknecht, 1993, *Climate Responsive Buildings, Appropriate Building Construction in Tropical and Subtropical Regions* (St. Gallen: SKAT), <http://www.nzdl.org/fast-cgi-bin/library?e=d-00000-00---off-0envl-00-0---0-10-0--0---0direct-10---4-----stt-0-11-11-en-50---20-about-climate+responsive+building--00-0-1-00-0-0-11-1-0utfZz-8-10&cl=search&d=HASH7fb3fd71d302d3efdf64e&gc=1>.
5. Roland Stulz and Kiran Mukerji, 1993, *Appropriate Building Materials, A Catalogue of Potential Solutions (Revised)* (St. Gallen: SKAT), <http://nzdl.sadl.uleth.ca/cgi-bin/library?e=d-00000-00---off-0cdl-00-0---0-10-0--0---0direct-10---4-----0-11-11-en-50---20-about--00-0-1-00-0-0-11-1-0utfZz-8-00&cl=CL2.1&d=HASH51495f314e8d35f51533d4.2&gc=1>.



Issue	Relevance	Recommendations
Town, settlement, territory, land, planning	Planning criteria determine position, size, function, form, and materials of the house and the relation between buildings and infrastructure.	Modify, improve, or obtain an exemption for elements of the proposed plan that hinder implementation of sustainable housing solutions.
Policies, guidelines, building codes, standards, strategies	Existing documentation may not provide appropriate instructions.	Identify and suggest possible improvements (hazards, environmental impact, socio-cultural aspects, flexibility, etc.). Propose guidelines and standards for new alternative technologies that provide more appropriate solutions, ² not only for use in the reconstruction period, but covering the needs of further long-term housing development. ³
Infrastructure and community services	Water supply, drainage, treatment, sanitation, access roads, energy supply, communication systems, and community services directly influence housing design.	Ensure housing design is consistent with infrastructure plan so that all necessary services are provided (either in the community or in the individual house) and are not redundant. Examples: sanitation systems provide for local and/or community treatment of sewage; kitchen design accommodates available energy source for cooking.
Beneficiaries' needs, social structure, culture, livelihoods, aspirations	Social structure determines spatial organization and size; culture affects forms, function, and aesthetics; livelihoods dictate spatial organization, morphology, size, land use; community's aspirations determine the "housing standard."	Ensure intense community participation in the design and decision-making process (house size, morphology, spatial organization, functions, form, position on the plot). Example: houses without verandas or shading areas in hot climates affect the social structure by not providing gathering places for social interaction.
Climatic conditions	Indoor conditions must be within the human comfort zone, which varies according to population's culture, apparel, and activities. The main function of a house with respect to climate is to protect against and take advantage of the climatic conditions.	Design the house and landscape to take advantage of the climate and reduce the demand for operating energy: sun/shadow exposure, solar shading, thermal insulation, passive solar energy, solar hot water, photovoltaic electricity, rain water collection, wind ventilation system, etc. Consider biodiversity enhancement as a tool for improving the local climatic conditions. Example: trees are essential for improving indoor and outdoor conditions in hot climates and can help reduce the impact of wind, soil erosion, and solar radiation. ⁴
Need for flexibility, modular design, expandability, incremental housing	As a family grows, the needs of space and functions change; a house needs to adapt to these changes. Housing and public buildings should be accessible to all (see box, above, on universal design).	Incorporating flexibility, modular design, and expandability in the housing design and concept will make those operations easier and cheaper to carry out when necessary. Incremental housing provides a basic house structure, allowing the users to complete it according to their will and means. Universal design principles reduce the barriers to use and movement by the handicapped and elderly.
Environmental impact	Worldwide, the housing sector has a huge environmental impact, contributing substantially to the deterioration of the local environment and natural resources. See  Chapter 9, Environmental Planning, for a detailed discussion of environmental issues in reconstruction.	Study vernacular architecture and tradition; they are the best reference for developing new designs that lessen environmental impact. Assess environmental impact over the entire life span of a house. Employ basic rules for low environmental impact design: land use that respects and safeguards the soil and biodiversity; simple and reasonable design and size limits that minimize the quantity of building materials and the house's energy requirements; and use of building materials with low environmental impact. ⁵ In regions under water stress, incorporate rainwater-harvesting systems.
Cost	The entire life span of the house, not just the construction phase, determines the true cost of a design option; higher initial construction cost may lower the life span cost.	Consider the cost of upkeep as well as initial investment. Include materials transport cost. Use an appropriate factor to discount future costs. Design a house that facilitates future expansion (or reduction); it will reduce modification costs. Limit the needs of operating energy through the design; heating and cooling costs may force inhabitants to forego comfort.

Issue	Relevance	Recommendations
Exposure to risks and hazards	Improving a house's physical resistance to hazards is an essential element of risk reduction and disaster preparedness.	Limit a house's vulnerability to hazards through its design elements, especially form, dimension, morphology, and detailing. ⁶ Identification and analysis of a house's vulnerability should be observed so that improved structures can be designed. Consider not only the risk of the particular disaster, but the risks from other possible hazards.
Available construction technologies and building materials	Housing design may be influenced by the construction technology and materials and vice versa. The 🏠 case study on the 2003 Bam earthquake reconstruction, below, explains how demonstration buildings were used at an exhibition site to show locally appropriate construction technologies and materials.	When possible and appropriate, use traditional technologies. They often provide the most appropriate solutions by integrating costs, climate, culture, and technical capacity. When possible and appropriate, adapt traditional solutions by integrating modern technologies. Assess and factor into the design the availability of local material and manpower, especially after a large-scale disaster. In many cases, reuse and recycling of debris can be an alternative material source; however, measures may be needed to store, sort, and reprocess rubble.
Relation with the built heritage	A house's form, size, and construction material has a visual impact on the environment, and its relation with nearby historical and vernacular elements affects an area's overall architectural quality.	Observe and carefully consider the existing built environment in designing new dwellings; incorporate its context into the design.

Technical Issues and Recommendations: Construction Technology

Construction technology involves the choice of building materials and the technique and means used to erect a house. As with the housing design process, cautious consideration of contextual conditions is crucial to developing appropriate construction technologies. In addition, any selected technology must be constantly reviewed and, if necessary, upgraded during the construction process. The following criteria can be used to compare various construction technologies and identify the most suitable technology options.

6. Andrew Chaleson, 2008, *Seismic Design for Architects* (Oxford: Architectural Press), http://www.elsevier.com/wps/find/bookdescription.cws_home/716362/description#description.

Issue	Relevance	Recommendations
Policies, guidelines, building codes, standards, strategies	Existing documentation may not provide appropriate instructions. The 🏠 case study from Kenya on building code reform, below, describes how the building code was updated to reflect popular housing construction practices and designs.	Identify and suggest possible improvements (hazards, environmental impact, socio-cultural aspects, flexibility, etc.). Propose guidelines, standards, and building codes for new alternative technologies that provide more appropriate solutions. ⁷ Once the guidelines to be followed have been agreed on, use them as a tool to unequivocally determine which technical solutions can be applied and which cannot. Carefully and systematically monitor compliance with guidelines and standards.
Housing design	Housing design influences the choice of construction technology and materials.	Ensure that the physical characteristics and limits of a particular technology are coherent with the design. Example: the size of a room can determine the choice of the roofing technology; a big room may not allow for the use of locally available wood for the roof.
Availability of construction materials	Indigenous materials—unlike those imported from outside—support the local economy and livelihoods.	To the greatest extent possible, use indigenous materials, unless the scale of the disaster, the origin of the materials, and/or the available transportation hinder access to local materials. Use the materials from demolished houses as much as possible. ⁸
Costs: materials technology	Local and abundant construction materials reduces transportation costs and limits price inflation of alien materials. Technology easily adopted by local builders limits the expensive involvement of external skilled manpower or contractors. Local technologies and materials that are durable and inexpensive to maintain reduce long-term maintenance costs.	Reduce both immediate and long-term costs by using local materials and technologies that are abundant, easily adopted, affordable, durable, and easily maintained). Save costs by using materials and technologies that can be easily dismantled, demolished, and recycled. ⁹ Establish the cost/benefit and comparative analysis of building materials considering the quantitative needs and availability, with consideration of possible inflation risks.



Issue	Relevance	Recommendations
Exposure to risks/hazards	Engineers and architects are not always trained in the use of recent developments in the engineering of hazard-resistant structures. Contextual conditions guide the choice of appropriate solutions.	Mitigate risks by merging modern technology components with traditional construction practices and improving existing traditional practices. Carefully adapt unfamiliar solutions to the contextual conditions of every situation. ¹⁰
Construction speed	Shortages of materials and manpower can drastically slow reconstruction.	Provide training to increase the number of skilled builders. Use a large number of people to construct houses rather than a few specialists, because more can be built concurrently. An owner-driven reconstruction approach, combined with the promotion of upgraded indigenous technology, generally allows for faster reconstruction. See  Chapter 6, Reconstruction Approaches, for more information.
Climatic conditions, indoor comfort, operating energy needs	Thermal transmission, thermal storage, and vapor diffusion of materials play a large role in determining a house's thermal comfort and its energy consumption.	Select building materials by considering their impact on indoor comfort to ensure an appropriate climate-responsive house.
Socio-cultural appropriateness, acceptance	Technology and building materials influence a community's way of life. People may want modern imported technologies because of the social status they confer rather than improved traditional solutions that are more appropriate and far cheaper to maintain.	Help communities make appropriate decisions by demonstrating how to analyze advantages and disadvantages of materials and technologies and their relevance to the social and cultural context. Combinations of materials could be a good option to enhance the acceptance of alternative technologies (e.g., one room [core house] made of brick and concrete and the rest made of bamboo, as experimented with in Bihar).
Environmental impact (including transportation, maintenance, and demolition and recycling possibilities)	Certain technologies and materials can substantially contribute to the deterioration of both the local and the global environment and natural resources. See  Chapter 9, Environmental Planning, for a detailed discussion of environmental issues in reconstruction.	Whenever possible, use: <ul style="list-style-type: none"> ■ locally available, low-energy-consumption building materials, especially those produced with renewable energy sources; ■ materials from sustainable production chains (e.g., avoid use of timber from savage deforestation); ■ non-toxic materials; ■ materials easily dismantled (and recyclable as building materials or energy sources); and ■ in regions under water stress, materials that require minimum amounts of water (including the curing, drying, and maintenance processes).¹¹
Availability and capacity of local skills	The quality of construction depends on manpower skills. Skilled manpower from other regions is likely to migrate to the disaster area.	Address a skilled manpower shortage with proper training, management, and monitoring. Technical instruction should be provided to builders at all skill levels. Construction quality must be monitored and documented through systematic quality control procedures. See  Chapter 16, Training Requirements in Reconstruction.
Opportunities for participation and livelihoods	Traditional methods and materials are generally easier for local people to implement and replicate. The feasibility of community participation in the reconstruction phase is largely determined by the technology being applied. When local artisans understand what the problem is, they can often devise appropriate solutions.	Train and monitor local laborers regarding new components, such as earthquake-resistance features and imported technologies. Use model houses to teach improved technologies. Devise simple measures to test resistance in the field. Assimilate new technologies in a community with long-range measures that ensure their replicability beyond the reconstruction period.

7. GSDMA, 2003, *Guidelines for Construction of Compressed Stabilized Earthen Wall Buildings* (Gujarat: GSDMA), <http://www.gsdma.org>; and National Information Centre of Earthquake Engineering, "IITK-GSDMA Project on Review of Seismic Codes & Preparation of Commentary and Handbooks," http://www.nicee.org/IITK-GSDMA_Codes.php.

8. See  Chapter 9, Environmental Planning.

9. Roland Stulz and Kiran Mukerji, 1993, *Appropriate Building Materials, A Catalogue of Potential Solutions (Revised)* (St. Gallen: SKAT), <http://nzdl.sadl.uleth.ca/cgi-bin/library?e=d-00000-00---off-0cdl--00-0----0-10-0--0--0direct-10---4-----0-11--11-en-50---20-about---00-0-1-00-0-0-11-1-0utfZz-8-00&cl=CL2.1&d=HASH51495f314e8d35f51533d4.2&gc=1>.

10. Rajendra Desai, 2008, "Case Studies of Seismic Retrofitting - Latur to Kashmir and Lessons Learnt," National Centre for Peoples' Action in Disaster Preparedness (NCPDP), <http://www.ncpdindia.org/Retrofitting%20Case%20Studies.htm>; <http://www.ncpdindia.org/images/03%20RETROFITTING%20LESSONS%20LEARNT%20LATUR%20TO%20KASHMIR.pdf>; and other sources listed in Resources section.

11. R Roland Stulz and Kiran Mukerji, 1993, *Appropriate Building Materials, A Catalogue of Potential Solutions (Revised)* (St. Gallen: SKAT), <http://nzdl.sadl.uleth.ca/cgi-bin/library?e=d-00000-00---off-0cdl--00-0----0-10-0--0--0direct-10---4-----0-11--11-en-50---20-about---00-0-1-00-0-0-11-1-0utfZz-8-00&cl=CL2.1&d=HASH51495f314e8d35f51533d4.2&gc=1>.



Lesson Learned related to Construction Technology

Availability of skills. Following the 2001 earthquake in Gujarat, India, there were initially insufficient local mason skills to properly use hollow interlocking compressed stabilized earth blocks, which resulted in slow construction. But news of employment opportunities spread fast, and trained artisans from other parts of the country came to Gujarat to provide their services. The same happened following the 1999 earthquake in Uttarakhand, India: bricks from the plains soon arrived, as did masons from Bihar state. Likewise, following the 2005 earthquake in Kashmir, masons and laborers from Bihar played a pivotal role in speedy reconstruction.¹²

Participation and livelihoods. After the 2005 earthquake in Kashmir, as part of the National Centre for People's Action in Disaster Preparedness (NCPDP) project, sponsored by the Aga Khan Development Network, local building systems, architecture, lifestyle, and preferences formed the basis of the reconstruction design. Local artisans played a large role in the development of the reconstruction technology. Feedback from local women and from local master artisans was incorporated, and technical guidelines from government were translated into practical guidance and gradually improved to ensure replicability and affordability.

Properly designed and monitored projects for repairing and retrofitting houses can drastically improve the reconstruction process in terms of cost, environmental impact, speed, supply of resources, community participation and satisfaction, recovery of psychological well-being, and heritage conservation.

The Importance of Technical Guidelines. Technical guidelines on HDCTs are essential references in the process of housing reconstruction and retrofitting. They should provide guidance on standards and codes to be respected; damage assessment; structural safety related to various risks; construction techniques, means, and procedures; building materials and quality; and professional skills needed for successful implementation to take place. To be effective, it is crucial that technical guidelines are appropriate to the given context. If unavailable, they must be developed. If available but not suitable to the current post-disaster situation, they must be modified. Guidelines must be incorporated as an integral part of the training curricula for builders and used as a working tool throughout the reconstruction phase, including during inspection and monitoring.

The Debate Concerning the Promotion of Vernacular Technologies

Vernacular technologies are often appropriate solutions in terms of cost, environmental impact, climate, and cultural and architectural suitability, and should generally be given priority. However, these technologies are not always optimal due to such concerns as their vulnerability to hazards and durability, and often need to be improved through the introduction of modern technology or components. There is considerable debate in the development community concerning the promotion of vernacular technologies in reconstruction. Agencies should ensure that a reputable organization has tested the hazard resilience of a particular technology, and that any recommended improvements or retrofitting approaches are incorporated in housing designs, before financing a large-scale program to repair vernacular buildings. (For some of the resources available from organizations working to merge modern and vernacular technologies to produce more appropriate solutions, see the annex to this chapter.) Vernacular building technologies were approved for use by the Earthquake Reconstruction and Rehabilitation Authority (ERRA) following the 2005 North Pakistan earthquake, as discussed in the  case study, below.

Technical Issues and Recommendations: Repair/Retrofit versus Demolition

In reconstruction efforts, repairing and retrofitting a house may make more sense than demolishing and rebuilding it. Many practitioners and policy makers think that programs designed to repair and/or retrofit housing are difficult to design and implement. However, such programs can save many partially damaged houses, often with excellent results. Properly designed and monitored projects for repairing and retrofitting houses can drastically improve the reconstruction process in terms of cost, environmental impact, speed, supply of resources, community participation and satisfaction, recovery of psychological well-being, and heritage conservation. In addition, structures that are vulnerable but not damaged by the disaster can have their vulnerabilities addressed as part of the program. Comprehensive reconstruction programs should have a component for repair and retrofit that addresses similar technical issues as those considered for reconstruction, including layout, infrastructure, and building technology and materials. Detailed guidelines and training should be made available for ensuring efficient and safe retrofitting; if guidelines do not exist, they may have to be developed for a particular context. Listed below are some of the issues that should be addressed in a repair/retrofit program.

12. Rajendra Desai, 2009, personal communication.

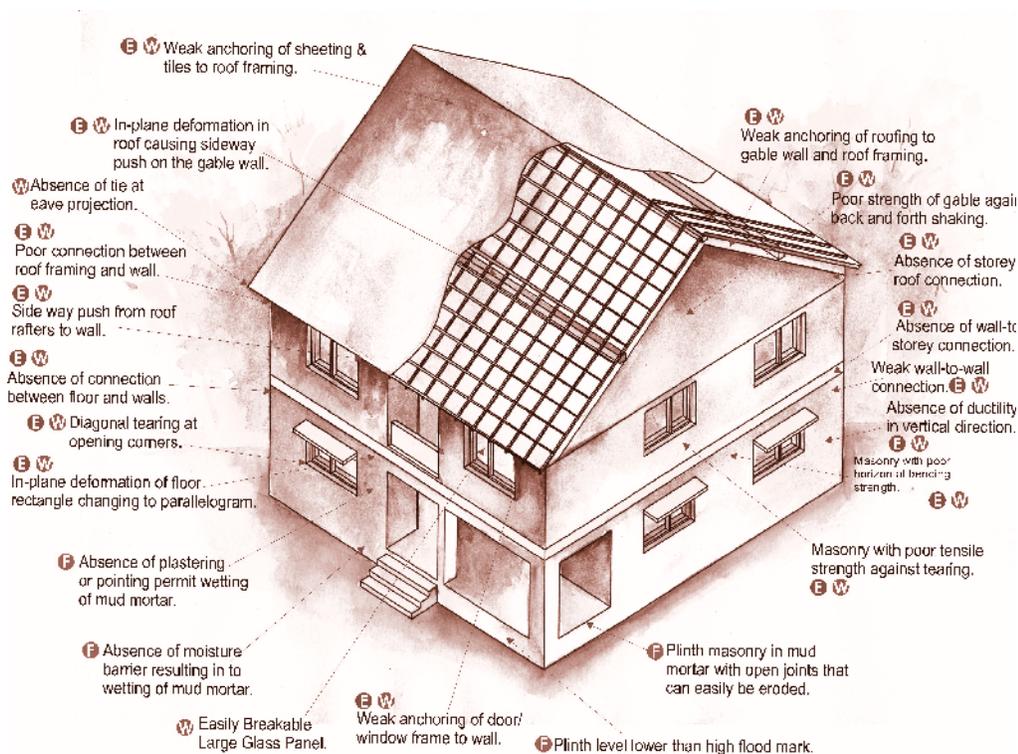


Issue	Relevance
Relocation	The repair or retrofit option is moot if a house must be relocated.
Damage level	Before a decision can be made about whether the repair/retrofit option is appropriate, the level of damage to the house, to the neighborhood, and to the infrastructure, as well as the related risks to residents, must be considered.
Cost of the repair or retrofit option versus reconstruction	To be justifiable, the total cost of the repair or retrofit option should generally be lower than that of demolition and reconstruction.
Willingness and capacity of people to repair or retrofit their houses	It is essential that the local population participate in the discussion about repairing and retrofitting. People do not always perceive repairing or retrofitting as viable or desirable options. Without local support, a project to repair or retrofit may even encounter passionate objections. Communications, public outreach, and training are all crucial elements of a successful repair and retrofit program, as they are for reconstruction.
Architectural, historical, cultural, and socioeconomic value of damaged houses	If a particular house has a high architectural, historical, cultural, or socioeconomic value, substantial efforts to overcome any cost or technical difficulties and prevent it from being demolished may be justified. The owner may be offered extra financial or technical assistance if the house is considered part of community heritage, in order to encourage preservation of the property.

The Vulnerabilities of Houses and How to Reduce Them

Disasters affect house structure in a variety of ways. Consequently, the technical solutions for constructing and repairing affected buildings have to respond to the type of disaster and have to take into consideration the building technology and materials being used. This principle applies to risk reduction in both new and retrofitted houses. A variety of technical materials on this topic are listed below in the Resources section. See Chapter 16, Training Requirements in Reconstruction, for instructions on designing a training program for builders. For a list of organizations working to improve the risk of vernacular buildings, see the annex to this chapter. The figure above depicts the range of vulnerabilities associated with housing, taken from the *Manual on Hazard-Resistant Construction in India*. The example shown here is applicable to both engineered and non-engineered building types. Training builders and supervisors to understand these vulnerabilities is crucial.

Vulnerability of Non-Engineered Buildings against Earthquake, Cyclone, and Flood Hazards



Key
 (E) Earthquake
 (W) Wind/Cyclone
 (F) Flood/Rain

Source: United Nations Development Programme (UNDP) India and NCPDP, 2008, *Manual on Hazard-Resistant Construction in India: For Reducing Vulnerability in Buildings Built without Engineers* (Gujarat: UNDP India and NCPDP), http://www.ncpdindia.org/Manual_on_Hazard_Resistant_Construction_in_India.htm.

Risks and Challenges

- The lack of local knowledge about appropriate housing design and current construction practices.
- Specialized expertise to inform the choice of building technology is not available.
- Building materials and skilled labor are in short supply, leading to inflated prices.
- Poor construction quality results in structures that are vulnerable, fragile, and expensive to maintain.
- Imported building technologies and materials require more energy to produce comfortable indoor conditions, leading to increased costs and negative environmental impact.
- Building technologies are poorly adapted to risks in the environment in which they are located, or adapted to only one of numerous risks (e.g., they provide wind protection, but are vulnerable to earthquakes).
- New housing designs or building technologies are incompatible with local traditions or with the local population's willingness to change.
- Design and construction contribute to local and global environmental damage.
- Demolition of repairable houses results in loss of cultural identity and heritage, slower psychosocial recovery, adverse environmental impacts, and extended time for reconstruction.
- Improperly designed or implemented repair and retrofitting projects damage the architectural integrity and quality of a house.
- Donors are not willing to finance non-standard reconstruction approaches, such as repair and retrofitting.¹³
- Building codes and regulation prohibit the use of local building technologies or do not adequately incorporate the use of local materials and practices.

Case Studies

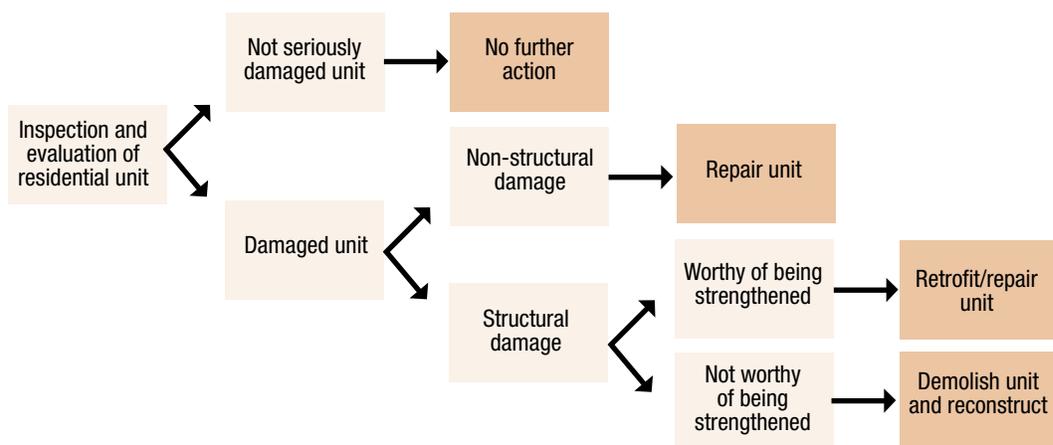
2003 Bam Earthquake, Iran

System for Classification of Housing Damage Level

After the 2003 earthquake in Bam, Iran, reconstruction planning was based on a rating of housing damage that had two components: "damage to residential area" and "damage to residential unit."

Damage to residential area. This rating took into consideration issues related to geology, such as soil stability, land condition, and the percentage of the village that was damaged (ratio of damaged housing units to total housing units).

Damage to residential unit. This rating took into account the condition of the damaged units, the type of damage, and the type of technical expertise that might be needed to develop the reconstruction plan. The following diagram demonstrates the rating procedure.



Source: Housing Foundation of the Islamic Revolution, 2009, written communication.

13. NCPDP, "Good Practices Review: Latur, Kashmir, Kutch, Uttrakhand," <http://www.ncdpindia.org>.



2003 Bam Earthquake, Iran

Using Demonstration Buildings and Local Professionals to Improve Reconstruction Outcomes

Only few months after the 2003 earthquake in Bam, Iran, the HF established the Engineering and Technical Services Exhibition Site in Bam, where more than 500 housing designs, techniques, and building materials were publicly exhibited, enabling people to choose the housing model they preferred. Also at the site, modular and real-scale model buildings demonstrated environment-friendly, cost-effective, and locally appropriate shelter models. The structure and material of the model buildings were tested and licensed by the Building and Housing Research Center of the Iran Ministry of Housing.



The High Council of Bam Architecture mobilized and trained engineering, architectural, and technical firms to provide professional services to people who selected housing designs and construction techniques for their homes. Under the HF-UNDP joint program, engineers and architects organized a series of consultations to ensure that the views of the program's female-headed households (FHHs) were incorporated into the construction and design of the units (see photo). CRATERre-EAG, a French construction research center, provided training for builders on earthquake-resilient construction. In addition, 20 skilled local masons and other builders were trained on quake-resilient traditional building techniques. In the exhibition site, trainees demonstrated the features of earthquake-resilient construction using small model buildings they built themselves. The trainers were able to transfer their knowledge and skills to masons from Bam and elsewhere in the country. A recovery loan of US\$220 million from the World Bank helped HF procure building materials in large quantities. The success of the UNDP-backed training encouraged government and CRATERre to later replicate these experiences in other earthquake-prone areas of the country.

Quake-proof model buildings built by trained local workers under the UNDP-backed project were cost-effective and consistent with the cultural identity of the ancient city of Bam.

Source: Victoria Kianpour, UNDP Iran, 2009, personal communication, <http://www.undp.org.ir/>.



Design consultations among engineers, architects and planners, and FHHs, 2005.

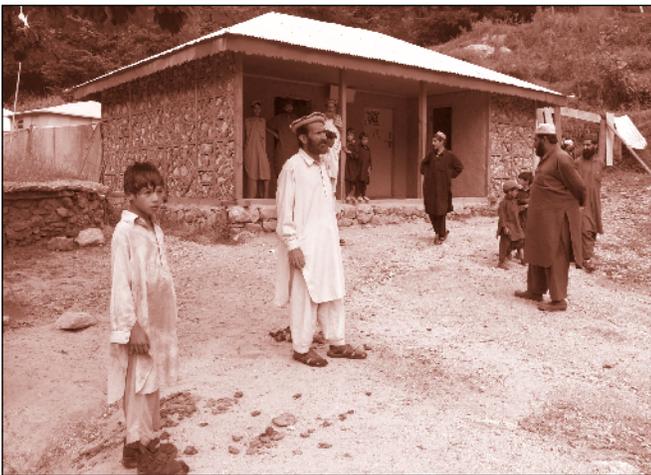
1995 Building Code Revision, Kenya

Stakeholder Participation in Legislative Reform

As a consequence of the significant urban population growth in the last several decades in Kenya, informal housing settlements became ubiquitous. (In fact, more than half of the population of Kenya's capital, Nairobi, currently lives in informal housing.) Kenya's building codes, like those in all countries, were intended to protect people from poor construction and to reduce vulnerability to disasters. However, in the 1980s, many of Kenya's building codes still dated from the colonial era, and progressive building—the most common form of home construction in the country—was not even permitted by the codes. As a result, the minimum acceptable house according to the code was beyond the means of poor and even middle-income families. The effect was to discourage investment in housing and limit the types of construction that lenders could finance.

In 1990, the Intermediate Technology Development Group (ITDG, now Practical Action) initiated a participatory effort to modify the codes to reflect local building practices while still encouraging safe building practices. With the participation of stakeholders from the construction field, "Code 95" was developed and, in 1995, was approved by Parliament. Code 95 is performance-based and permits the use of innovative and popular materials, alternative building technologies, outdoor cooking areas, and pit latrines. A Department for International Development (DFID)-funded pilot project in the city of Nakuru, managed by ITDG, demonstrated that housing construction under the new code reduced costs by at least 30 percent and helped trigger an upsurge in residential construction. Understanding the importance of building codes in the housing supply chain, the business community, housing finance institutions, developers, and materials manufacturers have supported the implementation of Code 95. Although updating the code was a first step toward improving building safety and increasing disaster resilience, other challenges, such as simplifying approval processes and establishing incentives to fully apply the building codes, must still be tackled.

Sources: Saad Yahya et al., 2001, *Double Standards, Single Purpose: Reforming Housing Regulations to Reduce Poverty* (London: ITDG Publishing); Mohini Malhotra, ed., 2002, "The Enabling Environment for Housing Microfinance in Kenya," *Cities Alliance Shelter Finance for the Poor Series*, [http://www.citiesalliance.org/citiesalliancehomepage.nsf/Attachments/kenya/\\$File/kenyafinal.pdf](http://www.citiesalliance.org/citiesalliancehomepage.nsf/Attachments/kenya/$File/kenyafinal.pdf); and Shailesh Kataria and Saad Yahya, Royal Institution of Chartered Surveyors (RICS), 2009, personal communication.



DANIEL PITTET

2005 Northern Pakistan Earthquake, Kashmir

Earthquake-Resistant Dhajji Dewari Technology

During the 2005 earthquake in Kashmir, buildings constructed using several traditional methods held up much better than did many "modern" structures. Two types of construction that did well were those that used the techniques known as *Taq* (timber-laced masonry bearing wall) and *Dhajji Dewari* (complete timber frame with a wythe of masonry forming panels within the frame). Although there were many cracks in the masonry infill, most of these structures did not collapse, thereby preventing the loss of life. During rural owner-driven reconstruction, the use of the *Dhajji Dewari* technology was promoted and facilitated. It was rapidly adopted by local communities and it provided a high level of satisfaction among beneficiaries. Not only do these construction techniques stand up well in earthquakes (when properly constructed), but they also make use of local

materials (wood, stones, mud), have low environmental impact, are economical, and are part of the housing culture and know-how. Other vernacular construction techniques that performed well in the earthquake included wooden log houses; construction that employed the use of well-laid masonry with through-stones and well-designed arches; and buildings with trusses, tongue and groove joinery, and balconies resting on projecting wooden joists. Traditional building technology has been approved by the government of Pakistan's ERRA on the basis of the observation of existing structures.

Sources: Maggie Stephenson, United Nations Centre for Human Settlements (UN-HABITAT), 2009, personal communication; and Rohit Jigyasu, 2009, personal communication.

Resources

- ADPC. 2005. "Handbook on Design and Construction of Housing for Flood-Prone Rural Areas of Bangladesh." Dhaka: ADPC. http://www.adpc.net/AUDMP/library/housinghandbook/handbook_complete-b.pdf. Focuses solutions for various construction technologies exposed to flooding.
- Applied Technology Council (ATC). <http://www.atcouncil.org/>. ATC provides a range of materials on the hazard resistance of building technologies, building retrofitting techniques, and methodologies for post-disaster building inspections.
- Arya, A. S. et al. 2004. *Guidelines for Earthquake Resistant Non-Engineered Construction*. Kanpur: National Information Center of Earthquake Engineering. http://www.nicee.org/IAEE_English.php. Information specifically on earthquake-exposed structures.
- Benson, Charlotte, John Twigg with Tiziana Rossetto. 2007. "Tools for Mainstreaming Disaster Risk Reduction. Guidance Note 12: Construction Design, Building Standards and Site Selection." International Federation of Red Cross and Red Crescent Societies, ProVention Consortium. http://www.proventionconsortium.org/themes/default/pdfs/tools_for_mainstreaming_GN12.pdf.
- Blondet, Marcial, Gladys Villa Garcia M., and Svetlana Brzev. 2003. *Earthquake-Resistant Construction of Adobe Buildings: A Tutorial*. Oakland: Earthquake Engineering Research Institute. <http://www.preventionweb.net/english/professional/trainings-events/edu-materials/v.php?id=7354>.
- CDMP. 2001. "Hazard-Resistant Construction." Caribbean Disaster Mitigation Project. <http://www.oas.org/CDMP/document/papers/parker94.htm>.
- Earthquake Engineering Research Institute (EERI)/International Association of Seismology and Physics of the Earth's Interior (IASPEI). 2006. "International norm for seismic safety programs." Draft paper of the working group of the International Association for Earthquake Engineering (IAEE) and the International Association of Seismology and Physics of the Earth's Interior. http://www.iitk.ac.in/nicee/skj/Norms_for_Seismic_Safety_Programs-2-23-06.pdf.
- Minke, Gernot. 2001. *Construction Manual for Earthquake-Resistant Houses Built of Earth*. Eshborn: Building Advisory Service and Information Network at GTZ GmbH. <http://www.basin.info/publications/books/ManualMinke.pdf>.
- Papanikolaou, Aikaterini and Fabio Taucer. 2004. "Review of Non-Engineered Houses in Latin America with References to Building Practices and Self Construction Projects." European Commission Joint Research Center. http://elsa.jrc.ec.europa.eu/showdoc.php?object_id=26.
- Patel, Dinesh Bhudia, Devraj Bhandari Patel, and Khimji Pindoria. 2001. "Repair and strengthening guide for earthquake-damaged low-rise domestic buildings in Gujarat, India." Gujarat Relief Engineering Advice Team (GREAT). <http://awas.up.nic.in/linkfile/Disaster/Retrofitting%20Low%20rise%20houses.pdf>.
- RICS. 2009. *The Built Environment Professions in Disaster Risk Reduction and Response Guide*. London: University of Westminster. http://www.rics.org/site/scripts/download_info.aspx?downloadID=829&fileID=991.
- Schneider, Claudia et al. 2007. *After the Tsunami: Sustainable Building Guidelines for South East Asia*. Nairobi: United Nations Environment Programme. <http://www.preventionweb.net/english/professional/publications/v.php?id=1594>.
- Szakats, Gregory A. J. 2006. *Improving the Earthquake Resistance of Small Buildings, Houses and Community Infrastructure*. Wellington, NZ: AC Consulting Group Limited. <http://www.preventionweb.net/english/professional/publications/v.php?id=1390>.
- Twigg, John. 2006. "Technology, Post-Disaster Housing Reconstruction and Livelihood Security." <http://www.practicalaction.org>.
- UN-HABITAT. 2003–2005. *Building Materials and Construction Technologies: Annotated UN-HABITAT Bibliography*. Nairobi: UN-HABITAT. <http://www.unhabitat.org/pmss/getPage.asp?page=bookView&book=1087>.
- UNDP India. 2008. "Manual on Hazard-Resistant Construction in India." Gujarat: UNDP India and NCPDP. <http://data.undp.org.in/dmweb/pub/Manual-Hazard-Resistant-Construction-in-India.pdf>. Includes illustrated practical solutions covering earthquake, cyclone, and flood situations for various technologies.

Adapting Vernacular Building Technologies: Some Good Practices

Technology/Project	Country/Region	Organizations/Links	Remarks
"Bunga" houses built with compressed stabilized earth blocks; earthquake-resistant structures derived from traditional houses of cylindrical shape	India, Gujarat State, Kutch District	Hunnarshala Foundation for Building Technology and Innovations, Bhuj, India, http://hunnar.org	Governmental approval through GSDMA, 2003, <i>Guidelines for Construction of Compressed Stabilized Earthen Wall Buildings</i> (Gujarat State Disaster Management Authority)
Manual on hazard-resistant construction in India	India	UNDP India and Government of India, Ahmedabad, India, http://www.ncdpindia.org	For reducing vulnerability in buildings without engineers; focuses on construction and retrofitting of masonry buildings
Manual for restoration and retrofitting of rural structures in Kashmir	Pakistan, Kashmir India, Jammu	UNDP India and NCPDP, Ahmedabad, India, http://www.ncdpindia.org	For reducing vulnerability of existing structures in earthquake-affected areas
Guidelines for earthquake-resistant construction of non-engineered rural and suburban masonry houses in cement sand mortar in earthquake-affected areas	Pakistan	ERRA, Government of Pakistan, http://www.erra.gov.pk	Practical guidance for non-engineered structures, covering site-selection issues, planning, construction, and retrofitting measures of various housing elements
Model bamboo house	Ecuador, Guayaquil	International Network for Bamboo and Rattan, http://www.inbar.int	Demonstration and comparison of 10 different technologies based on the use of bamboo for walling systems that have been developed to improve the quality and reduce the cost
Earth-based building materials and technologies	India	Auroville Earth Institute, Tamil Nadu, India, http://www.earth-auroville.com	Development, training programs, publications, and realization of numerous constructions using earth as building material and integrating modern technology for improving structural safety
<i>Construcción de casas saludables y sismorresistentes de Adobe Reforzado con geomallas</i>	Peru	Pontificia Universidad Católica del Perú, http://www.pucp.edu.pe	Technology based on the use of mud blocks walls reinforced with plastic nets for improving seismic resistance
Mitigation measures for post-hurricane reconstruction	Honduras	Centre des Etudes et Coopération International, http://www.ceci.ca	Technical improvement of dwellings for reducing the vulnerability to hurricane and flood
Collection of information and publications on seismic resistance of various building technologies	Various	World Housing Encyclopedia, an EERI and IAEE initiative, http://www.world-housing.net	