POST-EARTHQUAKE HOME RECONSTRUCTION IN THE SURROUNDING HILLS OF KATHMANDU VALLEY, NEPAL

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Post-Earthquake Home Reconstruction in the Surrounding Hills of Kathmandu Valley, Nepal

Project Directed by

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List of Acronyms

ABT: alternative building technology

CSEB: Compressed Stabilized Earth Brick

EHDC: Earthquake Housing Damage and Characteristics Survey

EHRP: Earthquake Housing Reconstruction Program

GON: Government of Nepal

HRRP: Housing Reconstruction and Recovery Platform

MDTF: Multi-Donor Trust Fund

NGO: nongovernmental organization

NRA: National Reconstruction Authority

NRHRP: Nepal Rural Housing Reconstruction Program

SHIV: Shah Hemp Inno-Ventures

SOP/EHRE: Standard Operating Procedure for Earthquake Housing Reconstruction Enrollment

UN: United Nations

Foreword

The Lyndon B. Johnson School of Public Affairs has established interdisciplinary research on policy problems as the core of its educational program. A major element of this program is the nine-month policy research project, during which one or more faculty members direct the research of ten to twenty graduate students of diverse disciplines and academic backgrounds on a policy issue of concern to a government or nonprofit agency. This “client orientation” brings the students face-to-face with administrators, legislators, and other officials active in the policy process and demonstrates that research in a policy environment demands special knowledge and skill sets. It exposes students to challenges they will face in relating academic research, and complex data, to those responsible for the development and implementation of policy and how to overcome those challenges.

The curriculum of the LBJ School is intended not only to develop effective public servants, but also to produce research that will enlighten and inform those already engaged in the policy process. The project that resulted in this report has helped to accomplish the first task; it is our hope that the report itself will contribute to the second.

This post-earthquake rural home reconstruction project was developed by faculty of Hiroshima University’s Graduate School for International Development and Cooperation and its TAOYAKA Program. Other participating programs included the Lyndon B. Johnson School of Public Affairs at The University of Texas at Austin and the Department of Architecture at Institute of Engineering, Tribhuvan University. During 2017, students and international research staff under faculty guidance investigated challenges and opportunities for reconstruction of homes in rural areas damaged by the 2015 Nepali earthquake in rural areas in and around the hinterland of the Kathmandu Valley. The first chapter describes the Government of Nepal’s response to the 2015 earthquake and its consequences for housing in rural Nepal. The second chapter reports on technologies appropriate for sustainable earthquake-resistant construction of rural homes in Nepal. The third chapter describes the participants’ field investigation of barriers and opportunities for home reconstruction. The final chapter develops suggestions derived from the research that could facilitate rural home reconstruction in Nepal after the 2015 earthquake.

Neither the LBJ School nor The University of Texas at Austin necessarily endorse the views or findings of this report.

Angela Evans
Dean

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There were many scholars and experts who provided information and assistance to the students through lectures and interactions. These persons are listed below.

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Draft materials for this report were prepared by many of the persons listed above as participants. This report manuscript was drafted by Christine Ngan, Leah Havens, and Walter Ellison. David Drew, who was not a participant in Nepal 2017, copyedited a draft of the text and assisted in finding references. The cover was designed by Taisia Kitaysky. Taisia Kitaysky copyedited the text and formatted the final report which was printed at The University of Texas at Austin. Photographs and video materials were collected by many project participants. Levi Methvin and Drake Hernandez shot and edited video documentary footage. Levi Methvin and Nina Martinez edited the documentary. Nina Martinez formatted and edited the final video documentary, which was produced by David Eaton. Hina Acharya translated text related to the report and video documentary commentary from Nepali into English.

Research staff included Internet hyperlink references active during 2017 when this report was prepared. No author or editor can assure that hyperlinks remain active. As a result, the authors and editors cannot assure that persons who read this report will be able to use the cited hyperlinks to locate specific source material referenced in the report. This report refers to two currencies, Nepali rupees and US dollars, where relative values depend on exchange rates that change continuously. This report assumes an estimate that 100 Nepali rupees are approximately worth one US dollar. Any table or figure that includes values expressed or estimated solely in dollars or Nepali rupees remains in dollars or Nepali rupees, respectively.

As indicated above, many persons contributed to this report and video. Any errors or omissions are those of the coeditors, David Eaton, PhD, and Niraj Prakash Joshi, PhD.

Executive Summary

In April of 2015, a 7.6 magnitude earthquake struck the Kathmandu Valley at the center of Nepal. Within the following year, Kathmandu was struck by a 7.3 magnitude earthquake and multiple aftershocks. The initial earthquake caused the deaths of 8,856 people, injured 22,309, and affected eight million more. Many agencies around the world came together to fund reconstruction efforts as part of a Nepal and a Multi-Donor Trust Fund (MDTF). The MDTF conducted an Earthquake Housing Damage and Characteristics Survey (EHDC) which led to the creation of Nepal Rural Housing Reconstruction Program (NRHRP), which sought to reconstruct earthquake-resistant homes. The NRHRP developed a homeowner-driven grant process and established the National Reconstruction Authority (NRA) to distribute housing reconstruction grants to families. Those grants were to be paid out via three tranches, each after the completion of a specific construction phase.

During 2017, an international collaborative effort began among four parties: Hiroshima University (HU); Tribhuvan University (TU); Nepal's Alternative Energy Promotion Center (AEPC); and the Lyndon B. Johnson School of Public Affairs (LBJ) of the University of Texas at Austin (UT). The team investigated the challenges and opportunities for reconstruction of homes in rural areas damaged by the 2015 earthquake in and around the hinterland of Kathmandu Valley, Nepal. Within the context of a university course, students began by studying alternative building technologies (ABTs) being implemented in Nepal by local nongovernmental organizations (NGOs). When project members visited Nepal in March 2017, they interviewed rural residents to identify barriers to home reconstruction. During a field study, the students also met with local governmental officials and NGO representatives.

This report describes students' field investigation in Nepal, background research on alternative building technologies (ABTs) for home reconstruction, and recommendations developed from consultation with stakeholders and technical advisors. The first chapter starts with the earthquake and its associated damage and describes the response of the Government of Nepal (GON) and the international community in forming the MDTF, the NRHRP, and the NRA. The second chapter discusses different alternative building technologies (ABTs) considered by the GON, including bamboo, hempcrete, rammed earth, Compressed Stabilized Earth Brick (CSEB), earthbags, and modified conventional housing. Each section describes the type of building style, its construction, materials and labor required, estimates of construction time (if available), costs, and a brief section on comparative advantages and disadvantages.

The third chapter describes the 2017 field study in Nepal, included the locations of the field study and interviews and discussions with local NGOs, the governmental agencies, and local residents. The research group sought to learn whether a lack of affordable and appropriate building methods could explain why many villagers still live in temporary shelters. Village residents discussed barriers to housing reconstruction unrelated to the type of home being built. The final chapter presents conclusions from 2017 field study observations of the three villages. Researchers found four common barriers to reconstruction: the cost of transportation and materials; insufficient reconstruction incentives; grant processes with many procedural

barriers to funding; and the need for consistent interaction of the community with governmental agencies. One suggestion is to evaluate the home reconstruction program to assess its procedures and outcomes. A second suggestion is for Nepal to enhance the number and authority of mobile teams of professionals to assist villagers seeking to reconstruct homes.

Chapter 1: Rebuilding Nepali Rural Homes After the 2015 Earthquake

Nepal is undergoing major changes after the 2015 earthquake which brought setbacks to its national development. Nepal's population is currently between 27 and 28 million; this number is rising at about 1.5 to 1.8 percent per year. Around 25 percent of the population lives below the national poverty line.[1] Most of the population lives in rural areas. Only 5 percent of Nepalis live in Kathmandu, even as the capital grows rapidly. As the country becomes increasingly urban, changes to accommodate denser populations and the seismic risk of the country remains a challenge.

On April 25, 2015, Nepal was hit by a magnitude 7.6 earthquake, which caused 8,856 deaths and 22,309 injuries. Almost one million homes were destroyed.[2] Many families continue to live in houses that were partly destroyed, creating dangerous living situations. According to an Oxfam report, over eight million people across 31 districts were affected by the earthquakes. The housing sector was affected most, with 755,549 houses collapsed or damaged due to earthquakes.[3] Two years after the disaster, 600,000 families still needed shelter and most of them were still living in temporary or unsafe arrangements as of March 2017. To make matters worse, those without a land title are often not eligible for reconstruction aid. At least 40,000 families had no land documentation to begin with.[4]

In the aftermath of the 2015 Nepal earthquake, the Government of Nepal (GON) developed a grant program under its National Reconstruction Authority (NRA) to assist rural residents in rebuilding homes damaged or destroyed by the earthquake. In 2015, the NRA estimated that reconstruction could require 9.4 billion US dollars to complete reconstruction of an estimated 800,000 critically damaged homes, 12,379 destroyed schools, 1,100 health institutions, and 2,000 government buildings.[5] The GON created a Multi-Donor Trust Fund (MDTF) to support reconstruction efforts. Initial donors included the World Bank, the United States Agency for International Development (USAID), the Swiss Agency for Development and Cooperation (SDC), the Government of Canada, and the United Kingdom's Department for International Development (DFID). Together these donors pledged 3.27 billion US dollars for investment into the EHRP, an amount estimated to cover less than half of Nepal's total rural home reconstruction needs.[6,7] As of March 2017, donors and the GON had pledged approximately 4.1 billion US dollars.[8]

Access to quality construction materials is an issue in a nation where most people are poor. Those who rebuild might reuse or rework material from their damaged homes. If another earthquake were to strike or another major disaster came about, weakened infrastructure could cause even greater damage and injury than before.

Project members began this project with a study of alternative earthquake-resistant building technologies, such as: conventional construction using stone and brick; technologies using compressed earth, such as earthbags, earth bricks, and rammed-earth construction; as well as inclusion of bamboo and/or hempcrete in both conventional and nonconventional construction. For three days between March 15 through March 17, 2017, a group of students and researchers from three universities (Hiroshima University, Japan; Tribhuvan University, Nepal; and The University of Texas at Austin, US) worked with Nepali officials and staff of Nepali nongovernmental organizations to investigate post-earthquake conditions in three villages nestled in Kathmandu Valley hillsides. The goal of fieldwork was to observe conditions that remain after the 2015 earthquake; discuss opportunities and barriers that hinder reconstruction with homeowners; and report on activities that could improve the rural home reconstruction program. Project members spoke with homeowners in three affected villages and stayed in one village overnight.

This study sought to identify differences between NRA program intentions and outcomes. The NRA grant policy sought to reconstruct earthquake-destroyed homes based on owner initiative alone. The actual pattern of funding has not yet translated into a large volume of home reconstruction among rural Nepal's most impoverished citizens. Research staff sought to understand both the opportunities and challenges of post-earthquake rural home reconstruction through the GON's Earthquake Housing Reconstruction Program (EHRP).

The GON created a homeowner-driven program requiring applicants to meet performance expectations before funds can be released to participants' bank accounts. One reason that the GON established a homeowner-initiated, post-earthquake rural housing grant program is because prior research on post-earthquake reconstruction programs indicated that homeowner-driven programs can be more successful than government-controlled "top-down" programs, enabling families to rebuild homes sooner.[9] In principle, a family whose home had been damaged or destroyed could control the pace of reconstruction rather than waiting for a government agency to organize construction efforts. The EHRP pays for reconstruction in three phases to provide incentives to rural homeowners (see Table 1.1). To receive any funds, an owner must document how the proposed home design meets national standards for an earthquake-resilient home, as developed by the GON.[10] The EHRP approves payments based on three stages of reconstruction. Each family must notify a Village Development Committee (VDC) when each stage of the reconstruction process is complete. At the end of each stage, a National Reconstruction Authority (NRA) engineer will inspect the home.[11] The maximum EHRP grant was initially 200,000 Nepali rupees per family; that amount increased in 2016 to the present maximum grant amount of 300,000 Nepali rupees per home.[12]

To receive the first payment, a homeowner must be on the list of families deemed eligible for a grant. After the earthquake, a team of NRA engineers traveled to affected districts and inspected homes. Based on the initial survey, engineers compiled a list of families eligible for the grant and published a list of authorized homes in each VDC based on criteria for what would allow a house design to be eligible.[13]

To promote its grant program, the NRA convened meetings to encourage families to enroll in the program. Once an agreement between the NRA and land owner is signed, money can be allocated to a family bank account. If a family does not have a bank account, the NRA can assist in creating an account, which the family can keep even after the program ends. The first funding tranche of 0.5 lakh (1 lakh = 100,000 Nepali rupees) is dispersed after a family signs the agreement to participate in the program and reconstruct the home using an earthquake-resilient design. The 50,000 Nepali rupees represent seed money to assist the family with the demolition and salvage of the earthquake-damaged home and building a foundation of a new home. Once the foundation has been inspected and approved by an NRA engineer, a family is eligible for a second tranche of 1.5 lakh to start building the walls of the home. The final tranche of 1 lakh is allocated when a NRA engineer approves that the walls have been built according to an approved design. The final 1 lakh is intended to pay for the construction of a roof, installation of a toilet, and purchase of an improved cooking stove.[14] To receive second and third program payments, a NRA engineer must approve two supplemental home inspections.

Table 1.1[15]

Phases in the Home Construction Program

Phase	Task	Amount	
		Rupees*	US Dollars
1	Cleanup of debris; building a foundation	50,000	$500
2	Wall construction	150,000	$1,500
3	Roof construction, toilet, and improved stove	100,000	$1,000

*Nepali rupees; the Nepali rupee conversion rate to US dollars is assumed to be approximately 100 Nepali rupees to 1 US dollar.

The GON created a grievance registration system to resolve any process issues. For example, if a family whose home was destroyed in the earthquake was not included in the initial eligibility list, they could file a grievance at the enrollment camp. Cases could be resolved at a meeting with a NRA social mobilizer. If a case cannot be settled at the meeting, a family can file a grievance sent to the VDC. Grievances are listed in an NRA management information system (MIS) and then reviewed by the grievance manager at the VDC. If a family did not file a grievance in the initial enrollment period, its members could file a grievance later with the local VDC. Details of the process for determining eligibility for a GON grant or how to file a grievance are available in the public domain.[16]

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[1] "Multidimensional Poverty Index: Analysis Towards Action," Government of Nepal National Planning Commission and University of Oxford Poverty and Human Development Initiative, published 2018, accessed July 3, 2018, https://www.npc.gov.np/images/category/Nepal_MPI.pdf.

[2] "Nepal Earthquake 2015: 2 Years On," Housing Reconstruction and Recovery Platform, published April 24, 2017, assessed July 3, 2018, http://hrrpnepal.org/download/2Gedhw7ntk9pHxiDQszJ_2017_04_24.pdf/maps_infographics.

[3] Ruth Jackson, Daniel Fitzpatrick, and Prabin Man Singh, "Building Back Right," Oxfam International, published April 21, 2016, accessed March 14, 2017, https://www.oxfam.org/sites/www.oxfam.org/files/file_attachments/bp-building-back-right-nepal-210416-en.pdf.

[4] "Nepal one year on: Millions still displaced or in temporary shelters, most vulnerable people risk exclusion from earthquake recovery," Oxfam International, published April 22, 2016, accessed March 14, 2017, https://www.oxfam.org/en/pressroom/pressreleases/2016-04-22/nepal-one-year-millions-still-displaced-or-temporary-shelters.

[5] Sabin Mishra, "NRA estimates Rs 394.55bn funding gap in reconstruction," The Himalayan Times, published July 19, 2017, accessed March 12, 2018, https://thehimalayantimes.com/business/nepal-reconstruction-authority-estimates-rs-394-55bn-funding-gap-in-reconstruction/.

[6] “Nepal Earthquake Housing Reconstruction Multi-Donor Trust Fund: Annual Report July 1, 2015 – July 31, 2016,” The World Bank Group, published 2016, accessed April 15, 2017, https://www.nepalhousingreconstruction.org/documents/annual-report-nepal-earthquake-housing-reconstruction-mdtf-july-1-2015-july-31-2016.

[7] “Nepal Rural Housing Reconstruction Program: Program Overview and Operations Manual Summary,” Swiss Agency for Development and Cooperation, United States Agency for International Development, and the World Bank, published January 2016, accessed April 2017, http://documents.worldbank.org/curated/en/135481468187745015/Nepal-Rural-housing-reconstruction-program-program-overview-and-operations-manual-summary.

[8] Astha Rai, “Broken Promises,” Nepali Times, published March 31, 2017, accessed March 12, 2018, http://archive.nepalitimes.com/article/nation/broken-promises-reconstruction,3627.

[9] David Todd and Hazel Todd, “Natural Disaster Response: Lessons from Evaluations of the World Bank and Others,” The World Bank: Independent Evaluation Group, published 2011, accessed February 2017, http://documents.worldbank.org/curated/en/621591468350106378/Natural-disaster-response-lessons-from-evaluations-of-the-World-Bank-and-others.

[10] “Design Catalogue for Reconstruction of Earthquake Resistant Houses: Volume II,” Government of Nepal: Ministry of Urban Development and the Department of Urban Development and Building Construction, published March 2017, accessed April 2017, https://www.buildupnepal.com/wp-content/uploads/2017/04/design-catalogue-volume-II-final.pdf.

[11] “Earthquake Housing Reconstruction Programme SOP for Enrollment,” National Reconstruction Authority, published April 2016, accessed April 15, 2017, https://shocksafenepal.files.wordpress.com/2016/05/final-report-ssn3.pdf.

[12] “Nepal Government Distribution of Earthquake Reconstruction Cash Grants for Private Houses,” The Asia Foundation, published 2016, accessed February 2017, https://asiafoundation.org/wp-content/uploads/2016/12/Nepal-Govt-Distribution-of-Earthquake-Reconstruction-Cash-Grants-for-Private-Houses.pdf.

[13] Unpublished materials provided to project members, Ram Prasad Dhital, received March 2017.

[14] “Earthquake Housing Reconstruction Programme SOP for Enrollment,” National Reconstruction Authority, published April 2016, accessed April 15, 2017, https://shocksafenepal.files.wordpress.com/2016/05/final-report-ssn3.pdf.

[15] Unpublished materials provided to project members, Ram Prasad Dhital, received March 2017.

[16] “Earthquake Housing Reconstruction Programme SOP for Enrollment,” National Reconstruction Authority, published April 2016, accessed April 15, 2017, https://shocksafenepal.files.wordpress.com/2016/05/final-report-ssn3.pdf.

Chapter 2: Alternative Building Technologies

In the first stage of this project research, students and staff from Japanese, Nepali, and United States universities investigated sustainable, earthquake-resistant building technology options for post-earthquake reconstruction in the Kathmandu Valley and its surroundings. The technologies selected for study were: bamboo, hempcrete, rammed earth, earthbags, Compressed Stabilized Earth Brick (CSEB), and improved conventional construction. This chapter describes these technologies and how to build earthquake-resilient homes using them. The information for this chapter was gathered from public sources and incorporates information gained from lectures and interviews with Nepali nongovernmental organizations which specialize in these topics.

Bamboo

Bamboo is a flexible and strong material that has been used in housing construction throughout Nepal and the world. Bamboo is low cost, available throughout Nepal. It can be earthquake resistant and uses materials often available on the local market. There are 81 species of bamboo which grow in Nepal. Bamboo is fast-growing, even in poor soils; plants typically reach full size and strength in three to five years. The total bamboo coverage area in Nepal is estimated to be around 63,000 hectares, with approximately 60 percent estimated to be growing in natural forests.[1]

Bamboo has excellent structural qualities that, when properly treated, make bamboo well suited to earthquake-resistant construction. Bamboo can be stronger than wood; some species can be stronger than steel.[2] The plant is more flexible than hardwood and concrete materials.[3] Engineers sponsored by the UK Department of International Development tested bamboo structures at the Earthquake Engineering and Vibration Research Centre, a state-of-the-art earthquake simulator, to evaluate its flexibility under earthquake conditions. Researchers shook the house with five consecutive 30-second pulses, equivalent to a 7.8 earthquake on the Richter scale. The simulation was more than ten times as violent as the vibration and sheer effects of Nepal's 2015 earthquake, yet the house emerged unscathed.[4]

Bamboo can be cost-effective as a construction material if a viable market for its use exists. Because it is lightweight, bamboo can be easy to transport. Bamboo can be used for diverse buildings and can be combined with many other technologies, such as rammed-earth housing. Figure 2.1 illustrates the so-called bamboo ecosystem: the process of growing, harvesting, and treatment. Treatment of the bamboo against natural insect predators increases the longevity of its use in construction.

Figure 2.1[5]
ABARI Bamboo Supply Chain

To enhance bamboo's resistance to insect attack from termites or beetles, ABARI (a Nepali organization which innovates in bamboo housing design) tested diverse bamboo treatments (see Figure 2.2). One traditional treatment, soaking, requires bamboo to be submerged for six weeks. An autoclave pressure technique uses a large pressure chamber to force a chemical solution into bamboo, forcing out sugars and starches that attract insects. Large pressure chambers that operate at an industrial scale could be impractical for bamboo in rural Nepal. ABARI developed the Modified Boucherie Treatment (BT) to treat 1,200 adult bamboo plants a month.[6] The BT process attaches an airtight nozzle around one end of a still-green bamboo stalk and use manual pressure to flood a preservative solution into the stalk. The BT (see Figure 2.3) uses a preservative that consists of borax, boric acid, and water in 1:1:10 ratio.[7] The airtight cylinder is pumped manually to a pressure of 20–25 pounds per square inch. This pressure forces preservatives into the bamboo, where it will eventually push out sugars and starches which attract pests, leaving the preservative in the stalk. After an hour, the bamboo can be stored in a dry area. In a field study, ABARI reported that 70 percent of treated bamboo was pest-resistant, while the remaining bamboo was affected by pests mildly.[8]

Bamboo construction can be implemented in multiple ways, typically in the construction of roofs, walls, or as supporting beams. The versatility and availability of bamboos within Nepal could allow it to be widely available as a building material for home building for most rural regions. A common design for wall construction with bamboo begins with a timber frame. The builder can add a split-bamboo weave, between and covered on both sides with cement, fortified plaster, or even hempcrete, which will be discussed later in this report. Plaster is used on both sides of walls, providing insulation during hot or cold months; it also protects bamboo and timber from moisture and fire. Once a house foundation is laid, bamboo walls can be assembled using this wattle and daub technique. Figure 2.4 illustrates a rammed-earth home with a bamboo roof covered by a layer of earthen tiles. Figures 2.5 and 2.6 illustrate how a worker can create walls through the wattle and daub technique.

Any bamboo roofing beam diameter must meet design requirements that take into consideration the stress to which the beam may be subject in the event of an earthquake. Researchers have already started research experiments to determine the buckling column strength of bamboo.[9] Steel brackets, items easily produced in rural Nepal, can be used to connect bamboo roofing beams (see Figure 2.7). The engineering behind these brackets are simple and various brackets can be easily reproduced from other existing mounts as construction templates. Figure 2.8 illustrates how brackets can be used to stabilize a roof.

Although bamboo grows naturally throughout Nepal, costs depend on the region. One estimate of the total cost of a modest three-room bamboo home is around 800,000 Nepali rupees, or 8,000 US dollars.[10] The cost for steel joints can be modest as these joints are simple and can be made by local welders; a bamboo truss can cost about 15 percent less than a steel truss. As bamboo can grow rapidly on marginal or waste lands and can mature rapidly and be extracted at a relatively low cost. Its multi-functionality makes bamboo a useful crop for subsistence and the income needs of rural communities, especially those with few alternative resources or employment opportunities.

There may be some barriers to widespread use of bamboo for rural home reconstruction in Nepal. No proper bamboo supply chain is in place in rural Nepal, and bamboo farming has yet to develop on a national basis. Treatment can be dependent on either a pressure chamber or handheld device; automation may be necessary to increase the scale of bamboo treatment. There are no common measuring devices in Nepal to test bamboo strength. A key barrier to bamboo construction is a social perception of bamboo as a building material for disadvantaged persons. The common village preference for brick and stone versus all alternative building materials (including “unprocessed” earth materials) may transcend bamboo’s relatively low cost.

Figure 2.2[11]
Termite-Affected Bamboo

Figure 2.3[12]
Modified Boucherie Treatment

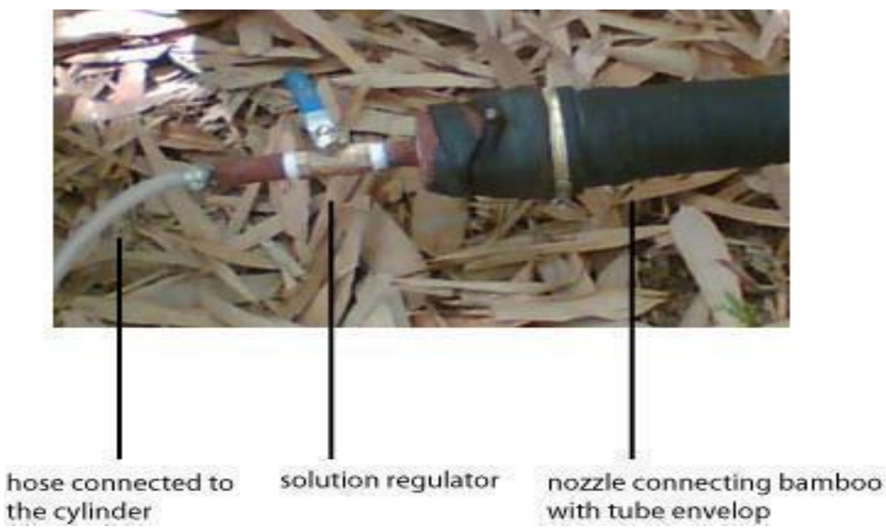


Figure 2.4[13]
Rammed-Earth Structure with Bamboo Roof
Covered by a Layer of Earthen Tiles

Figure 2.5[14]
Use of Split Bamboo between a Wood Frame

Figure 2.6[15]
A Wattle and Daub Wall

Figure 2.7[16]
Multiangular Bamboo Roofing Beam Connector Bracket

Figure 2.8[17]
CSEB School Building with Bamboo Truss

Hempcrete

Hempcrete is a plant-based building material used in place of traditional concrete. Hempcrete is created by mixing three ingredients: water, hemp shiv, and a binder of either lime or cement in a 1.5:1:1.5 ratio, respectively. After hempcrete is formed and allowed to cure, it can be used in construction. The material can be blended manually, but the process can be sped up with the use of a mixer.[18] Hempcrete is easy to create, use, and clean up; it can be environmentally friendly because it uses plant matter as a central component.

Hempcrete can be an efficient replacement for concrete or other building materials. When hempcrete acts as a concrete replacement, it cannot bear loads and requires structural materials such as steel or wooden framing. Hempcrete would be a viable material in some part of western Nepal, where hemp plants grow and are readily available. Hempcrete-based construction is rarely used in Nepal because of its association with growing cannabis, which is illegal in Nepal. Due to hemp's negative connotation, its potential as a construction material may be overlooked. As one analyst writes:

> In 1976, the Nepal government passed laws that treated cannabis as a narcotic and banned its cultivation and recreational use. This was largely a reaction to pressure applied by the US-government, out of concern that its own citizens were being lost to the growing hippie movement in Nepal at the time.[19]

Following the ban on cannabis, Nepali authorities attempted to eradicate the production of hemp in western Nepal but were largely unsuccessful. Hemp is native to Nepal, and untended fields are numerous throughout the country. Enforcement is focused in urban areas, while hemp is cultivated or grows wild unmolested in rural areas, especially western Nepal. Farmers in western Nepal continue to grow and sell cannabis.[20]

The cannabis plant has a wide range of applications familiar to farmers in Nepal. Hemp has many cultural uses, including traditional foods, sauces, oil, and clothes. It can be used in industrial applications such as paper production, industrial textiles, building materials, personal hygiene, fertilizers, bags, and medicine. However, the stigma associated with cannabis drug use undermines nationwide acceptance of the plant for industrial uses.[21]

Hempcrete could become an attractive alternative building technology (ABT) in Nepal for its economic potential, sustainability, and structural properties. The potential for multi-industry use could boost economic growth across markets as hemp grows naturally in the country, which allows the plant to be sourced locally rather than imported like other building materials. Hemp plants are low-maintenance and consume little energy throughout their life cycle. Hempcrete is an easy-to-make and easy-to-use material that requires little training and can easily be carried out by local community members.

Hempcrete homes have performed well across many different climates, but they are particularly successful in hot and humid climates. This is due to hempcrete's moisture buffer, which reflects the thermal insulation resulting from pockets of air trapped between hemp shiv particles and within the pores in the hemp shiv itself.[22] Hempcrete provides good insulation from external temperature changes which reduces the need for additional mechanical heating or cooling. Hemp houses are thermally and acoustically insulated, waterproof, fireproof, and can be recycled if damaged.[23] Hemp structures are fire retardant, as hempcrete's ignition level is delayed when the fiber composition is above 25 percent.[24] In addition to thermal resistance, hempcrete houses resist earthquake damage because the material is lightweight, flexible, and does not produce large cracks under movement. Hempcrete develops minor cracks that can be sealed over time, as free lime encounters moisture.[25] The lime content repels pests, mold, and rodents. Hempcrete should be protected from intense water exposure, such as floods. To maximize the lifespan of the hempcrete, the base of the building should be tall enough to minimize contact between hempcrete and flood water. Hempcrete can be repaired easily; home construction in other regions using hempcrete can last for hundreds of years, if maintained properly.[26]

Hempcrete itself provides limited structural strength,[27] so materials with load-bearing capacity must be used to create a strong foundation, superstructure, and roof for an earthquake-resistant building. Hempcrete has some structural advantages for use in earthquake-prone areas because it is light in weight in comparison to other materials, such as reinforced cement, concrete, or stone masonry. Should hempcrete fall during an earthquake, inhabitants would not be in as great physical danger versus residing in a home composed of heavier materials. Hempcrete is a more elastic material in comparison to traditional building materials and can allow walls to sustain lateral earthquake motion.[28] Hempcrete is a so-called zero carbon material but also acts as a carbon sink for the lifetime of the building, providing an environmentally safe and green home for its dwellers.

While there are multiple hempcrete construction methods, one low-cost approach is called "cast-in-situ" or a "cast-in-place" method. Mixed hempcrete is placed into wall forms by hand and then tamped down. Such a method requires minimal tools or skilled labor. The cast-in-situ method creates a monolithic structure, appropriate in areas prone to earthquakes.

Hempcrete material can also be used as the daub (reinforced plaster) in the wattle and daub technique. It can be applied in the same way that plaster is applied to a bamboo structure, as discussed above. Hemp house construction is a comparatively easy task and requires only a few raw materials. One analyst has estimated the total requirement of labor in building a hemp house to involve one person for mixing; two to three people for forming; two to three people for placing; or a total of five to six people to cast an average of approximately 100 square feet per day.[29] Shah Hemp Inno-Ventures (SHIV), a local Nepali social enterprise that promotes and executes hempcrete construction in Nepal, provided a schedule for the construction of a hempcrete home in a rural area (see Table 2.1). Most of the materials required to build a hempcrete house would be available locally throughout Nepal. Binders (hydrated lime) are available in local markets. While Nepal possesses local limestone, lime is currently imported from India. Many Nepali lime processing plants have recently been shut down, although some attempts have been made to restart Nepali plants.[30] Clay and other materials are available locally and can be used as additives, but lime remains a vital constituent for completing construction.

A decorticator device creates shivs out of dried cannabis plants; for energy it uses about 7 kWh. or about 5 liters of diesel for two to three days. SHIV is trying to develop a portable decorticator machine which can be used locally and transported where necessary. Such machines ought to be repairable and easy to build locally so that the training becomes easier as well.[31]

SHIV has estimated the total cost of construction of basic hempcrete house to be about 520,000 Nepali rupees (5,200 US dollars), less than the cost of conventional housing, with costs varying with design complexity and materials. Certain circumstances facilitate savings in hempcrete construction.[32] About 90 percent of total expenses are local costs, such as labor, energy, etc.[33] For example, if the ground isn't suitable for a strip foundation, a low-density hemp building can survive on a cheaper raft foundation, thus lowering costs versus a concrete foundation.[34] Hempcrete's comparative advantages over conventional construction are listed in Table 2.2.

Hempcrete also has some comparative disadvantages. It is not suitable for loadbearing purposes. Furthermore, raw hemp is only locally available if a community grows the plant. The construction process requires molds to form the hempcrete into appropriate shapes. Hempcrete's curing time, at six to eight weeks, is lengthy compared to that of other materials.

A key barrier in Nepal to the use of hempcrete remains the cannabis plant's illegal status. As Nepal receives funds from the United Nations (UN), its government abides by UN rules banning cannabis. As previously mentioned, hemp is both cultivated and grows wild in western Nepal. It is unclear if hemp can be grown legally for construction purposes. It would be an economic boon and an aid to the reconstruction effort if hemp rules were clarified.

Hempcrete construction in Nepal, while previously rare, has been expanding since SHIV began commercial operations in 2015.[35] Cultural acceptance of hempcrete remains a barrier to scaling up its use. The illegal status of the cannabis plant has cast a shadow of uncertainty over its use throughout Nepal, except for the western region, where its cultural acceptance is high. Education regarding the strength of hempcrete and its ability to withstand earthquakes could play a role in promoting the material's cultural acceptance. Project members learned from interviews that a family's willingness to use a building material is related to the material's strength and performance during an earthquake event.[36]

Table 2.1[37]
Schedule for Hempcrete Construction

Length of Time	Activity
4 days	Construct the foundation
3 days	Create a bamboo structure
10 days	Prepare a hempcrete wall
3 days	Add a roof

Table 2.2[38]
Advantages of Hempcrete Construction

- Growing hemp absorbs carbon dioxide and produces oxygen
- Site cleanup is relatively easy, as excess material can be tilled into the soil
- Hempcrete is less brittle than concrete and one-eighth the weight
- Hempcrete is resistant to rodents and insects
- Hempcrete can be used for multilevel buildings
- Hempcrete walls can survive for decades
- Nepali farmers are familiar with growing hemp
- Hempcrete insulates and breathes, well suited for climates with temperatures that vary
- Hemp wall construction requires less foundation concrete because it is lighter than other wall structures
- Hempcrete has been tested to be successful in temperatures above 40 degrees F (5° C) (average Nepal temperatures rarely go below 9° C)

Although hempcrete house construction in rural Nepal would use local materials, total costs could add up to nearly the same expense required to build a stone home—if the builder includes all housing expenses, including transportation, labor, machinery, and local and imported materials. Establishing hempcrete as a construction alternative could generate local employment in Nepal. Some training programs for hempcrete-based construction have been tested in the Dhanusha district.[39] Job creation can occur in various construction steps, such as hemp production and processing, lime sourcing, machine operation, and construction.

Should hempcrete production be scaled up, producers would need to consider the environmental impacts and take care not to overexploit the resource. Due to the widespread damage caused by the 2015 earthquake, materials for reconstruction will be in demand. In the case of hemp, farmers might seek to grow hemp, creating their own hempcrete to meet demand.

In summary, people in rural Nepal reported uncertainty as to whether hempcrete is a viable construction technology because the legality of hemp remains an issue. The building techniques associated with a hempcrete house are relatively easy to learn and practice. Materials can be sourced locally, and the potential exists for the development of local industry based around hemp cultivation, processing, construction, and export.

Rammed Earth

Rammed-earth homes are structures made of soil, stabilizers, and diverse additives compacted to form stiff walls. Figure 2.9 illustrates an example of a rammed-earth home. This method of building can be compared to the formation of sedimentary rock (see striations in Figure 2.10). Thick earthen walls can support multiple stories and be earthquake resistant if reinforced properly. A rammed-earth building relies on four components to ensure strength and stability: correct mixture, proper compaction, a solid foundation, and reinforced walls. The section below describes the rammed-earth construction process.

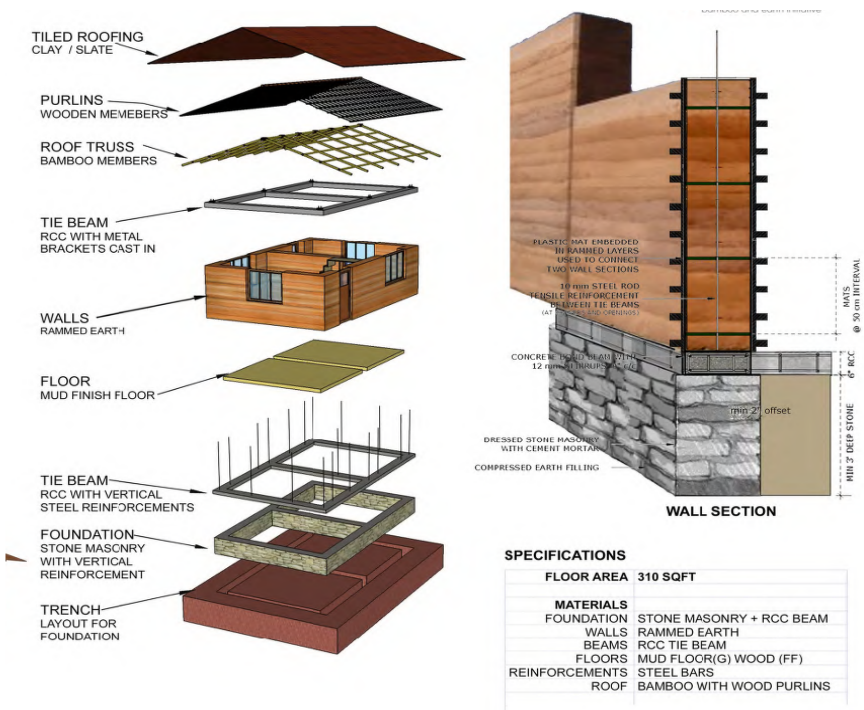
The first step in constructing a rammed-earth house is to pour or construct a rubble or concrete foundation. Families may use old stone from a previous home for the foundation to save on material cost. A trench is typically dug, in which the foundation is placed. Rebar reinforcement can fix walls to the foundation. Once a foundation is finished, formwork is built on top of it to guide compaction. Walls resemble modern concrete or adobe construction formwork. ABARI publishes examples of rammed-earth home schematics on their website. An example of the model home is shown in Figure 2.11.

The formwork used in rammed earth differs from concrete, in that the formwork may be removed almost immediately after compaction. Traditionally formwork uses timber and ropes. A somewhat modern twist on low-tech formwork would use ropes to maintain a consistent tension during the compaction process. For example, traditional formwork includes two wood shutters 20 to 30 millimeters thick and two end stops the width of the wall, held together by timber props and rope ties. Rope ties may be substituted with steel bolts, with planks spaced 65 to 70 centimeters apart.[40]

Figure 2.9[41]
ABARI Rammed-Earth Model Home

Figure 2.10[42]
Rammed-Earth Wall Sample

Figure 2.11[43]
ABARI Permanent Rammed-Earth Home Rendering



Formwork extending the full height of the wall is not necessary, as smaller forms can be used which move up the wall as each completed section cures. Using this type of form saves material cost to build a home. To achieve a proper connection among sequential horizontal sections, the formwork can be moved so that there is 15 to 20 centimeters of overlap between the new and old sections. After a section is compacted, formwork can be raised vertically to compress an additional layer roughly 60 to 90 centimeters tall. Traditional formwork has evolved to incorporate steel plates, screws, and beams that resemble concrete fabrication structures. In some countries like the US and Australia, formwork is placed to the full height of the future wall. The *Review of Rammed Earth Construction* lists additional formwork styles, as well as construction codes (see Table 2.3).[44] Wall thickness depends on climate and reinforcing materials.

Table 2.3[45]
Rammed-Earth Building Codes

Reference	**Thickness of Wall**	
	Internal	External
Standards Australia (2002)	125mm	200mm
New Mexico Code (Tibbets, 2001)	12" (305mm)	18" (457mm)
New Zealand Code (NZS 4297:1998, 1998)	250mm	
Zimbabwe Code (SAZS 724:2001, 2001)	300mm	

ABARI, a local Nepali design firm, has designed and built many rammed-earth structures. They estimated that formwork erection, checking, stripping, cleaning, and other processes take roughly half the onsite construction time. Alignment, erection, cleaning, and movement of formwork accounts for the other half. Based on the ABARI rammed-earth home plan, an 8-foot length of wall has a volume of 2.4 cubic meters, or about 5 cubic meters of loose soil. One analyst estimated that with hand loading, tamping, and inefficient formwork, only about 1.5 cubic meters of wall can be constructed per day with average hand compaction rate of 0.04 to 0.06 cubic meters per person per hour. In other words, using traditional compaction methods, one worker can compact around 0.5 to 1 cubic meters per day. Modern compactors or rammers will reduce the time required for construction. Production rates with modern compactors range from 0.2 to 0.42 cubic meters per person per hour. An adequate quantity of formwork structures and an efficient organizational strategy can facilitate simultaneous compaction labor and formwork labor. [46]

Compaction has traditionally been accomplished using a hand tamper. A hand tamper or rammer is most often made with a wood handle and metal head. The total weight of the equipment ranges from 5 to 15 kilograms. To increase the rate of compaction and decrease the amount of needed labor, modern instruments like pneumatic, vibrating plate, and sheep's foot compactors can be employed.

Before compaction, soil must be tested and altered with stabilizers or other additives, as necessary. A typical soil mixture includes sand, clay, water, and a stabilizer such as cement or lime. This soil should be free of large rocks, earth clumps, human or animal wastes, high organic matter, and debris. A materials section below describes specific soil mix ratios and optimum water content. The depth of soil added before compaction, also known as lift, varies based upon compaction effort, formwork, and soil type. The lift size ranges from 4 inches (10 centimeters) to 8 inches (or 20 centimeters) per compaction period. Each lift is tamped until approximately 50 percent of compaction is achieved. Some practitioners advise the scarring or scabbing of layers in between compaction layers to increase bonding strength. If a surface is left overnight, re-moisturizing to prepare for successive layers may be needed.[47]

When compacting, generally 4 to 8 inches of soil is added; it is tamped until the noise changes from a "dull thud" to a "resonant ringing." To ensure structural consistency, each wall section should be completed in one session. If sections must be left for longer than a few hours before continuing work, it is possible that a so-called "cold joint" could occur, caused by the interruption or delay in the building operation, where one surface sets before a second is added, so the two surfaces do not intermix or connect. A cold joint can cause a weakness in the wall. If a layer has dried, loose material should be swept off the top and should be remoistened. A thin lift should be added first before continuing normal compaction.[48] Once the lift has been properly compacted, formwork can be removed and built for the next layer.

Rammed-earth buildings are designed as single-story structures. Two-story structures have been built but must be designed to account for the lower strength of rammed earth as compared to concrete or masonry. A 10:1 ratio of wall height to thickness is typical for load-bearing walls, and walls do not need to exceed 24 inches of thickness.[49] Window and door frames require wood lintels above the opening, with minimum overhangs of 8 inches on either side for support.[50] Embedding wood frames or anchors is typical in all door and window openings during wall construction, rather than attempting to secure frames to earth walls after they cure.[51] Methods to mitigate seismic loads include the addition of plastic matting horizontally every 50 centimeters as well as embedding rebar at key points.

As mentioned in a previous section, compact earth construction design methods rely heavily on the proper soil mixture. Ideally, soil from the property can be used for home construction, thus requiring purchase of minimal outside materials. If the soil on the property does not meet specifications, additional sand or clay must be purchased. Table 2.4 lists materials and tools needed for construction.

Table 2.4[52]

A Materials List for Rammed-Earth Construction

- **Soil**: Mixed in appropriate ratios (silt/clay/sand/gravel)
- **Soil Mixer**: Garden cultivator, rotating drum, forced action mortar/slurry mixers, tractor
- **Cement**: For the structure's footing and soil stabilization, as required or preferred
- **Rebar**
- **Formwork**: Commercial forms, plywood, wood planks
- **Compactor**: Hand tamper or pneumatic tamper

On average an ideal soil composition should be between 20 and 35 percent silt and clay and 50 to 75 percent sand and gravel. If the soil has less than 25 percent clay, cement can be used as a stabilizer at about 5 to 10 percent. Soils with high organic matter content should be avoided due to the possibility of long-term structural decay. Topsoil should be scraped away during excavation. Particles with diameters greater than 5 to 10 millimeters should be sieved out for rammed-earth application.[53] Soil should be prepared in batches that can be used within three hours, as otherwise moisture and stabilizer properties may be inconsistent through the wall section.[54]

Stabilizers such as clay are used to help bind soil particles together to form stiff walls. For local soils low in clay content, it may be necessary to add stabilizers like cement or hydrated lime to achieve the desired properties rather than adding additional clay. Cement stabilization is capable of increasing wall strength up to five times the strength of a raw earth wall.[61] Hydrated lime does not add strength but does increase water resistivity and therefore the life expectancy of the wall. Calcium cations from hydrated lime replace cations on the clay materials facing the sun, leading to plasticity reduction, reduction in moisture holding capacity, reduced swelling, and improved stability.[55] Stabilizer additions should be calculated based on the compacted volume of earth rather than lose volume.[56] Commonly cited cement proportions within the mixture range from 4 to 15 percent, with 6 to 10 percent being commonly cited values.[57]

Mixing can enhance a soil's aesthetic and structural strength and homogeneity. Mixing can be accomplished using garden cultivators, rotating drums, forced action mortar and slurry mixers, or using a tractor and bucket. Pulverization is required for chunky soil. After mixing, soil moisture and color should be consistent. Soil at optimum moisture content should be tarped or placed in an area where neither excessive precipitation nor excessive evaporation is likely. A variety of factors affect the total time and amount of labor needed for completion of a rammed-earth structure. Soil suitability and the degree of soil processing (pulverization, mixing, extraction, etc.) affect labor productivity. The dimensions of the structure, simplicity of design, and weather conditions all increase the total time needed. While rammed-earth technology may make sense in one village, it may not be appropriate in others. Sites ought to be inspected for the feasibility of any technology before construction.

ABARI quoted a build time of two weeks for a rammed-earth designs;[58] however, they did not specify the size or skill level of the construction crew. Mero Gaon, a separate nonprofit working in conjunction with ABARI, quoted a total of 70 to 80 days per home in a project proposal, based on a plan to train locals for most construction tasks. Mero Gaon estimated that a skilled crew of five could lay a foundation within two weeks, construct walls in four weeks, spend four weeks in framing carpentry and one week for finishing trim.[59] The majority of the building crew can be recruited locally and trained on the job, although some construction can require skilled carpenters or masons. If all labor can be locally sourced, one remaining limitation to rammed-earth construction is the cost of nonlocal materials.

Using soil as a main building component presents many advantages because of its low cost and potential for onsite use. If the soil onsite does not have the correct proportion for a rammed-earth structure, then specific additives or types of soil must be sourced elsewhere, which can become costly, depending on the supply chain access. To consider soil as a main building component, the builder ought to confirm preexisting soil conditions and access to labor and material supply chains.

Construction and living style represent two comparative advantages of rammed-earth homes. The main construction advantage is the use of a local and inexpensive building material, provided that the property has appropriate soil. Rammed earth may not require as much cement or timber compared to conventional brick or stone construction. The use of rammed earth is simple to teach and does not require expensive equipment. The most expensive equipment, the formwork, can be reused site-to-site. One advantage of a rammed-earth home is the high thermal heat capacity due to its mass, which makes it effective insulation. Nepal can have high temperatures during the day and low temperatures at night; rammed earth's insulation can smooth out the interior temperature of the home, as heat is stored in the walls and dissipates slowly. If insulation is still desired, it should be installed on the exterior of the wall.[60] A structure's life span can be over a hundred years, if properly constructed. Rammed-earth homes have low maintenance requirements, noise reduction properties, and barriers to pests. As the walls are load bearing, Nepali families can expand the design vertically into two-story homes.[61]

Rammed earth's advantages are reliant on certain preexisting conditions, such as the correct soil mixture on the property, whether the family can perform construction labor, and proximity to a road. The formwork requires trained labor and a substantial portion of the construction timeline is dedicated to building formwork. Forms can be costly if a family must purchase them, even if the family can sell the forms to the next user at a discounted rate. Attention to quality control is vital for earthquake resistance and the structural stability of the rammed-earth home.

Compressed Stabilized Earth Bricks

Compressed Stabilized Earth Brick (CSEB) is a building material that represents a cross between a classic ceramic-fired brick and a cured concrete block.[62] Building with CSEB resembles rammed-earth methods, but use a mold instead of a formwork to create a homogenous structure. Individual bricks are compressed, cured, and assembled to build a structure.[63] CSEBs can be made onsite in villages using local materials and local labor. Much of the content of this section is derived from the Auroville Institute website.[64] CSEBs are made from a soil mixture and compressed into a final shape. While it is possible to make earth bricks without stabilizers, stronger, longer-lasting bricks are made using lime or concrete as a stabilizer. CSEBs can be used to build two-story structures.

The first attempts to use compressed earth block in home construction are reported in nineteenth-century Europe. An architect named Francois Cointereaux precast small blocks of rammed earth and used hand rammers to compress the soil into small wooden molds held with the feet. CSEBs were designed as alternatives to conventional masonry that could be made locally with less energy. The transition from hand-tamped methods to compression press use for building and architectural purposes began around 1952, following the invention of the CINVA-RAM press.[65] Compression machines are now used throughout the world. After the Gorkha earthquake in Nepal, the country began using the technology because of its many advantages, as discussed below.

CSEBs have been used in Nepal, such as in the Department of Architecture in IOE Pulchowk, which uses CSEB as its primary building material. It was built onsite with 24-centimeter by 24-centimeter bricks built via Auroville method, where a set of interlocking compressed earth bricks are used to construct walls.[66] The bricks were manufactured onsite by Auram Press 3000, made by Auroville, using the soils of the site based on prior lab quality tests.[67] Some of the brick molds were designed to make interlocking bricks that could be reinforced with rebar. Walls were reinforced by sliding rebar tied into the foundation through two cylindrical holes in the CSEB. Mortar was poured into separate holes, which joined the bricks together and provided a solid concrete column running through the wall to provide additional strength.[68]

This approach is similar to conventional masonry techniques. Depending on the mold, some CSEBs are designed to interlock into each other while others are more traditional in shape, with a smooth surface finish. Compression machines have exchangeable molds which can create different types of bricks. Ideally, soil excavated for a foundation can be used to make the bricks for the home. Before beginning construction, the local soil needs to be tested to verify if it complies with CSEB soil requirements.

The soil added to the machine press must be free of lumps, debris, and rocks, and it should be mixed homogeneously. The proper proportions of CSEB component raw materials are 15 percent gravel; 30 to 50 percent sand; 15 to 20 percent silt; and 20 to 35 percent clay, with higher proportions of clay also requiring stabilization through the addition of lime.[69]

The production of the earth bricks themselves is comparable to fired earth bricks produced by compaction, except that there is no firing stage. CSEB typically utilizes the addition of a stabilizer such as cement or lime that aids in binding soil particles. Once the CSEBs are removed from the mold, they must cure prior to use. Care must be taken to not let excessive evaporation or precipitation on the bricks occur by either covering with a tarp or drying in a covered shelter. The "green" CSEBs are left to cure for four weeks; once dried, they can be used in construction. Table 2.5 lists building steps for using CSEB.

Building a structure can begin once the bricks finish curing. Curing the bricks and excavation and pouring of the foundation can take place in parallel, provided there is enough labor. With the foundation in place, bricklaying commences. The bricks are stacked in layers with mortar between each layer and between each brick, taking great care to remain level and even. If the CSEBs are of the interlocking or ridged variety, then laying the CSEBs is easier since they fit into each other for easy stacking. While the mold may cost more, it can decrease construction time and the necessity for skilled labor. Build up Nepal, a Swedish nonprofit working in Nepal with CSEB structures, recommends that builders incorporate a horizontal concrete band to increase the rigidity of the structure.[70] The addition of horizontal rebar reinforcement ties the walls together, and vertical rebar reinforcement improves the tensile strength of the building. Together these reinforcements make a CSEB structure earthquake resistant.[71] Once walls are built, the wall should be capped with another concrete horizontal band that secures the rebar reinforcement in the wall and provides a connection point for the roof.

Table 2.5[72]
Steps for Creating CSEB

1. Extract soil from a quarry or pit
2. Pulverize soil to break any lumps of clay
3. Screen to eliminate undesirable debris
4. Measure dry soil by weight or volume
5. Dry soil by spreading it on to thin layers
6. Dry mix to uniformly distribute stabilizer, sand, and clay
7. Wet mix to enable a mixing reaction to begin
8. Pour soil for optimum brick density for compression and adding it to the mold
9. Compress soil into CSEBs in the machine press
10. Lay "green" CSEBs out to cure for four weeks
11. Keep CSEBs dry prior to use

Producing and building with CSEB can be labor intensive, depending on the timescale of the project. Producing CSEB requires two to three people for mixing and filling the mold and one to two people for pressing the brick. While fewer people can create CSEB, many people working simultaneously makes the process more efficient. Laying CSEBs requires few workers, and if the bricks are interlocking, even fewer and less skilled people are required.

Build up Nepal offers a training course for persons planning to build with CSEB technology. The initial three days focus on foundation training, where participants learn how to select a good location to construct the home, conduct measurements, dig a foundation, perform quality control activities, anchor rebar and make stirrups, and perform concreting and stone soiling. The next two days involve training in beam casting. Participants learn how to use formwork, cast a beam, anchor rebar into the beam, and fit the rebar. After this step, participants learn to build the walls so that they are level. In a fourth step, participants are trained in how to attach a roof and false ceiling. Participants also learn how to conduct a quality check of the final constructed building and complete any remaining details.[73]

The cost savings for CSEB construction, when compared to fired brick and concrete counterparts, is due to the raw materials used. For example, Build up Nepal estimates that

CSEBs are 40 to 60 percent less costly than fired bricks that are delivered on dirt road.[74] If the local soil meets the requirements for CSEB production, a family can save by making bricks themselves. If the soil does not meet the mixture requirements, then a family must bring in the necessary materials, which will increase the overall cost of the CSEB home.

Build up Nepal estimates that the total cost for building with standard fired brick is on the order of 12 Nepali rupees per brick, versus between 41and 46 Nepali rupees for a CSEB brick. The cost of a standard brick wall, including labor, bricks, cement, and sand is on the order of 3,510 and 4,230 Nepali rupees per square meter of wall, versus between 1,844 and 2,552 Nepali rupees for a CSEB wall.[75]

While one of the major advantages of CSEB is the possibility of using locally-sourced soil as raw material, some local conditions may not permit its use. Build up Nepal suggests that CSEB works best for communities no further than four to six hours from Kathmandu or another urban area with access to necessary materials. If soil conditions do not meet requirements, this does not rule out the use of CSEB, but it does add additional cost to the project.

CSEBs also have environmental benefits. Unlike ceramic and fired alternatives, CSEBs do not require wood or fuel to cure. There are fewer materials to purchase and ship from a city to the village. Furthermore, CSEBs require less cement than conventional concrete blocks. CSEBs also require less energy, using only about 1 percent of the energy required to manufacture and process the same volume of cement concrete blocks.[76]

From a social standpoint, Nepalis are accustomed to brick and other types of masonry in cities like Kathmandu. In Nepali culture, brick construction conveys a certain status.[77] CSEB will be easier to assimilate into the culture because it resembles the bricks homeowners prefer. The architects and inhabitants of CSEB buildings are drawn to the quality of well-designed and well-executed compressed earth brick buildings.[78] Its high thermal heat capacity translates to slower fluctuations in indoor temperatures. The heat during high temperature days slowly moves through the dense CSEB walls in time for the low temperature nights in Nepal. CSEB materials are fire resistant, which is helpful because many Nepalis cook indoors.

There are some comparative CSEB disadvantages. CSEB construction is labor intensive, especially the brickmaking process. As the cost benefits are associated with having the correct soil mix available locally, a family must learn how to test their soil and purchase any supplemental sand, clay, and cement to meet the correct mixture ratios. Shipping building materials such as rebar, a machine press, and soil mixers can be difficult and expensive. The machine press itself is too expensive for any one village family to purchase on its own, requiring group collaboration. Making and building with CSEB requires training. Otherwise, the quality of the structure can be compromised. The feasibility of this building technology relies upon proximity to a city and contact with an experienced individual who can teach villagers how to make and build with CSEB.

Earthbags

Earthbag houses are a sustainable and cost-effective option for building durable houses in natural disaster-prone areas. Earthbag houses provide insulation from cold weather, stand up to natural disasters such as earthquakes, and provide a protective barrier in cases of flood. Traditionally, these homes were used by the military to build protective barriers. Earthbags are an option for sustainable and cost-effective housing. In US military field construction, earthbags have been used to construct round or dome-shaped structures.

The bags used in this technology are filled with sand and clay, which can be found on any rural building site in Nepal. External materials include polypropylene bags, rebar, and barbed wire. Polypropylene bags are filled with materials such as the natural soil, rocks, and gravel cleared from the home site. The material is moistened and rammed into the bag or used in the foundation. The soil content of the bag is important, as the main component of the earthbag technology is the earth incorporated into the bag. To build durable housing the correct ratio is 25 percent stable clay with 75 percent well-graded sand and gravel.[79]

Bag shape matters for flexibility and stability. Good Earth Global prefers tube-shaped bags with an 85 millimeters thickness.[80] The use of polypropylene gives earthbag tubes flexibility to be shaped and stacked to form the walls of the building. Once shaped, the contents of the bags naturally dry.

Figure 2.12[81]
Bare Earthbag Wall

Metals—such as iron, steel, rebar, or barbed wire—can be added to reinforce the structure between each layer for increasing friction between the rows of bags to provide more support. For vertical support, rebar can be spaced based on ratios between corners, windows and doors, and bond beams, as rebar enhances the earthquake resistance properties on the structure.[82] Wooden window and doorframes can be added to homes as a finishing step. These can be sourced from local timber and harvested using local labor. Earthbag houses are finished with a clay or lime plaster. Color is a choice based on financial resources of the household but can easily be applied.

Earthbag houses are simple, durable, and sustainable houses. Organizations such as Good Earth Global believe earthbag homes can last a lifetime. Table 2.6 lists the components and costs of building an earthbag home.

One challenge for building with earthbags is the transportation of rebar, barbed wire, bags, and concrete to rural villages. For example, based on the requirements in Table 2.6, one 2-ton truck is required to bring materials for two houses. Another issue is that workers need to be trained on the correct soil combinations for filling earthbags. Otherwise, earthbags may fail under heavy loads or have uneven surfaces.

Table 2.6[83]

Input Estimation for Earthbag House Construction

Materials	**Units**	**Type A Standard***	**Type B Medium**	**Type C High**	**Type D Extra**
		Amount	**Amount**	**Amount**	**Amount**
Solid poly bags	Each	890	890	930	860
Solid poly tubes 38/15”	Meters		130	130	110
Barbed wire (4 point)	Meters	820	1100	1010	940
Earthen fill (bags, floor)	Meters	24	27	25	19**
D12/#4 1/2-inch rebar	Meters	110	160	130	180
D9/#3 3/8-inch rebar	Meters			32	
Bags of Portland cement or building and stucco	43 kilograms/ 94 pounds each	4 bags	23 bags	41 bags	39 bags
Other materials		Wood for lintels	Mesh wire	Geo-mesh wire	

*Type A: Calculated with 2.7-meter-high walls; taller walls are shown in sketches that follow.
**Type D: Assumes thin walls of 33 centimeters or 13 inches.

Earthbag structures can be more efficient than conventional buildings. Some benefits of using earthbags: (a) bags are cheap and easily available; (b) fill material can include a variety of construction waste materials, contributing to site recycling; (c) no special construction equipment is required, as bags can be manipulated by hand; and (d) use of cement and chemical agents can be limited, making earthbags a sustainable option.

There are some limitations to the earthbag technology. One of the major limitations relates to the sheer house weight. Earthbags are heavy and cannot be built on soft soil or near cliffs and slopes. Because of their weight, earthbags cannot be used for second story additions. This does not mean that earthbag homes cannot have two stories, as it is possible to utilize other building materials to construct second stories. While two-story homes would increase costs, it would add to function and flexibility for the household.

While earthbag houses are simple, reliable, safe, and sustainable alternatives to conventional housing, there are cultural limitations on designs based on what villagers will want to live in. According to Good Earth Global, rectangle houses with a trussed roof are more accepted by villagers.[84] Nepalis did not express a preference in interviews to live in round or dome-shaped houses. There is not a local culture of round houses, and round homes are not shaped to meet the cornered edges of furniture. Further, a round house decreases the open square footage of the house, limiting a house's function and use.

There are still many Nepalis who do not know about earthbag technology, as indicated from project interviews of villagers in Kaule, Kotdanda, and Simpokhari. Only residents living in Kaule knew about the earthbag technology, as Good Earth Global works in Kaule to build structures using earthbag technology.[85] In other settlements, respondents reported no knowledge of earthbags. Respondents in all villages expressed a shape and form preference of a rectangular or square shape with a sloped roof. Residents indicated that they would prefer to stay in a safer home rather than the temporary shelters in which they are now residing; safety as a priority was made clear during interviews.[86]

In the village of Kaule, Good Earth Global is partnering with German nonprofit Carisimo and Kaule Environmental Nepal to build ten homes as a community-oriented undertaking. Six houses are being built by the families who will live in them, and all the neighbors are aiding in the construction of one another's homes.[87]

Figure 2.13[88]
Earthbag Home Wall with Typical Mud Plaster

55 earthbags structures were built in Nepal prior to the earthquake; all of these structures survived the earthquake with no structural damage.[89] This technology may flourish in Nepal as an affordable, earthquake-resilient building material because of its durability, safety, and sustainability. Based on project interviews and site visits, earthbags represent a viable option for home reconstruction that maintain safety and well-being to create a harmonious and promising place to live.[90]

Conventional Nepali Housing

Conventional Nepali home building uses locally available materials such as stone, brick, mud, timber, and bamboo. Nepali houses are usually located in cluster settlements on the southern slope of a hill. The houses tend to be compact, with two to three stories, each with a maximum height of 7 feet. A typical first floor contains the kitchen and dining area and *pidhi* (resting space and temporary storage space in front of the house). The second floor contains sleeping spaces. Attic space is used for additional storage. Roofs are slanted and made of *jhingati* (terracotta) or slate tiles, corrugated galvanized iron, or hay. Traditional houses are adapted to the climate; similar building types are found in locations of similar climate and culture. Building and lifestyles vary, and various adaptive actions are used to produce comfortable thermal conditions where possible. Figure 2.14 shows conventional Nepali homes. Table 2.7 lists the type of materials used in conventional home construction.

Figure 2.14[91]
Conventional Nepali Homes in Hills

Table 2.7[92]
Conventional Home Construction Materials

- Mud
- Animal products (cow dung)
- Bricks
- Rocks and stone
- Timber and wood
- Bamboo
- Concrete or cement

Mud has been used extensively in home construction since ancient times, particularly as an input for making bricks. Mud is also used in conventional housing as a binder or plaster. The mud used for walls ought to be free from organic materials. It should be neither too sandy nor too clayey, with a sand content of not more than 40 percent by volume.[93] Cow dung ash can be used as a supplementary cementing material in mortar. A mixture of cow dung ash with mud and chopped straw is used as mud mortar in conventional housing in parts of Nepal.

Nepali families in interviews most often reported that they prefer to build homes using clay-fired bricks. These bricks are typically fired in traditional kilns for a period of seven weeks to gain proper strength. Gray and black clays are commonly used to manufacture bricks and tiles. Nepali bricks from the Terai are considered of high quality; Chinese factory-made bricks are usually stronger. A common conventional wisdom from Nepalis in interviews was that smaller kilns create better products and larger kilns produce cheaper bricks.[94]

While a brick face typically will be roughly 9 inches by 4 inches, there is no "standard" brick dimension used in Nepal, which often results in uneven wall thicknesses. Bricks walls are traditionally built double-width, with the space in between filled with a mix of clay soil and pieces of broken brick. Mud mortar can be used between brick layers; newer houses use cement mortar. As cement is heavy, transporting it into rural areas without good roads can be expensive. About 70 percent of the concrete found in Nepal is imported as cement from India.[95] The same clay used to make masonry bricks are also used to make roof tiles. Roof tiles are flat and have two longitudinal grooves where one tile can be fitted to the next.[96]

Stone is a common conventional building material in the rural parts of Nepal because it is available and durable. The major varieties in Nepal are limestone, sandstone, dolomite, granite, quartzite, and marble. Stone is quarried in the surrounding hills and mountains of the Kathmandu Valley, particularly in the south near Pharping village, Kirtipur city in Macche Narayan Gaon, and near Chobar gorge. Marble stone can be found near Godavari. Other stones are found along the riverbeds and are neither cut nor squared. The two main types of stone are black stone and white stone; both are metamorphic rock with finely packed grains. White stone is more easily quarried than black stone, while the black stone is stronger and more resistant to weathering elements.[97]

Houses may be made completely out of stone, or stone may be used for portions of the house or foundations. Stone masonry walls are supported by continuous stone masonry strip footings. In some rural adobe houses, first-floor walls are also made of stone. In urban areas, entranceways around doors may be made of stone. Stone may be stacked without the use of mortar, or mud or cement mortar may be used. Like bricks, stone may be used to construct double-width walls.[98]

Wood has been used as a building material in conventional Nepali housing construction for doors, windows, staircases, flooring, roofing, and wall panels, as well as for structural members such as columns, beams, and trusses. Timber flooring, bands, and knee braces are sometimes used in home construction.

Sal (Shorea robusta), a tree genus in the Terai, is a high-quality wood that is strong and durable, with trees growing as tall as 30 meters. Apart from the sal, the most common species used for construction are *gwaisasi* (Schima wallichi), *salla* (Pinus roxburghii) and *utis* (Alnus nepalensis).[99] Large-scale tree harvesting today is primarily done in the Terai region, even though all of these trees grow on the slopes and hills around the Kathmandu Valley. Deforestation of the Terai hills and valleys has left the region with inadequate trees to meet market requirements.[100]

Slate, a fine-grained, foliated metamorphic rock, is used in Nepal for the roofing and cladding of home yards. Good quality slate can be found at Bandipur area, Tanahu. Slate occurrences have been also reported in Singchyang Garhi (Udayapur), Gairimudi (Kavre Palanchok), the Chautara area (Sidhupalchok), Bigu (Dolakha), Gaighat (Tanahu), Kelodighat (Syangja), Ranipauwa (Nuwakot), Gajuri (Dhading), etc. There are 31 sites producing slate in different parts of the country, although studies of slate occurrences for identifying quality, quantity, and the possibility of mining are not in the public domain.[101]

Roofs can be thatched or covered with *jhingati* (roof tiles). About four decades ago, rural Nepalis started using corrugated galvanized iron (CGI) sheets as well. For such sheet-covered roofs, the load is almost negligible, reducing the burden on the stories below the roof.

The volume of required local labor supply to rebuild houses is massive. One estimate is that 887,356 homes were destroyed or damaged by the earthquakes.[102] As Nepal seeks to recover from the earthquake, many families are challenged to manage necessary labor for home rebuilding. Table 2.8 lists criteria for facilitating labor for home reconstruction.

Table 2.8[103]

Labor Options for Home Reconstruction

- Family labor supply requires active participation and self-dedication
- Local labor supply is a key element for constructing sustainable but earthquake-resilient homes
- Persons building houses should have knowledge about home design, the quantity and quality of useful construction materials, and material market prices
- Local workers can provide training to others on earthquake-resilient design, site selection, building configuration, and construction quality assurance
- Adequate training should be provided to masons to reduce vulnerability to potential earthquakes and ensure building code compliance
- It is useful to foster knowledge exchange among workers and groups
- Nepali students may be available to contribute labor through cooperation with schools, colleges, and universities
- One way to attract workers is to promote "food for work"
- Local NGOs may be able to provide training support
- Laborers ought to be recognized for their knowledge and skills
- Laborers ought to be recognized for the volume and quality of their labor

The costs of conventional houses in Nepal can vary widely depending on size, type, and availability of materials. For rural homes in need of reconstruction, the materials used in conventional-style building may not be locally available; when not available, they must be transported to the necessary locations. Table 2.9 lists an estimate for costs for constructing a conventional house.

Table 2.9[104]
Costs of a Conventional House

Cost Component	Cost (Nepali Rupees)
Labor	342,000
Building material	692,366
Equipment and chemicals	20,672
Technical assistance	195,000
Miscellaneous	20,000
Total cost	1,270,038

Conventional local construction methods have some comparative advantages. Local practices can be adopted and adapted more easily by Nepali citizens. The use of indigenous knowledge allows for the incorporation of local expertise for local challenges that may not be addressed by foreign building techniques. Local materials can be obtained through existing supply chains, to avoid high transportation costs of building materials that cannot be obtained easily in remote rural areas. Materials used by local building practices may be less costly and produce a lower level of carbon emissions than manufactured modern building materials.

There are some disadvantages of conventional stone and/or brick construction. Materials used for steel reinforcement may not be available locally and may need to be transported to remote rural areas. The additional cost of these materials and their transportations may not be feasible for poorer villagers. Additional costs may lead to the reuse of materials salvaged from destroyed homes, some of which may no longer have structural integrity.

[1] "Bamboo Engineered House," ABARI, accessed March 12, 2018, http://abari.earth/bamboo-engineered-house/.
[2] S. Karthik, P. Ram Mohan Rao, and P.O. Awoyera, "Strength properties of bamboo and steel reinforced concrete containing manufactured sand and mineral admixtures," *Journal of King Saud University* 29, no. 4 (October 2017), https://www.sciencedirect.com/science/article/pii/S1018363916300484#.
[3] A.P. Adewuyi, A.A. Otukoya, O.A. Olaniyi, and O.S. Olafusi, "Comparative Studies of Steel, Bamboo and Rattan as Reinforcing Bars in Concrete: Tensile and Flexural Characteristics," *Open Journal of Civil Engineering* 5 (2005): 228–238, http://dx.doi.org/10.4236/ojce.2015.52023.
[4] Jagadish Vengala, B.N. Mohanthy, and S. Raghunath, "Seismic performance of Bamboo housing– an overview," accessed March 12, 2018, http://www.worldbamboo.net/wbcx/Sessions/Theme%20Architecture%20Engineering%20Social%20Housing/Vengala,%20Jagadish%20et.%20al.pdf.
[5] ABARI, accessed March 2017, http://abari.earth/.
[6] Nripal Adhikary, "Experiment with a Locally Constructed Boucherie Treatment Plant in Nepal," ABARI, accessed March 12, 2018, http://abari.earth/treatment/.
[7] Ibid.
[8] Ibid.
[9] M.J. Richard and K. Harries, "Experimental Buckling Capacity of Multiple-Culm Bamboo Columns," *Key Engineering Materials* 517 (2012): 51–62, accessed March 30, 2018, https://doi.org/10.4028/www.scientific.net/KEM.517.51.
[10] Unpublished materials provided to project members, Dhiraj K. Shah, "Shah Hemp Inno Ventures (SHIV) Pvt. Ltd.," Tribhuvan University, received March 14, 2017.

[11] Nripal Adhikary, "Experiment with a Locally Constructed Boucherie Treatment Plant in Nepal," ABARI, accessed March 12, 2018, http://abari.earth/treatment/.
[12] Ibid.
[13] "Recent Projects," ABARI, accessed February 2017, http://abari.earth/project/.
[14] "A New Initiative of Bamboo Housing by HFHI-Nepal," Habitat for Humanity, published 2007, accessed February 2017, http://hfhi-nepal.blogspot.com/2007/08/new-initiative-of-bamboo-housing-by.html.
[15] Ibid.
[16] Unpublished photo developed by project members, March 2017.
[17] Ibid.
[18] "How to Make Hempcrete," Florida Hemp Alliance, published March 3, 2015, accessed February 27, 2017, https://www.youtube.com/watch?v=MzsJT3Wu0So.
[19] David Caprara, "In Defense of Nepal's 'Miracle Plant,'" The Kathmandu Post, published January 30, 2016, accessed March 5, 2018, http://kathmandupost.ekantipur.com/news/2016-01-30/in-defence-of-nepals-miracle-plant.html.
[20] "Cannabis Fields of the Himalayas: How US & UN Policies Affect Others!" United Patients Group, published November 2, 2016, accessed March 5, 2018, https://unitedpatientsgroup.com/blog/2016/06/ 28/cannabis-fields-himalayas-us-un-policies-affect-deeply-rooted-cultural-practices.
[21] David Caprara, "In Defense of Nepal's 'Miracle Plant,'" The Kathmandu Post, published January 30, 2016, accessed March 5, 2018, http://kathmandupost.ekantipur.com/news/2016-01-30/in-defence-of-nepals-miracle-plant.html.
[22] Johan Ahlberg, Elza Georges, and Mikael Norlén, "The Potential of Hemp Buildings in Different Climates: A Comparison Between Common Passive House and the Hempcrete Building System," published June 15, 2014, accessed March 5, 2018, https://www.diva-portal.org/smash/get/diva2:722306/fulltext01.pdf.
[23] "Thermo-Hemp Natural Insulation," accessed March 5, 2018, http://www.ecologicalbuildingsystems.com/docs/Thermo-Hemp-Insulation-Data-Sheet.pdf.
[24] Alexander Naughton, Mizi Fan, and Julie Bregulla, "Fire resistance characterization of hemp fiber reinforced polyester composites for use in the construction industry," *Composites Part B: Engineering* 60 (2014): 546–554.
[25] Johan Ahlberg, Elza Georges, and Mikael Norlén, "The Potential of Hemp Buildings in Different Climates: A Comparison Between Common Passive House and the Hempcrete Building System," published June 15, 2014, accessed March 5, 2018, https://www.diva-portal.org/smash/get/diva2:722306/fulltext01.pdf.
[26] "What is Hempcrete?" American Lime Technology, accessed March 5, 2018, http://www.americanlimetechnology.com/what-is-hempcrete/.
[27] Ibid.
[28] Agnita Mukherjee, "Structural Benefits of Hempcrete Infill in Timber Stud Walls," published January 2012, accessed March 13, 2018, https://qspace.library.queensu.ca/bitstream/handle/1974/6986/Mukherjee_Agnita_201201_MASC.pdf;jsessionid=B49E15618D0957020A674AC7D55E50C0?sequence=1.
[29] Unpublished materials provided to project members, Dhiraj K. Shah, "Shah Hemp Inno Ventures (SHIV) Pvt. Ltd.," Tribhuvan University, received March 14, 2017.
[30] Ibid.
[31] Unpublished materials provided to project members, SHIV staff, received March 2017.
[32] Unpublished materials provided to project members, Dhiraj K. Shah, "Shah Hemp Inno Ventures (SHIV) Pvt. Ltd.," Tribhuvan University, received March 14, 2017.
[33] Ibid.
[34] Ibid.
[35] Shah Hemp Inno-Ventures Pvt. Ltd. (SHIV), http://shivhomesnp.weebly.com/projects.html/.
[36] Unpublished interview conducted by project members, March 2017.
[37] Unpublished materials provided to project members, Dhiraj K. Shah, "Shah Hemp Inno Ventures (SHIV) Pvt. Ltd.," Tribhuvan University, received March 14, 2017.
[38] Ibid.
[39] "SHIV nears completion of a hemp home," Hemp Today, published December 2016, accessed March 13, 2018, https://hemptoday.net/shiv-nears-completion-hemp-home/.
[40] Kaki Hunter and Donald Kiffmeyer, *Earthbag Building: The Tools, Tricks and Techniques* (Canada: New Society Publishers, 2004).
[41] Unpublished photo provided to project members, Nripal Adhikary, ABARI, received February 2017.

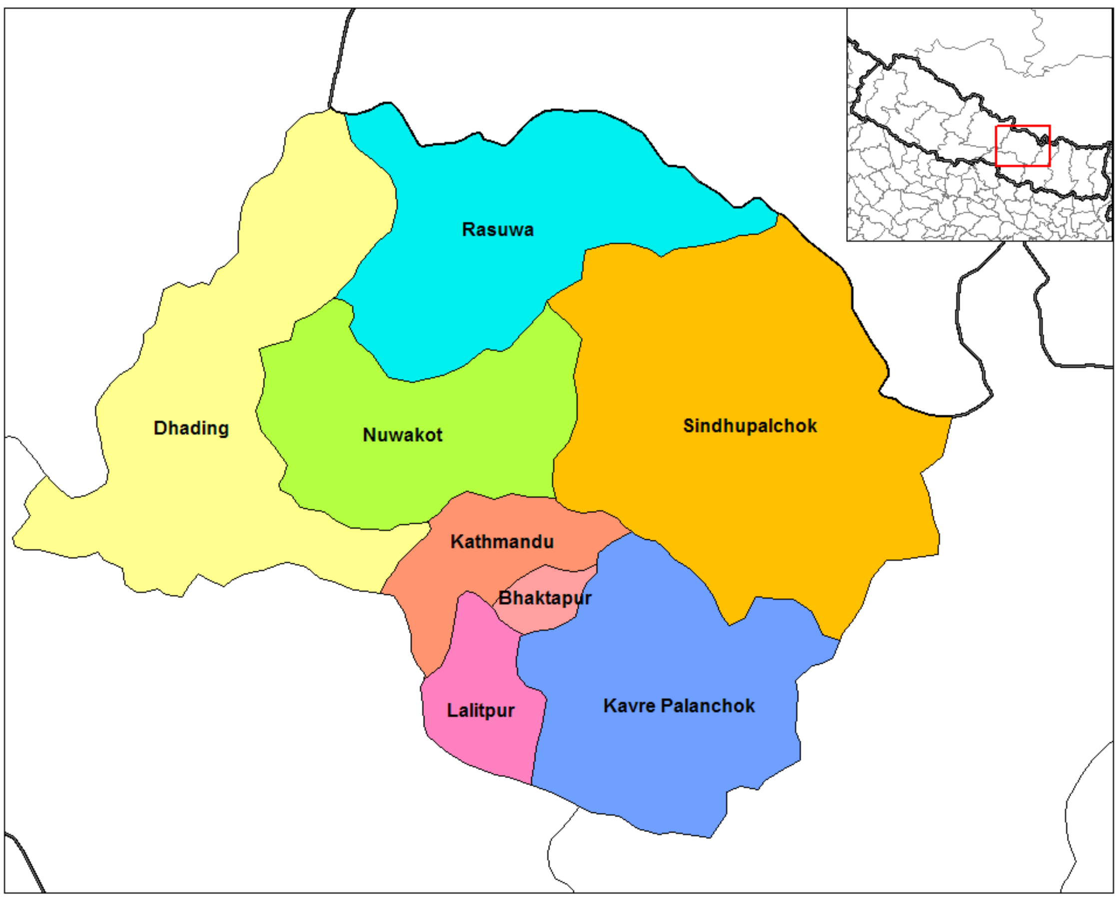
[42] Paul Downton, "Rammed Earth," Your Home, published 2013, accessed March 2017, http://www.yourhome.gov.au/sites/prod.yourhome.gov.au/files/pdf/YOURHOME-Materials-RammedEarth.pdf.
[43] "Permanent Housing Prototypes," ABARI, accessed February 2017, http://abari.earth/open-source-design/2017/12/18/permanent-housing-prototypes.
[44] Vasilios Maniatidis and Peter Walker, "A Review of Rammed Earth Construction. Developing Rammed Earth for UK Housing," published May 2003, accessed February 27, 2017, http://staff.bath.ac.uk/abspw/rammedearth/review.pdf.
[45] Ibid.
[46] Unpublished materials provided to project members, Nripal Adhikary (ABARI), received March 14, 2017.
[47] Vasilios Maniatidis and Peter Walker, "A Review of Rammed Earth Construction. Developing Rammed Earth for UK Housing," published May 2003, accessed February 27, 2017, http://staff.bath.ac.uk/abspw/rammedearth/review.pdf.
[48] David Easton, *The Rammed Earth House* (Vermont: Chelsea Green Publishing Company, 1996).
[49] Paul Graham McHenry Jr., *Adobe and Rammed Earth Buildings: Design and Construction* (Tucson: The University of Arizona Press, 1984).
[50] Ibid.
[51] Ibid.
[52] "Rammed Earth Construction," How Products Are Made, http://www.madehow.com/Volume-3/Rammed-Earth-Construction.html.
[53] Vasilios Maniatidis and Peter Walker, "A Review of Rammed Earth Construction. Developing Rammed Earth for UK Housing," published May 2003, accessed February 27, 2017, http://staff.bath.ac.uk/abspw/rammedearth/review.pdf.
[54] David Easton, *The Rammed Earth House* (Vermont: Chelsea Green Publishing Company, 1996).
[55] "Lime Meets the Construction Challenge," http://www.lime.org/documents/publications/free_download/fact-soil-stabilization.pdf.
[56] David Easton, *The Rammed Earth House* (Vermont: Chelsea Green Publishing Company, 1996).
[57] F.R. Arooz and R.U. Halwatura, *Mud-concrete block (MCB): mix design & durability characteristics, Case Studies in Construction Materials* 8 (2018), https://doi.org/10.1016/j.cscm.2017.12.004.
[58] Unpublished materials provided to project members, Nripal Adhikary, ABARI, received February 2017.
[59] Unpublished materials provided to project members, Gyetrul Jigme Rinpoche, "Project Proposal: Project Mero Gaun," ABARI, received 2015.
[60] Paul Downton, "Rammed Earth," Your Home, published 2013, accessed March 2017, http://www.yourhome.gov.au/sites/prod.yourhome.gov.au/files/pdf/YOURHOME-Materials-RammedEarth.pdf.
[61] Unpublished materials provided to project members, March 2017.
[62] Bill Ashwell, "Nepal Post Earthquake Reconstruction Using Interlocking Compressed Earth Bricks," accessed February 20, 2017, https://www.youtube.com/watch?v=nPRc6DR6F5g.
[63] H. Guillaud and T. Joffroy, "Compressed Earth Blocks: Manual of Design and Construction," accessed February 28, 2017, http://www.rivendellvillage.org/Compressed_Earth_Block_Design_and_Construction.pdf.
[64] Auroville Institute, http://www.earth-auroville.com/compressed_stabilised_earth_block_en.php.
[65] Ibid.
[66] Ibid.
[67] Auram Press 3000 Site at Aureka, Machinery for Sustainable Construction, http://www.aureka.com/earth-construction-equipment/auram-press-3000.
[68] Unpublished materials provided to project members, Sushil Bajracharya, Tribhuvan University, received March 2017.
[69] "Compressed Stabilised Earth Block: Good Soil for Compressed Stabilised Earth Blocks," Auroville Earth Institute, http://www.earth-auroville.com/compressed_stabilised_earth_block_en.php.
[70] Unpublished materials provided to project members, Björn Söderberg, Build up Nepal, received March 14, 2017.
[71] "Rebar reinforcement of compressed earth bricks," Build up Nepal, accessed April 2017, http://www.buildupnepal.com/earth-bricks/.
[72] Unpublished materials provided to project members, Build up Nepal, received March 2017.
[73] Unpublished materials provided to project members, Björn Söderberg, Build up Nepal, received March 14, 2017.
[74] Unpublished materials provided to project members, "Cost Comparison CSEB vs Fired Bricks," Build up Nepal, received February 2017.
[75] Unpublished presentation provided to project members, "Reconstruction with Compressed Stabilized Earth Bricks (Slide 12)," Build up Nepal, received March 2017.

[76] Y. Etzion, *Energy Economics of Soil Construction* (Tel Aviv: The 6th World Congress of Engineers and Architects in Israel, 1983).
[77] Unpublished interview conducted by project members, March 2017.
[78] Hubert Guillaud and Thierry Joffroy, "Compressed Earth Blocks: Manual of Design and Construction," accessed February 28, 2017, http://www.rivendellvillage.org/Compressed_Earth_Block_Design_and_Construction.pdf.
[79] Kaki Hunter and Donald Kiffmeyer, *Earthbag Building: The Tools, Tricks and Techniques* (Canada: New Society Publishers, 2004).
[80] Owen Geiger and Kateryna Zemskova, "Special Issue on Ghorka Earthquake 2015," *Nepal Engineers Association* XLIII, no. 1 (2015), https://static1.squarespace.com/static/5583171fe4b0329e24785056/t/57a81603f5e231cfd15aa5ac/1470633477579/NEA Technical Journal.pdf.
[81] Unpublished interviews conducted by project members, March 2017.
[82] Kaki Hunter and Donald Kiffmeyer, *Earthbag Building: The Tools, Tricks and Techniques* (Canada: New Society Publishers, 2004).
[83] Patti Stouter, "Earthbag Options for Nepal: Draft Guidelines for Reinforcement," Build Simple, Inc., accessed March 1, 2017, http://www.earthbagbuilding.com/pdf/EB%20Options%20for%20Nepal.pdf.
[84] Unpublished materials provided to project members, Roshan K. Jha, Good Earth Global, received March 14, 2017.
[85] Unpublished interview conducted by project members, March 2017.
[86] Ibid.
[87] "Earthbag Projects," Good Earth Global, accessed March 27, 2018, http://goodearthglobal.org/earthbag-houses/2016/6/25/ten-homes-project-kaule-nuwakot-district.
[88] Unpublished photo developed by project members, March 2017.
[89] Owen Geiger and Kateryna Zemskova, "Special Issue on Ghorka Earthquake 2015," *Nepal Engineers Association* XLIII, no. 1 (2015), https://static1.squarespace.com/static/5583171fe4b0329e24785056/t/57a81603f5e231cfd15aa5ac/1470633477579/NEA Technical Journal.pdf.
[90] Unpublished interview conducted by project members, March 2017.
[91] Unpublished photo, Sushil Bajracharya, Tribhuvan University, provided to project members, received March 2017.
[92] Unpublished materials provided to project members, Tribhuvan University staff, received March 2017.
[93] "Build Change Post-Disaster Reconnaissance Report," published May 31, 2015, http://www.buildchange.org/wp-content/uploads/2015/12/2015.10.01-Nepal-EQ-Reconnaissance-Report_Build-Change_Rev-Oct-2015.pdf.
[94] Unpublished materials provided to project members, Sushil Bajracharya Tribhuvan University, received March 2017.
[95] Unpublished materials provided to project members, Sushil Bajracharya, Tribhuvan University, received March 2017.
[96] "Build Change Post-Disaster Reconnaissance Report," published 2015, http://www.buildchange.org/wp-content/uploads/2015/12/2015.10.01-Nepal-EQ-Reconnaissance-Report_Build-Change_Rev-Oct-2015.pdf.
[97] Unpublished materials provided to project members, Sushil Bajracharya, Tribhuvan University, received March 2017.
[98] Ezra Jampole, Reagan Chandramohan, Timothy Frank, and Matthew Bandelt, "Shelter, Retrofit, and Reconstruction of Housing," published 2015, accessed March 29, 2018, https://reaganc.bitbucket.io/publications/technical_reports/Jampole_Chandramohan_Frank_Bandelt_(2015)_Nepal_earthquake_housing_(World_Bank).pdf.
[99] Unpublished materials provided to project members, Sushil Bajracharya, Tribhuvan University, received March 2017.
[100] Ibid.
[101] Naba Raj Neupane and Lalu Prasad Paudel, "Quality and Economic Aspects of Roofing Slates in the Tharpu Area, Tanahu," *Bulletin of the Department of Geology* 14 (2012), http://www.nepjol.info/index.php/BDG/article/download/5438/4523.
[102] "Nepal Earthquake 2015: 2 Years On," Housing Reconstruction and Recovery Platform, published April 24, 2017, assessed July 3, 2018, http://hrrpnepal.org/download/2Gedhw7ntk9pHxiDQszJ_2017_04_24.pdf/maps_infographics.
[103] Unpublished table produced by project members, March 2017.
[104] Unpublished materials provided to project members, Sushil Bajracharya, Tribhuvan University, Tribhuvan University staff, received March 2017.

Chapter 3: Field Investigation and Analysis

During March 15 through March 17, 2017, project participants traveled to rural Nepal to visit three villages to discuss opportunities and challenges of post-earthquake home reconstruction in three earthquake-affected districts of Nepal: Nuwakot, Lalitpur, and Kavre Palanchok (see Figure 3.1). One purpose for field investigation in rural villages affected by the earthquakes was to assess the efficacy of the home reconstruction program.

Figure 3.1[1]
Field Study Districts in Nepal



Project teams familiarized themselves with the Government of Nepal (GON) rural home reconstruction program through interviews with government officials to gain an understanding of their goals and objectives. Research staff visited the three villages in earthquake-affected regions and collected information from villagers about their lives before and after the earthquake, as well as what they knew and thought about the Nepal Rural Housing Reconstruction Program (NRHRP). These interviews were conducted by students from the architecture program of the Institute of Engineering, Tribhuvan University, the TAOYAKA Program of Hiroshima

University, and the Lyndon B. Johnson School of Public Affairs at The University of Texas Austin. This approach allowed the research team to compare the GON's goals and objectives with information reported by residents. Villagers identified local barriers to the reconstruction process in interviews. Villager responses were used to assess the efficacy of information dissemination on the local level.

The three villages visited during the field investigation are located in the hills surrounding Kathmandu, a region that lies between Nepal's southern Terai region and its northern mountain region. The landscape is characterized by steep hills, where residents support themselves via terrace farming. On March 15, 2017, the research group visited Kaule, a village in the Nuwakot district, located approximately 30 kilometers from Kathmandu. Good Earth Global, a local nongovernmental organization (NGO), has a model home in this community and is working to train locals in earthbag house building techniques. After the tour of the model home, students split into groups and interviewed families around the village. On March 16, project members departed to Kotdanda village in the Lalitpur district, located approximately 15 kilometers from Kathmandu. Build up Nepal, a Swedish NGO, hosts training on the use of Compressed Stabilized Earth Brick (CSEB) and is helping residents build homes and other structures. Project members interviewed local residents. From Lalitpur, the research group stayed overnight in Simpokhari, a village in the Kavre Palanchok district, approximately 35 kilometers from Kathmandu. The following day, a local design and construction firm called ABARI showed the research group two model structures in the village: a rammed-earth home and a CSEB-and-bamboo school. After the tour, the students separated into groups and visited households in the village to interview families.

In the first and last villages visited (Nuwakot and Kavre Palanchok, respectively), groups of students were sent to different households to interview families, each in their own homestead. In the second village (Lalitpur), students interviewed groups of villagers gathered at a central location. In each interview, at least one Nepali student acted as translator. Interviews ranged in length from one to two hours. Each meeting began with self-introductions, with a recording of the names of those being interviewed. However, to assure anonymity among village participants, interview notes do not attribute specific opinions to any named individuals. Interview notes were translated from Nepali into English, the common language among the three specific individual student groups.

To adjust for any potential bias of either an interviewer or an interviewee, villager responses from all three sites were evaluated. Responses were reviewed for themes consistent amongst many villagers. One issue that arose is the timing of the interviews. These interviews were conducted in March 2017, before Nepal published Volume II of the report, which described home designs that the Nepali government would accept as earthquake resilient.

Though located in different districts, these three villages are comparable in terms of demographics and post-earthquake experiences. In each community, families have adapted to living and farming on terraces on the steep slopes of the Hill Region. Many families rely on subsistence farming and unstable agrarian income. The topography of the region makes transportation to and from each village difficult and expensive. The population in each village consisted primarily of women, children, and the elderly, as a substantial fraction of the young adults and men moved to Nepali cities or abroad to work, supporting their families through remittances. Family farms grew a range of produce throughout the year, including strawberries, wheat, maize, spinach, rice, and cauliflower. Each of these villages had free access to a spring-fed water source used for potable water, washing, and irrigation. Each village was connected to the electrical grid, which villagers found reliable and reasonably priced.

Most of the families that had remained in the villages lived in temporary shelters, typically constructed of corrugated tin sheets and mud. Out of necessity, some families still lived in partially damaged homes. It was common to find multiple families living on one plot of land. For example, in Nuwakot, the families of four brothers shared one plot of land. Two brothers had left Nuwakot, one each to Kathmandu and Saudi Arabia. The remaining two brothers and their extended families lived on the plot. In Kavre Palanchok, a father and son had two separate dwellings on one plot of land before the earthquake. Now the father lives with his family in his partially damaged house, while the son lives with his family in the temporary shelter.

Some of the villages had created community partnerships to improve their lives. In Nuwakot, some villagers worked together to move produce to a local market near the village. To traverse the great distance between the village in Kavre Palanchok to the closest town of Dhulikhel, villagers created a small cooperative; members pooled their money to send representatives to the city to purchase necessary supplies. A group of seven Lalitpur villagers volunteered their time to learn how to make CSEB and construct a home with CSEB. They worked together to build all seven homes with CSEB and assist each other in the reconstruction process. In Lalitpur, the village community elected a leader to collect and pay electricity and water fees as well as relate to organizations and persons outside the village to aid on community issues. If community members were to become unhappy with the performance of an elected leader, they could elect another leader.

Barriers to Reconstruction

Based on village interviews, there were common barriers to reconstruction before, during, and after the earthquake. Some of the issues identified by villagers were: knowledge of the home reconstruction process; selecting the appropriate earthquake-resistant design; and hopes for their community. The subsections below describe villager misconceptions; reconstruction barriers; perception of alternative building technologies (ABTs); the process for managing funds; and materials and labor cost barriers.

Table 3.1[2]
Misunderstood Topics of the Home Reconstruction Program

- Villager eligibility for a grant
- The full cost of reconstruction
- Appropriate assistance from external organizations
- The grievance process
- Payment of engineers for inspection
- Satisfaction with the home reconstruction process
- Hidden costs

One common issue encountered was that villagers did not understand the eligibility rules for the GON grant program. A common misconception was the "victim card." After the earthquake, a victim card was given out to each affected family. The card identified the family as needing assistance with temporary relief.[3] Some villagers said that the victim card served as proof of a family's eligibility for a home reconstruction grant, which is inaccurate. Before the earthquake, many rural families kept their proof of homeownership with the Village Development Committee (VDC). When the earthquake hit, some of the VDC buildings were either destroyed or damaged.[4] While the victim card served as an important as a form of identification, the GON required proof of homeownership as a prerequisite for a grant. Eligibility for a home reconstruction grant also required that an NRA engineer inspect each home and the villager's proof of ownership of the land. [5]

As discussed in Chapter 1, there were three funding tranches for each home. Though the first funding tranche was meant to reimburse home foundation costs, there are many expenses associated with steps prior to the foundation. First, a family needed to demolish the remains of their old home and obtain building permits. Permit costs were not cheap; one villager reported that these permits cost between 15,000 and 20,000 Nepali rupees, or about 30 to 40 percent of the first tranche. Other villagers expressed frustration that the cost of necessary building materials (such as rebar, cement, or wood for formwork) may not be included in building design cost estimates.

Many villagers did not understand which costs could be covered by a NRHRP grant for home reconstruction and which costs they would have to pay for themselves. Many families erroneously believed that the grant was supposed to pay for their home's full reconstruction. No family could afford a complete home reconstruction based on the grant alone, as the NRHRP grant was only meant to provide a partial incentive to families to reconstruct earthquake-resistant homes. To supplement the grant, the GON also provided low-interest loans.[6]

Villagers expressed a common unfamiliarity with the exact NRHRP grant rules and a frustration with the process. Villagers noted that they had only learned about the grant through word-of-mouth and had not read the print copy of the grant rules.

Some families reported their belief that the GON and/or NGOs would come and help them rebuild their homes. Such families reported that they had halted home reconstruction, waiting for an NGO, nonprofit, or GON agency to help them rebuild. While there are several GON departments which support home reconstruction, the Nepali government had made it clear that it was not responsible for the reconstruction process. The NRHRP stipulated that reconstruction is a homeowner-driven process. A family could accept help from an NGO or a nonprofit in the reconstruction process. However, to be eligible for each tranche of the NRHRP, a house needed to meet the design criteria stipulated in Volume I and II of the Design Catalogue for Reconstruction of Earthquake Resistant Houses.[7] The GON had invested in training and deploying engineers, masons, and other professionals who could provide advice.[8,9,10]

Many villagers remarked that there was no way for them to express grievances to the GON, even though the NRA had outlined a grievance process in its Standard Operating Procedure for Earthquake Housing Reconstruction Enrollment (SOP/EHRE).[11] That SOP/EHRE document explains where to file grievances, how they are stored, the resolution process, and who oversees the resolution process.

Some residents from each village reported that they thought it was necessary to pay the GON engineer to inspect a home at each stage of reconstruction. In reality, the NRA pays the engineers. Another issue was that each VDC had its own approval process for home reconstruction. Project members could not confirm whether the differences in the process were due to a misunderstanding on the part of the villagers, or if VDCs had developed different processes in different regions.

Of the villagers who understood the actual purpose and limitations of the NRHRP grant, there were two common responses. Some families perceived the funds to be insufficient and did not use the NRHRP grant. Other families decided to use the money for other pressing needs, such as medical bills, school, or food.

According to one local NGO staff member, there was a general apathetic sentiment throughout the villages about the likelihood of rapid home reconstruction.[12] Some residents had lived in temporary shelters for so long that they begin to lose motivation to reconstruct. One man reported that his house was not earthquake resistant but that he and his family had continued to live in it anyway. The individual felt that the NRHRP grant would be insufficient to rebuild his home, so he decided to use the first tranche of money to patch cracks and build a better roof instead.

An initial focus of this student research project was on the type of innovative construction technologies and local materials that could improve outcomes from the home reconstruction process. Table 3.2 lists some village perceptions of these technologies.

Table 3.2[13]
Village Perceptions of Alternative Building Technologies

- Villagers did not report understanding which building technologies are considered earthquake resistant
- Stone-and-mud construction failed in the earthquake
- Reinforced concrete construction usually survived the earthquake
- Alternative building technologies (ABTs) may not be considered earthquake resistant in Nepal
- Brick and concrete buildings can be erected to multiple stories and survive quakes
- Brick and concrete were perceived by villagers to be superior to ABTs because they are preferred in Kathmandu

When the earthquake hit in 2015, the homes that were most damaged were those built with stone and mud alone and without rebar reinforcement. Many homes built with concrete brick and iron rebar reinforcement withstood the earthquake or were damaged partially. As a result, villagers reported distrust of the "old" way of building homes with stone and mud alone. They did not believe that stone-and-mud construction would protect them. Instead, many villagers wanted to build their next home using concrete. Concrete conventional homes could take the form of reinforced concrete columns, concrete mortar and fired bricks, or concrete blocks. Villagers reported that they recognized that horizontal crossband reinforcement represented a valuable structural element.

Some villagers expressed skepticism of building with alternative building technologies (ABTs). Villagers also expressed a willingness to use ABT in the event of financial and/or technical assistance to build with these technologies. Villagers expressed concern with ABTs, both because they did not know how to use them in home reconstruction and they were not certain whether the Nepalese government would accept ABTs as earthquake resilient. They also stated that they did not understand which ABT designs are earthquake resistant. Villagers were unfamiliar with ABT unless where was an NGO promoting it in their village. Some villagers expressed hesitation about working with local NGOs because they did not know whether the NRHRP would pay them the second and third tranches or accept the ABT designs as earthquake resilient.

Perceived strength is a determining factor for those willing to build with ABT. Project members observed in the visited villages that local NGOs had completed ABT structures and trained local villagers in the construction of model homes. For villagers willing to build with an ABT, some technologies were preferred over the other. For instance, Compressed Stabilized Earth Bricks (CSEBs) were perceived as "stronger" than bamboo because the appearance of a concrete and brick house resembles structures seen in cities such as Kathmandu.

While nonprofit organizations promoting ABTs strive to provide home designs that are less expensive and more sustainable than conventional building methods, the local economic situation and geographic location of villages could limit the use of these technologies. Some of the ABTs require specific soil mix ratios (i.e. CSEB, earthbag, and rammed earth), are labor intensive, and/or need additional processing (i.e. bamboo). In some villages, residents either did not have the correct soil to use excavated earth from their property or the distance was too far from a bamboo processing facility. Transportation costs are a major barrier to the adoption of ABTs. One woman in the Lalitpur district stated that she could not afford CSEB training; in the end, she chose not to reconstruct her home from CSEB. Many in the village were excited about CSEBs at first, as they liked the look of the bricks. However, according to interviews, the cost of labor, materials, and machinery have prevented this technology from being adopted widely in Lalitpur.

Villagers attributed social value to certain building designs over others. Villagers are skeptical of ABTs because they are unfamiliar with these ways of building, and they do not see their neighbors building with ABTs post-earthquake. Some perceptions may have been based on the use of common building materials in specific regions and social classes. For instance, many villagers expressed a preference of CSEB over bamboo because CSEB structures reminded them of the bricks and concrete structures in Kathmandu. Bamboo is a commonly used construction material in many villages, but it is mainly used to build structures for animals. Thus, villagers may perceive bamboo as weaker than concrete structures and other ABTs, as well as more appropriate for the construction of livestock housing. These perceptions and social values motivate families towards conventional concrete structures, rather than either traditional stone and mud or ABT methods.

Some villagers expressed interest in ABTs under certain conditions of financial or technical assistance. For instance, some villagers said they would consider using an ABT if the NRHRP would approve the ABT as earthquake resistant and if they could be assured of the ABT's grant eligibility. Some villagers reported that they would build with ABTs if the cost were to be less than conventional methods; if they observed their neighbors building successfully with a specific ABT; or if they were taught how to use ABTs with locally available materials.

Bank and Government Barriers to Home Reconstruction

Villagers expressed frustration with the GON's requirement that only distant institutions could distribute funds. Many villagers said that the loan interest rate was too high for them. The GON provided the major source of home reconstruction funds through its 300,000 Nepali rupees per home grant program and supplemental loan program. Some villagers reported that they would not take out a loan, fearing that a default would cost them their land.

Table 3.3[14]
Administrative Barriers to Nepali Home Reconstruction

- Distance from village to banks
- Complex bank procedures
- Land title issues cloud grant disbursement
- Loan programs complicat the reconstruction process
- Frustration with government administration, including the grant approval process and engineering supervision of reconstruction
- Lack of communication and cooperation among institutions
- High material and labor costs compared to villagers' income
- Grant funds are not sufficient in themselves to rebuild a house
- Loan funds are too expensive and carry a risk of foreclosure

Nepal relies solely on banks for grant money management, and home reconstruction funds are disbursed through local or regional banks. Villagers stated that it is difficult to make regular trips to banks due to distance and road quality. Some women reported concern about their safety when traveling to banks. Some persons who did visit banks to set up an account reported that the process required too much paperwork. However, villagers who did apply for the grants and filed bank paperwork properly reported that the GON transferred funds into their accounts rapidly.

Nepal distributed so-called "victim cards" to any family that had suffered in the earthquake, as a first aid response. The process of allocating home reconstruction aid was different, as a homeowner was required to document title to land and property prior to being considered eligible for a home reconstruction grant.

Villagers indicated that the process of establishing landowner rights is a difficult problem. They reported that the grant assumed that only one family lives on a plot of land and that a landowner lives on that plot. In Nepal it is common to have multiple families living on one plot, such as brothers with their wives and children, or a father and his sons' families. The owner could be related to the family on the land, but he/she could live in a distant city or abroad. In both these cases, the people living on the land and who were still in temporary shelters might not have had the right to receive any grant or loan. A GON grant was distributed only to the person who could prove that he/she owns the land. This led to some instances where the landowner received the first tranche but did not give the money to the family who lives on the land. The title requirements for proof of ownership had the result of excluding certain parts of the population from participating in reconstruction. Residents had difficulty receiving money if the land was not registered in their personal name, but instead was in the name of another member of their family who lived on or off the land. This land title requirement would exclude certain families or delay construction, especially if the person who owned the land did not live in the village or if they were elderly or unable to travel.

In interviews, villagers consistently expressed frustration with the GON's administration. Many villagers had not applied for a grant and did not know how to confirm their eligibility. Some villagers reported that the home approval process was convoluted and that the GON was slow to respond. Villagers indicated that they would prefer clear written directions on the funding process and more contact with an engineer or construction professional to aid in the reconstruction process; they reported that so far, they had received only verbal directions. Villagers reported that their interactions with engineers were too infrequent; some reported that they had not seen the engineer since the initial site inspection. Even those families who had progressed through construction phases indicated that their reconstruction was held up due to months-long waits for the GON engineer's inspection and approval.

Villagers reported cases of miscommunication and/or lack of collaboration among NGOs or nonprofits with the GON, suggesting that some agency efforts have been counterproductive. The GON has approved some ABT designs. Any yet-to-be-approved ABT designs would not be eligible for grant funding or other kinds of state support. Some households suggested that their use of ABTs in reconstruction deprived them of such grants and supports. Some expressed dissatisfaction towards NGOs as a result. The challenges for families seeking to reconstruct destroyed homes include two questions:

1) What designs and building methods are accepted as "earthquake resilient" and thus eligible for aid?

2) How can the family manage the Nepali grant, other supplemental funds (obtained from remittances or savings), and the building process to complete reconstruction and receive the second and third grant trances?

Material and Labor Cost Barrier for Reconstruction

Before Nepal published its Volume II of the design catalog for reconstruction of earthquake-resistant houses, the NRA approved only conventional home designs which used reinforced concrete, reinforced concrete columns, concrete blocks, or brick with concrete mortar. When Volume II was published, the building technology options expanded to include some ABTs such as CSEBs, earthbags, and bamboo structures. These technologies utilize local materials from village land and so reduce the volume of concrete needed to construct a home.

While the Volume II designs promote less costly home design technologies, the technologies require specific soil mix ratios (i.e. CSEB and earthbag) or raw material processing (i.e. bamboo). Some earth in some villages do not meet the soil mix requirements. This meant that some villagers would have to import materials. The cost of the materials, as well as the difficulty and costs of transporting materials would complicate the reconstruction process. Even though conventional concrete homes require more cement and/or bricks, villagers expressed a preference to pay more for a technology they knew would work in the event of another earthquake. Villagers expressed a clear preference for conventional home construction. Some reported that they had not begun the reconstruction process because of the high cost of acquiring and transporting building materials.

Some alternative technologies require expensive machinery or additional processing. A special machine is utilized to make CSEB; some versions of the equipment must be shipped in from outside the country if they are not available in Nepal. Such machines may be purchased by an aid organization and donated to a community to share; otherwise, it would be infeasible for one family to bear the full cost of a brick machine. Overall, cooperation among villages is vital for CSEB success. Bamboo requires processing at a central processing plant to prevent pests and rot. Even if a family grows bamboo on their land, they would need to ship the bamboo to be processed at a substantial cost. Other expensive equipment for construction can include formwork needed for foundations and some ABT options, such as rammed earth.

Labor is another key barrier. Reconstruction cost savings occur if a family can build part of the home themselves. Three common concerns expressed by villagers regarding home reconstruction were the cost and availability of materials, the absence of appropriate young adults and males as potential sources of reconstruction labor, and the challenge of raising sufficient funds for completing home reconstruction. While expatriates can provide a more stable income for the family, emigration has drained communities of people with home rebuilding skills. Some villagers have chosen to help each other reconstruct homes, but issues arise here as well. One villager voiced a concern with the amount of work: if he wants a small home, but his neighbor wants a large home, he will be donating more labor than his friend. At first, villagers from the Lalitpur district were excited about CSEB and joined the training. However, during the brickmaking process, the villagers realized how much work was required to make one brick. As a result, some decided that they no longer wanted to use this construction method.

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[1] "Lalitpur District, Nepal," https://en.wikipedia.org/wiki/Lalitpur_District,_Nepal#/media/File:Bagmati_districts.png.

[2] Unpublished materials collected by project members, March 2017.

[3] "Victims of earthquake get ID cards," The Himalayan Times, published July 20, 2015, accessed April 17, 2017, https://thehimalayantimes.com/nepal/victims-of-earthquake-get-id-cards/.

[4] "The identity crisis frustrating Nepal's quake survivors," IRIN News, published May 21, 2015, accessed April 17, 2017, http://www.irinnews.org/feature/2015/05/21/identity-crisis-frustrating-nepals-quake-survivors.

[5] "Earthquake Housing Reconstruction Programme SOP for Enrollment," National Reconstruction Authority, published April 2016, accessed April 15, 2017, https://shocksafenepal.files.wordpress.com/2016/05/final-report-ssn3.pdf.

[6] "Nepal Government Distribution of Earthquake Reconstruction Cash Grants for Private Houses," The Asia Foundation, published 2016, accessed February 2017, https://asiafoundation.org/wp-content/uploads/2016/12/Nepal-Govt-Distribution-of-Earthquake-Reconstruction-Cash-Grants-for-Private-Houses.pdf.

[7] "Design Catalogue for Reconstruction of Earthquake Resistant Houses," accessed March 2017, https://www.buildupnepal.com/wp-content/uploads/2017/04/design-catalogue-volume-II-final.pdf.

[8] "Nepal Government Distribution of Earthquake Reconstruction Cash Grants for Private Houses," The Asia Foundation, published 2016, accessed February 2017, https://asiafoundation.org/wp-content/uploads/2016/12/Nepal-Govt-Distribution-of-Earthquake-Reconstruction-Cash-Grants-for-Private-Houses.pdf.

[9] "Earthquake Housing Reconstruction Programme SOP for Enrollment," National Reconstruction Authority, published April 2016, accessed April 15, 2017, http://documents.worldbank.org/curated/en/488031468286831605/pdf/779070WP0Box370UBLIC00rural0housing.pdf.

[10] "Nepal Earthquake Housing Reconstruction Multi-Donor Trust Fund: Annual Report July 1, 2015–July 31, 2016," The World Bank Group, published 2016, accessed April 15, 2017, https://www.nepalhousingreconstruction.org/nepal-earthquake-housing-reconstruction-program.

[11] "Earthquake Housing Reconstruction Programme SOP for Enrollment," National Reconstruction Authority, published April 2016, accessed April 15, 2017, https://shocksafenepal.files.wordpress.com/2016/05/final-report-ssn3.pdf.

[12] Unpublished comment provided to project members, Nepali nonprofit representative, March 2017.

13 Unpublished materials provided to project members, March 2012.
14 Unpublished table developed by project members, March 2017.

Chapter 4: Discussion and Conclusions

Students and researchers traveled to Nepal in March 2017 to learn whether the lack of affordable and appropriate building methods could explain why many villagers still live in temporary shelters. During the field visit, villagers reported that technology was not the most important barrier to rural housing reconstruction. For villagers there were four key reconstruction barriers: the cost of transportation and materials; insufficient reconstruction incentives; the funding grant processes, and the need for more consistent interaction between the government and the villages.

Residents in all three communities reported that the embodied cost of transporting people, materials, and equipment to remote villages was a central barrier to reconstruction. For some villagers, the cost of traveling to and from cities to complete paperwork at a bank or at the local VDC was either a barrier to or significantly slowed reconstruction. Costs were a challenge, whether the family chose to build a conventional home using bricks, stone, and concrete or with an alternative building technology (ABT). Families reported that the cost of materials, equipment, and transporting equipment and materials exceeded the funds available under the housing grant. Families that chose reconstruction methods that rely on specific soil ratios or local treatment of materials reported that they incurred additional material and transport costs, which created cost disadvantages for ABTs. When NRA engineers or local VDC officials assist a family on housing design, it is important for the engineer or local official to explain these embodied costs, so a family can evaluate which technology is appropriate for their situation.

Volume II of the "Design Catalogue for Reconstruction of Earthquake Resistant Houses" includes many ABTs that are now considered earthquake resilient. The publishing of these technologies in Volume II will make it easier for nongovernmental organizations (NGOs) to promote these technologies and overcome barriers to their use. There is a widely held perception that concrete is the construction material preferred by city residents. Earthquake-resistant designs appear to dominate some families' home design decision over cost. Many families reported that they chose not to work with the ABT because they were not familiar with the new technologies, do not understand how to build with them, or know how the ABTs would respond to an earthquake.

The complexity of multiple phases of the Nepal Rural Housing Reconstruction Program (NRHRP) funding process appears to have slowed rebuilding of rural homes. Some families reported that they have not started reconstruction because they were confused about their eligibility for the NRHRP grant. If the Government of Nepal (GON) were to deploy mobile teams to live in or near villages throughout the reconstruction program, families could access professionals throughout reconstruction and those professionals could assist with the construction procedures, reconstruction process, material sourcing, and access to other social services. A GON program that relies on homeowner initiative alone may not be enough to help families move forward.

The GON ought to consider a formal program evaluation of the NRHRP process. Impact evaluations are common to evaluate direct, indirect, or induced outcomes of a government intervention. This approach could allow the GON to develop intelligence as to why specific housing outcomes have or have not occurred, as well as plan for future post-disaster response.

The research team found that villagers who understood that the grant was not supposed to pay for the full cost of reconstruction had two main reactions. Some villagers decided not to use the grant at all. Other villagers took the first tranche of grant money and used it for purposes other than reconstruction. In both cases, the GON's objectives were not achieved. Villagers suggest that increasing the grant amount alone would be insufficient for improving the efficacy of the GON's reconstruction program. When the earthquake struck in 2015, it not only destroyed homes, but also affected livelihoods and access to education and medical care. The NRHRP focuses on supporting housing reconstruction efforts, but it does not address the other financial constraints on these families. The program could have been more effective had the initial assessment considered and assessed each family's entire fiscal situation.

Given that the GON grant does not cover the full cost of home reconstruction, it could consider larger grants to empower villagers to rebuild. On the other hand, the amount of money may not be the most important factor limiting the initiative of families to rebuild their homes. In 2016, the NRA increased the GON whole-housing grant from 200,000 Nepali rupees to 300,000 Nepali rupees. The GON has the data to judge how effective this increase was in reconstruction outcomes.

Efforts should be made to improve the speed and clarity of communications among villagers, VDCs, and the reconstruction authorities. Considering that many of Nepalis have cellphones, there is already infrastructure in place to allow some procedures to be carried out over the phone instead of requiring villagers travel to a bank or VDC for every step of the process.

The research team visited three districts: Nuwakot, Lalitpur, and Kavre Palanchok. Reconstruction data from these districts is gathered by the Housing Reconstruction and Recovery Platform (HRRP). In April 2017, there were large disparities in the enrollment and completion of the reconstruction grant program. The rate of households which had received the first tranche was extremely high, but still subject to high variability between districts. The Nuwakot district reported that 94 percent of the beneficiaries were enrolled, and 93 percent had received the first tranche. Both Lalitpur and Kavre Palanchok have lower percentages. Lalitpur reported that 79 percent of the beneficiaries were reported as enrolled, and 76 percent received their first tranche. 88 percent of Kavre Palanchok's beneficiaries enrolled, but also reported that of those beneficiaries, 100 percent had received the first tranche and 8.2 percent had received the second tranche.[1] Based on the village interviews, it is hard to understand the difference between the GON's reconstruction statistics versus the comments from villagers in the field. While all three districts reported high enrollments and receipt of the first tranche, little real reconstruction was visible in the villages visited. An evaluation could examine both final outcomes as well as why the intervention worked or did not work, or even which parts of the intervention made an impact.

It may be infeasible to restructure the GON's rural home reconstruction grant program at this time. However, the GON may be able to send out mobile teams with members who have diverse useful skill sets. Such support teams could aid in a systematic improvement of the rural villages affected by the earthquake. A diverse mobile team could include an engineer, a construction professional trained in conventional and alternative building technologies, and a social mobilizer.

Each team member could be knowledgeable of the grant process so that they could assist families trying to follow the steps of the program. The social mobilizer could be equipped with knowledge of social services—such as healthcare, education, and job training—that might be useful to earthquake-affected families. By living in or near the community, the mobile team could support families throughout the home reconstruction process.

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[1] "Housing Recovery and Reconstruction Platform," published June 25, 2017, accessed April 2018, https://data.humdata.org/organization/hrrp-nepal.

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