Housing Subsector Report
Mercy Corps Intervention Areas
2015 Gorkha Earthquake, Nepal

September 2015

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1 Executive Summary

This Housing Subsector study was performed in order to collect and analyze important information regarding the housing-related needs and priorities of the people affected by the 2015 Gorkha earthquake in Mercy Corps' areas of intervention. In addition, detailed technical information was collected during the study which has been used to both inform the Demolition, Materials Salvaging and Materials Reuse flyer produced (refer to Section 5) and develop recommendations for the development of disaster-resistant reconstruction and retrofitting design guidelines for recovery.

Homeowner and home builder surveys were conducted in 6 rural villages located in the Kavrepalanchok and Sindhupalchok districts of Central Nepal on June 9, 2015 through June 13, 2015. Observations of damage to the home and school buildings in each village were conducted in conjunction with these surveys. The villages that were visited in the Kavrepalanchok district were Dhungkharka, Chyasingkharka, Mahankal Chaur, and Chalal Ganeshthan. The villages that were visited in the Sindhupalchok district were Ramche and Maneshwor. All 6 villages were among those that sustained substantial damage in the April 25 M7.8 earthquake, and the May 12 M7.3 aftershock. A total of seven homeowner surveys, six builder surveys, and six material surveys were conducted during the fields visits made between June 9-13, 2015. In addition to these surveys, a focus study was conducted in Sunkhani, a village development committee located in the Nuwakot district. During this focus survey additional information was collected from 71 homeowners.

The predominant building type used for housing in the villages consists of unreinforced stone masonry walls with mud mortar, wood framed floors and wood framed roofs. Concrete frame with unreinforced brick infill was also used in some of the villages for both housing and school construction. The use of framed infill appeared to be more prevalent the closer the village was to a larger municipality. There were also scattered examples of unreinforced brick masonry construction throughout the areas that were observed.

Techniques used to construct stone walls appeared to vary by district. Villages surveyed in the Kavrepalanchok district incorporated mud mortar and uncut stones, which were typically round in nature, for the majority of wall construction observed. Cut stones, when they existed, were typically only incorporated at wall corners. However, in the Sindhupalchok district the use of cut stones was more prevalent throughout the entire wall. The use of mud mortar was also common in Sindhupalchok, but the thickness of the mortar joints were much smaller than the mortar joints observed in Kavrepalanchok. Houses in Sindhupalchok also exhibited cases of dry stone construction, where no mortar was used to bind the stones together. Cement mortar was typically not used in either district.

The floors and roofs for the houses were typically framed with wood members that were cut from locally sourced trees. The locally sourced trees came from either local community forest or from privately owned land. The ends of the wood framing members were typically embedded into masonry walls at one end, and supported at the other end by wood girders/posts located along the interior of the building. The floor surfaces were made from mud plaster, and the roofing material consisted of corrugated galvanized iron (CGI) sheets, slate, or tile. Most of the houses were one to three stories in height, with the most common

configuration being two stories with a full height attic. Continuous stone footings typically ran underneath the exterior perimeter walls, and localized stone footings were typically located under interior posts. Floors on grade consisted of compacted mud.

The schools that were observed were built with either stone masonry walls or concrete frames with brick infill. Many of the older school buildings that were observed consisted of stone masonry walls with steel truss roof framing. Steel trusses observed in the field were made from either cold formed steel sections, or structural steel tubing/HSS sections. In some instances the trusses were supported by steel pipe columns that were embedded inside stone masonry pilasters.

While Nepal has national standards for stone masonry construction, there was little evidence that these standards were implemented in the field. For example, only a few houses included horizontal bands within the wall construction, and tie stones were essentially nonexistent. Many of the homeowners and builders were not aware that standards for stone masonry construction existed. Most of the builders that were interviewed had limited formal education, and did not have any formal construction training. Their craft was developed by observing the work of others, as opposed to undergoing proper training. Perhaps as a result, most of the houses within a certain village had the same plan layout and structural system.

Access to the villages visited is typically via narrow and steep dirt roads and pedestrian pathways that are cut into the hillside. While it is possible for small trucks and buses to travel on the roads when they are dry, it was apparent that this would be much more difficult when the roads are wet. Evidence of debris flow and cracks in hillsides suggest that the hillsides are prone to sliding, which often leads to blocked roads. Most of the villagers walk to the nearby towns for supplies or to attend school.

All of the houses that were surveyed were built either by the homeowners themselves or by local builders hired by the homeowner. Some of the houses were built by the father, or an earlier ancestor, of the current homeowner. Homeowners typically provide building supplies and materials to the builders. Schools were typically built by local builders, or by outside builders brought in by the government.

The homeowners surveyed indicated that they would like to rebuild their new home similar to their original home. However, they intend to rebuild using safer techniques. Some homeowners also indicated that if they had the money they would prefer to rebuild using RC frames with brick infill, as opposed to unreinforced stone masonry. In one village (Ramche) some of the people planned on using a steel framed roof truss system because they felt it was safer. Their opinion was based on observations made in a nearby town center where the majority of the buildings with steel framed roof trusses performed well.

2 General Background Information

2.1 Earthquake Details

On Saturday, April 25, 2015, at 11:56am local time, a M7.8 earthquake struck near the village of Barpak located 76 km (47 miles) northwest of Kathmandu. This earthquake is referred to as the Gorkha Earthquake, named after the district in which it occurred. Seventeen days later, on May 12 at 12:50 pm local time, an earthquake of M7.3 again shook Nepal, this one centered 74 km (46 miles) east of Kathmandu (refer to Figure 2.1). Although this second earthquake was large and several miles from the initial earthquake it is considered an aftershock of the April 25 event. Both earthquakes, including a subsequent series of smaller aftershocks, were the result of thrust faulting between the subducting India plate and the overriding Eurasia plate, which are converging at a rate of 45 mm/year in the north-northeast direction.

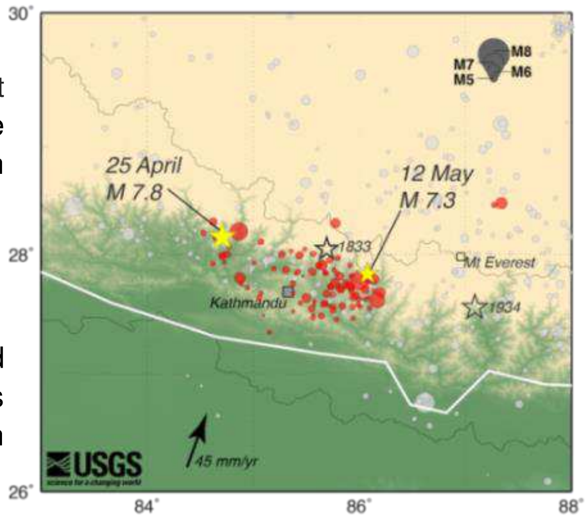

Figure 2.1 April 25, 2015 and May 12, 2015 earthquake epicenter locations, including epicenter location for the 1833 and 1934 Nepal earthquakes (USGS, 2015) [15]

The Post Disaster Needs Assessment (PDNA), issued by the government of Nepal, noted that 31 of the country's 75 districts were affected, out of which 14 were declared 'crisis-hit'. The PDNA also noted that the earthquake and the ensuing aftershocks killed over 8,700 people and injured approximately 22,300. The National Society for Earthquake Technology - Nepal (NSET) reported that over 500,000 houses were considered completely destroyed and over 269,000 houses were partially damaged. Of government buildings, nearly 1,000 were completely destroyed and over 3,000 were partially damaged. Reports have also indicated that nearly 7,000 public schools have been destroyed.

2.2 Political Boundaries and Framework

Prior to initiating construction of any type in a country, it is important to understand the country's political system, its political boundaries, and its process for implementing and permitting construction projects. Obtaining a firm understanding of these elements promotes efficient implementation of future construction and training activities. At the moment, Nepal's political system is in a transition phase which makes it important to acknowledge that the existing government structure, political boundaries, building codes and their method of implementation are all subject to change in the coming months.

Previously, Nepal's political framework functioned as a constitutional monarchy. However, as of May 28th, 2008 the constitution was altered by a constituent assembly to make the country a republic. Currently Nepal functions as a republic with a multi-party system. The President acts as the head of state, in a role that is primarily viewed as ceremonial, and the Prime Minister acts as the head of government.

The existing political boundaries of Nepal resolve the country into several development regions that are subdivided into administrative zones. Each administrative zone is further subdivided into districts, where each district consists of both municipalities and village development committees (VDCs). Both municipalities and VDCs are subdivided into wards which are defined as the country's smallest administrative unit.

Municipalities are defined as cities that incorporate 9 to 35 wards, have at least some minimum criteria of population and infrastructure, and have been officially declared as a municipality by the government. VDCs typically consists of 9 wards and are defined as not meeting the minimum criteria required to be classified as a Municipality. In total, Nepal currently consists of 5 development regions, 14 administrative zones, 75 districts, 130 municipalities (including 72 newly declared in May 2014), and approximately 3,915 VDCs. For a graphical representation of each development region, administrative zone, and district refer to Figure 2.2 and Figure 2.3

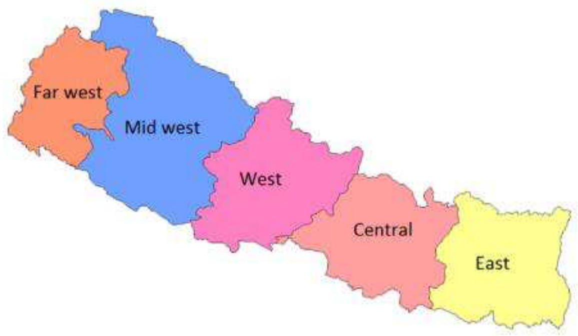

Figure 2.2. Map highlighting the five development regions of Nepal [1]

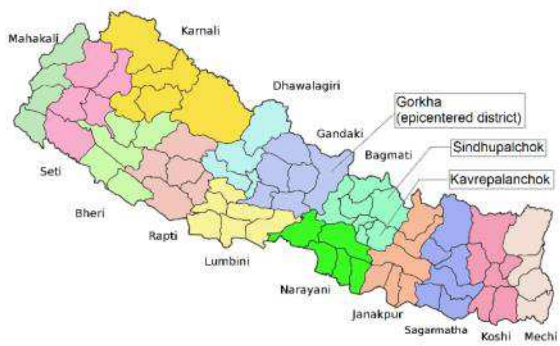

Figure 2.3. Map highlighting the fourteen zones and seventy-five districts of Nepal [2]

2.3 Building Codes

Following the 1988 earthquake in Nepal, Nepal's Ministry of Housing and Physical Planning (MHPP) requested assistance from the United Nations Development Program (UNDP) and their executing agency, the United Nations Centre for Human Settlements (UNCHS), to develop a national building code. With the aid of various consultants, the Nepal National Building Code (NBC) was prepared in 1993. It was primarily based on the Indian Building Code at the time and was officially published in 1994. The building code was approved by the government of Nepal in 2003, issued by the Department of Urban Development and Building Construction (DUDBC) within the Ministry of Urban Development (MoUD), and by 2006 it was made mandatory in all municipalities. However, a deadline for the implementation of the building code was not established, and the mandatory implementation of the building code did not extend into the smaller administrative areas defined as Village Development Committees (VDCs).

In 2009, the Government of Nepal (GON) issued a report identifying recommendations for updating the NBC. A draft of the new building code was intended to be published in July

2015, but this publication was never issued, and the publication date for the new draft of the code is unknown at this time.

The building permit review process varies by location as well. Responsibility for developing, adopting and enforcing the code or bylaws falls to the VDCs, Municipalities, and the District Development Committees for the implementation in their jurisdiction. A 2009 report on the *Recommendation for Update of the Nepal National Building Code* issued by the GON Ministry of Physical Planning and Works, describes examples of different permitting procedures in the Kathmandu Metropolitan City area and the Lalitpur Sub-Metropolitan City area. Both however, include phased permitting as a way to check progressively the construction quality.

According to the Earthquake Engineering Research Institute's (EERI) *Learning from Earthquakes Briefing for the April 25, 2015 Nepal Earthquake*, as of 2015, twenty-six of 191 municipalities had begun building code implementation. Observed enforcement of the building code varies however. In particular, they note that public buildings and schools seem to be generally more compliant than private schools and buildings. Rural areas do not seem to have building code implementation; instead it has been focused in more urban centers. Also, examples were found where the structure permitted did not match the structure built, for example – five stories constructed on a building permitted for two, or 17 stories built instead of 12 permitted.

For new construction, the existing version of the NBC covers the most common building types constructed in Nepal and consists of four different levels of sophistication: Part I - international state-of-the-art (alternative methods), Part II - professionally engineered structures, Part III - buildings of restricted size designed to simple rules-of-thumb, and Part IV - remote rural buildings where expected control is limited, but structures categorized under the latter two sections are permitted to be designed under Part II. Part II includes provisions for unreinforced masonry, plain and reinforced concrete, steel, timber, and aluminum structures which are comprised significantly of references to Indian Standards. Part III includes provisions for reinforced concrete frame buildings with and without infill as well as load-bearing masonry structures. Part IV includes provisions for low strength masonry (non-erodible walling units such as stones, burnt clay bricks, solid blocks, stabilized soil blocks, etc with mud mortar) and earthen buildings not taller than two stories plus an attic floor.

The NBC does not include technical literature on repair and retrofit of existing structures, and in practice, those who implement the NBC often reference the Indian Building Code for technical information that is not included. Although not considered a national code or standard, the National Society for Earthquake Technology (NSET) has issued several documents addressing existing structures such as *Seismic Vulnerability Evaluation Guideline for Private and Public Buildings Part I: Pre Disaster Vulnerability Assessment*, *Seismic Vulnerability Evaluation Guideline for Private and Public* Buildings*, Part II: Post Disaster Damage Assessment*, and *Retrofitting of Common Frame Structural (Pillar System) Houses*.

2.4 Geography

Nepal is a geographically diverse country that is landlocked by China's Tibet Autonomous Region to the north and by India along its remaining three sides. Its approximate land area is 147,181 square kilometers (56,827 square miles), and includes elevations ranging from approximately 60 meters (197 feet) above sea level to the earth's highest mountain peak, Mount Everest, which stands at 8,848 meters (29,029 feet). The wide ranges of elevations encompassed by Nepal are further categorized into three major regions that extend along the length of the country. The title for each of these regions is Terai, Hill, and Mountain, and their layout is shown in Figure 2.4.

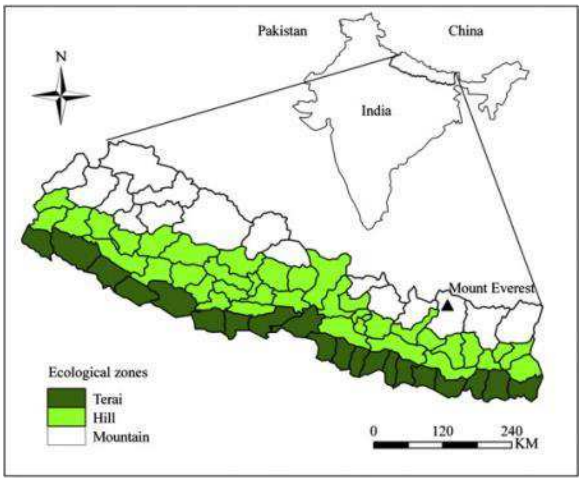

Figure 2.4. Map highlighting Nepal's Terai Region, Hill Region, and Mountain Region [14]

The Terai Region, which can be subdivided into Inner Terai and Outer Terai, encompasses low plains located along the southern belt of Nepal which extend into foothills to the north called the Siwaliks. The low plains are heavily farmed areas that consist of fertile alluvium fill which is fed by the Himalayas. The low plains begin at an approximate elevation 60 meters (197 feet) and extend into Siwaliks that rise to approximately 700 meters (2,297 feet).

The Hill Region extends across the middle belt of Nepal and includes the majority of Nepal's total land area. This region also includes the majority of the country's population along with its most populous city, Kathmandu. The elevation of this region is mostly between 700 meters (2,297 feet) and 3,000 meters (9,843 feet).

The Mountain Region begins where high ridges start to substantially rise above 3000 meters (9,843 feet) into the subalpine and alpine zones, and ends at the world's highest peak, 8,848 meters (29,029 feet). Approximately 17% of the total land area of Nepal falls within the Mountain Region, including most of the Himalayas, and the subalpine and alpine zones are mainly used for seasonal pasturage.

It's important to note that ethnic groups, and the altitude of each village, play a vital role in the type of housing construction found in Nepal. The ethnic groups of Nepal are very diverse, and that diversity is reflected in the various architectural and structural systems found in each region of the country.

The largest ethnic groups can be divided on the basis of geographic locations by region. Ethnic groups such as Sherpas, Gurungs, and Manang live in the Mountain Region. Other ethnic groups who live in the Mountain Region include Thudam, Topke Gola, and Lhomis. Brahmins, Chhetris, Kirats, Newars, Tamang, Magar, Gurungs, and Thakalis are the major ethnic groups who live in Hill Region. Sunwars, Jirel, Chepangs. Kusundas and Panchgaule also live in the Hill Region, however they are the minority. Usually, Tamang and Gurungs live in the high altitude areas of the Hill Region, whereas most of the Newars live in the valleys within the Hill Region. The ethnic groups living in the Terai Region consist of

Brahmins, Rajputs, Tharus, Rajbansis, Satars, and Muslims. For a breakdown of Nepal's ethnic groups as a percentage of the entire population, refer to Figure 2.5.

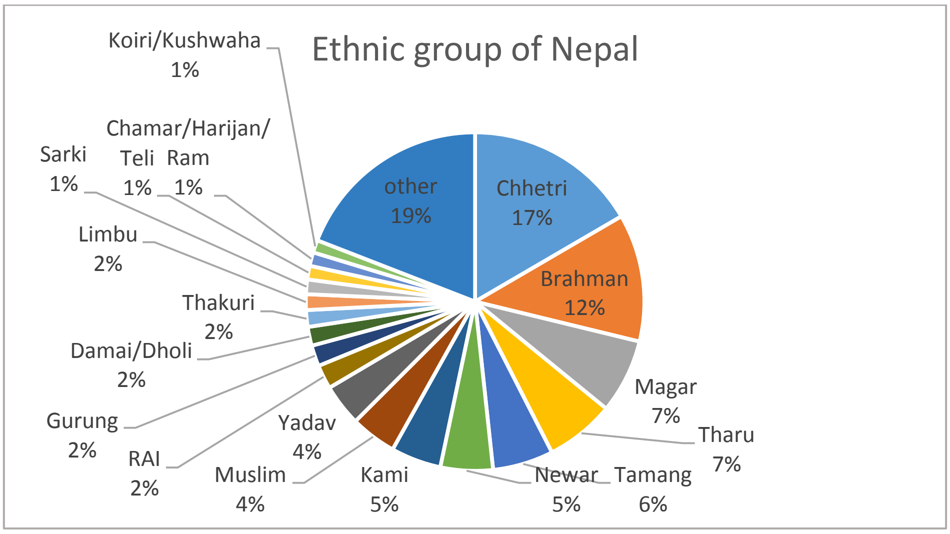

Figure 2.5. Ethnic groups of Nepal [3]

2.5 Climate

It's important to have a firm understanding of Nepal's climate during the design and construction phases of a project. Monsoon rains can promote landslides that may affect construction schedules by limiting access to rural areas, winters habitually extend the snow line to lower altitudes increasing the need for properly insulated structures, and the heat felt through the summer months highlight a homeowners desire to incorporate properly ventilated house designs.

Nepal's weather patterns vary from region to region, and there are five major seasons throughout the year: spring, summer, monsoon, autumn, and winter. The year is also typically categorized into a wet season, which extends from June to September, and a dry season, which extends from October to May. In the Mountain Region the snow line, defined as the point above which snow and ice cover the ground throughout the year, ranges between 5,000 meters and 5,500 meters (16,404 feet to 18,045 feet).

In the Terai Region, summer temperatures can exceed 37° C, and in the winter temperatures typically range from 7°C to 23°C. In the Hill and Mountain Regions summers are typically temperate but winter temperatures can plummet below subzero. The valley of Kathmandu typically has a pleasant climate, with average summer temperatures of 19°C to 35°C and average winter temperatures of 2°C to12°C.

3 Housing Subsector Study

3.1 Surveys

Housing surveys were conducted in six rural villages selected from the list of villages to which Mercy Corps was providing emergency supplies and support. The selection of the villages was based on their relative location, the type of construction (where known), their accessibility, their social structure, the relative size of their population, and other factors. Representatives of the VDCs in each village were contacted and arranged the interviews with the homeowners and builders. The VDC representatives also provided valuable assistance to the survey team during the site visit.

The goal of the homeowner and builder surveys was to collect data on the prevalent housing types in each village, which will be used to develop strategies for reconstruction of the homes using a “homeowner driven” approach that engages the individual homeowners and the local builders in the reconstruction process. Some of the data that was collected in these surveys included identifying the common characteristics of the buildings, the types and availability of building materials, the skills and training backgrounds of the builders, and the preferences of the homeowners in each village. Building material suppliers were also interviewed. The following sections of this report describes in detail the surveys and the survey results.

3.1.1 Survey Locations

The VDCs that the Build Change team surveyed were selected from the list of villages where Mercy Corps was distributing relief supplies. Other factors that were considered included the weather conditions, the altitude of each village, the ethnic groups prevalent in the area, and each village’s location relative to each other and to Nepal’s main highways.

3.1.2 Homeowner Survey

The housing subsector homeowner survey question set was designed to learn about the characteristics of each homeowner’s previous house and the homeowner’s preferences for the houses they would like to reconstruct. The data the survey team collected from these surveys included the age of old house, its use and functionality, the materials used, and how the houses were constructed. Each homeowner was also asked what they did during the earthquake, the number of casualties in their house that were caused by the earthquake, and their future plans for reconstruction of the house.

3.1.3 Builders Survey

The builder survey included questions about each person’s education level, the type of work they do, how they are hired and paid, their years of construction experience, and the type of professional training they may have received. The builders were also asked about the type of tools they own or use, the typical number of working hours they work each week and their typical per day salary.

3.1.4 Material Survey

The material survey was conducted to become familiar with the construction materials that are available locally, the cost of the materials, the material that needs to be brought in from other places, and transportation costs in that particular area. Both homeowners and builders were surveyed. If there was a construction material supplier or a fabricator in the village or a nearby town they were included in the survey. This information will be very helpful for preparing approximate cost estimates for future building projects.

3.2 Summary of Survey Data

3.2.1 Survey Locations

Based on the criteria discussed in the survey section, the Build Change team visited six VDCs in two of the earthquake affected districts as shown in , and Table 1 below. The population and household numbers were obtained from the Nepal National Population and Housing Census in 2011.

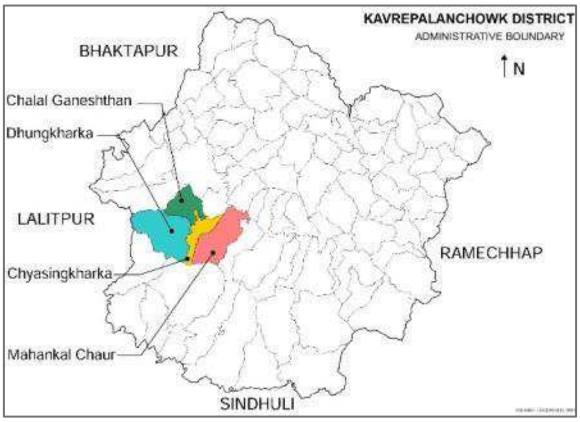

Figure 3.1. District map of Kavrepalanchok district showing the VDCs that Build Change's team visited [4]

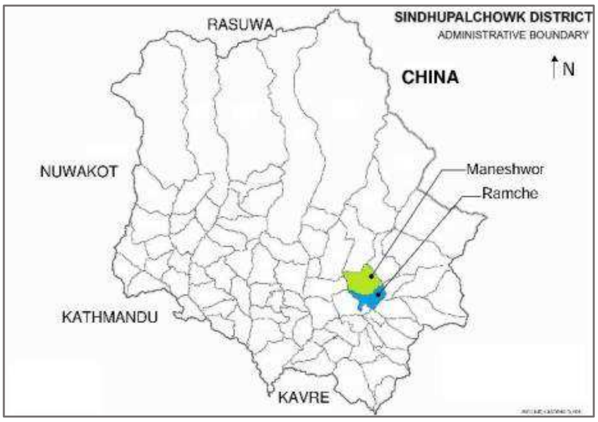

Figure 3.2. District map of Sindhupalchok district showing the VDCs that Build Change's team visited [5]

Table 1. Survey Locations

VDC	District	GPS coordinates		Approx. Altitude	Population	House-hold
		North	East			
Dhungkharka	Kavrepalanchok	27.510475	85.479598	2020 m	4916	1035
Chyasingkharka	Kavrepalanchok	27.516526	85.522599	1890 m	2789	611
Mahankal Chaur	Kavrepalanchok	27.516242	85.561801	1600 m	3470	787
Chalal Ganeshthan	Kavrepalanchok	27.531904	85.494277	1970 m	3973	864
Ramche	Sindhupalchok	27.776242	85.874355	2300 m	4092	999
Maneshwor	Sindhupalchok	27.805954	85.876483	1400 m	3393	789

3.2.2 Homeowners Survey Data

3.2.2.1 Architectural Systems

During the detailed surveys, one to two homeowners were interviewed in each VDC visited and during the focus survey 71 homeowners were interviewed in a single village. Many interviews included input from the homeowner's family and neighbors, as well as others in the village. A total of 11 houses were observed in detail during the survey. The interviewees were selected based on the construction type and damage level of their house. Almost all of the houses that were observed were built by local builders, and there were only a few houses that were constructed by builders from other cities. In the rural villages, the construction materials required to build a house were purchased by the homeowner after they had an opportunity to consult a builder.

A typical house in the areas that were visited consisted of two floors with an attic. The ground floor usually had a kitchen area, but some homeowners used part of their ground floor space to house farm animals such as cows, buffaloes and goats. Almost all of the houses surveyed had bedrooms on the first floor. New houses that were closer to towns typically had plywood partition walls separating the bedrooms on the first floor level, whereas old houses, and houses that were a farther distance from the town center, were more likely to have wooden plank partition walls. Since the main occupation of the homeowners living in villages is agriculture, a decent amount of space is required for them to store agricultural harvests and tools. The preferred area of storage for such items was the homeowners' attic space. The exterior wall finishes for the houses were primarily mud based plaster. Cement based plaster was also encountered in the field but it was not common. Figure 3.3 below provides floor plans and elevations that are representative of the typical houses encountered in Mahankal Chaur and the surrounding VDCs.

In the six villages that we visited, it was common for houses located along the main dirt roads to have multiple door openings at the ground level at both the front and back walls, refer to Figure 3.4 and Figure 3.5. One homeowner in Dhungkharka explained that this was done so homeowners could operate a small business from their house. Some of the common businesses encountered in these areas were small grocery stores, restaurants, and bars. The homeowner in Dhungkharka elaborated further and explained that even if a homeowner didn't intend to open his own business including multiple openings at the ground level would still be important because they could rent the space to others interested in operating a business. In cases where the space was not used for business, the extra doors were often used to provide access to storage rooms or served as separate access to living quarters for relatives.

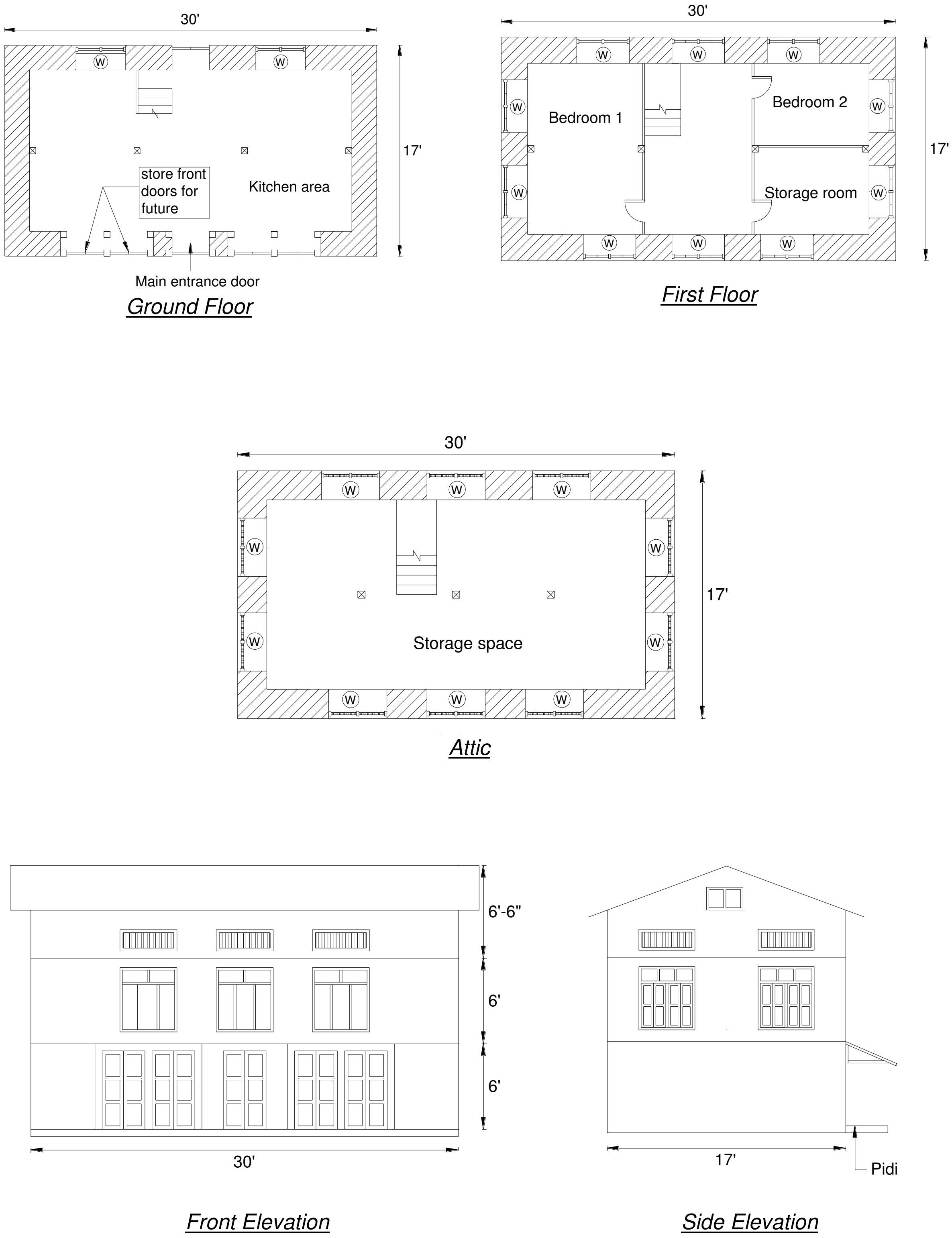

Figure 3.3. Plans and elevations for a typical house located in Mahankal Chaur, Kavrepalanchok.

Figure 3.4. Front of house, Chalal Ganeshthan

Figure 3.5. Front of house, Chyasingkharka

3.2.2.2 Outhouses

It is common practice to install outhouses outside of the houses rather than inside. In most cases the outhouse structures were separate from the house. In Chalal Ganeshthan there were outhouses constructed of brick masonry with cement mortar rather than with stone. The VDC representative told the survey team that these outhouses were constructed as part of a government sponsored program.

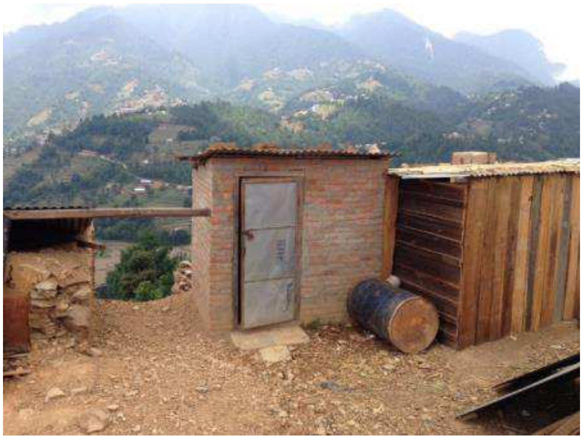

Figure 3.6. Outhouse, Chalal Ganeshthan

3.2.2.3 Structural Systems

The primary structural system found in the rural villages was exterior bearing and shear walls constructed out of stone masonry. Clay brick houses were less common. The use of concrete frames and clay brick walls in each village, where built, appeared to be related to the village's proximity to the larger cities in the valleys. For example there were many houses in Maneshwor constructed with concrete frames with brick infill. However, only a few brick houses were found in Manhankal Chaur and there were none seen in Ramche. In Chalal Ganeshthan concrete frame and brick construction was mostly limited to a cluster of houses at the center of the village, one school building and several outhouses. This is significantly different from the construction in Kathmandu and the surrounding towns, where the vast majority of the buildings were constructed out of either unreinforced brick masonry or reinforced concrete frames with brick infill.

There were no houses in the villages that had structural steel framing. There were, however, a number of school structures that had steel framed roofs. Many of the older school buildings had stone masonry walls and roofs supported by trusses made from light gage steel or small structural steel members. In some cases the trusses were supported by steel pipe columns that were embedded inside the stone masonry.

The raised floors of houses were typically constructed from mud and plaster supported by wood planks and sawn wood framing. The wood joists were supported by the exterior bearing walls and often by a line of wood girders and posts running down the center of the house. At the floors, the joists were typically embedded into the walls. At the roof level, the roof joists sat on top of the walls that typically were a few feet above the attic floor, whereas the joists supporting the attic floor were embedded into the walls similar to the joists at the floors below. The roofing material was corrugated galvanized iron (CGI) sheets, slate, or tile.

The builders and homeowners said that the houses typically had stone footings underneath the walls and posts and compacted mud floors on grade.

3.2.2.4 Summary of Focus Survey

On July 18, 2015 a focus survey was conducted in Sunkhani, Nuwakot. During this study a total of 71 surveys were conducted. The purpose of the survey was to become familiar with the availability of local material, identify the condition of the existing structures in the area, and determine the homeowner’s future plans and preferences for reconstruction.

All of the homeowners who participated in the survey lived in homes that exhibited some level of earthquake damage. Approximately 71% of the existing houses had completely collapsed, 25% had partially collapsed or showed signs of heavy damage, and the remaining 4% had only included cracks. The prevalent building materials used in Sunkhani were stone, mud, wood, and CGI for roofing. Typical houses were two stories tall with an accessible attic and housed an average of seven people. Approximately 87% of the houses in the village had a patio and a veranda (balcony). The patios were used as social areas where a homeowner would welcome guests or chat with neighbors. The toilets were generally outside of the house, and the typical footprint of the house was rectangular in shape with an approximate dimension of 20 feet by 15 feet. The ground floor of each house was used for cooking meals, the first floor was typically used for sleeping, and the attic level was typically used for storing grains and other agricultural products.

Homeowners typically hired builders to construct their homes; however one of the households that was surveyed could not afford to hire a builder so they intended to construct their own home.

Most homeowners mentioned they knew about earthquakes and the risks involved but they never imaged that their house would collapse during such an event. When asked how they would like to rebuild, homeowner's preferred construction types were reinforced concrete frames with brick infill (37% of responders) and clay brick with cement mortar (37% of responders). However, homeowners were also aware of the issues surrounding these construction types such as limited material accessibility, the increased cost of material, and the lack of trained builders who knew how to implement these construction types. Despite the fact that stone and mud construction was low on their list of preferred construction materials to rebuild with, 73% of homeowners were comfortable with the idea of building an engineered design that incorporated stone and mud, and the remaining 27% of the homeowners mentioned they would prefer to wait until others built an engineered home before making a decision.

Twenty eight percent of people interviewed said they were comfortable with rebuilding the same number of floors as their original house. The remaining 72% of homeowners preferred to build back with fewer floors than their original home with 41% choosing a two story option, and 31% choosing a one story house with a larger footprint.

In regards to toilets, men preferred to have them outside of the house, whereas women preferred to have them inside the house. The driving force behind women's desire to incorporate a toilet inside the house was safety. In general women don't feel safe walking outside during the night so including a bathroom inside the house would mitigate their concerns.

3.2.3 Builders Survey Data

Most of the builders were not formally trained. Instead they learned their skills by simply observing the work of others. Some of the builders were not aware that training opportunities were previously available and most of them seemed satisfied with their work until they observed the level of damage that their previous projects endured. After observing the damage created by the earthquake, the builders were eager to be trained to build safer houses, so much so that they were willing to leave their daily work and chores for several days if required.

Figure 3.7. Local village craftsman in Mahankal

According to our survey, most of the builders had primary level schooling up to Grade 5, some had lower secondary level schooling (Grade 6-8), and none had formal education beyond Grade 8. Very few of the builders knew how to read and write. All of the builders that we surveyed were born in the same VDC that they worked in.

The skill of builders and availability of material varied depending upon the distance of the village from larger municipalities. Builders in villages like Maneshwor that are near larger towns (3km from Barahabise) knew how to build in concrete whereas in villages like Mahankal Chaur that are far from municipalities (the nearest town, Panauti, is 22km away), the builders did not know how to build concrete structures. The only concrete frame/brick infill structure seen in Mahankal Chaur was one school building that was constructed by builders from another town. On the other hand most of the houses in Maneshwor were concrete frame/brick infill structures.

During the survey in Mahankal Chaur, the Build Change team met a village craftsman who had a small workshop. His expertise was wood work such as doors, windows and wooden furniture. He is also a supplier of plywood and wood in small scale.

3.2.4 Materials Survey Data

Due to the economic condition of the locals in the remote areas, locally available material has always been the first preference for construction because of its relative low cost and easy availability. Locally available materials include stones for walls and foundations, mud for mortar, and mud and straws for floors and roofs. Some old houses had clay tile roofing that was transported from Bhaktapur district, and others had stone tile roofing from the Dhading district. CGI sheets are gaining more popularity for roofing material in the villages because it is light weight and easily available.

3.2.5 Materials

3.2.5.1 Stones

The type of stones used to build houses were either round in nature or generally flat and rectangular. The technique used to construct the stone walls appeared to vary by district. In the villages surveyed in the Kavrepalanchok district it was common to use uncut stones for the walls with cut stones only at the building corners. Mud mortar was used throughout. In the Sindhupalchok district villages cut stones were typically used for the walls. Mud mortar was commonly used but there were houses where no mortar was used to bind the stones together. This was not found in the Kavrepalanchok villages. Cement mortar was not commonly used for the stone masonry buildings in either district.

Figure 3.8. Stones used for wall construction, Dhungkharka, Kavrepalanchok

Figure 3.9. Stones used for wall construction, Maneshwor, Sindhupalchok

Figure 3.10. Stone wall construction, Chalal Ganeshthan, Kavrepalanchok

Figure 3.11. Stone wall construction, Ramche, Sindhupalchok

3.2.5.2 Mortar

In Dhungkharka a particular type of common mud called “Chimte mato” (very fine clay in Nepali) is used in stone walls for mortar. It has good binding properties compared to other types of mud such as “Rato mato” and “Kalo mato”. In most of the other villages, the builders use any type of mud that is available near their construction site. There were some houses in Ramche, Maneshwor, and we understand in other villages in the Sindhupalchok district, where no mortar was used in the stone walls. Cement mortar is not a very common binding material in the rural areas due to the increase in cost relative to mud.

Figure 3.12. Local showing how Chimte mato binds when mixed with water.

3.2.5.3 Clay Brick

Clay brick is one of the key construction materials, especially in the urban areas of Nepal. The demand for bricks has gone up with time. There are brick plants located in all three districts of Kathmandu valley (Kathmandu, Lalitpur and Bhaktapur). Brick plants are also located in various districts in the Terai Region. Along with housing, brick plants were also affected by earthquake. Many brick plant chimneys partially collapsed in the 25th April Gorkha earthquake. Even though the kilns were damaged, they are in operating mode to meet the construction demand. The price of brick has remained at Rs 13.5 per piece after the earthquake as it was before. However, some anticipate that the price of brick will rise due to the widespread damage to the kilns, the shortage of workers at the plants, and the increase in demand. Many homeowners might choose to re-use bricks from collapsed buildings instead of purchasing new ones to avoid paying higher prices.

Selecting appropriate bricks for reuse is important. Cracked bricks or pieces of bricks should not be reused. Bricks that will be reused should be checked for sufficient strength and cleaned of existing mortar. For example, bricks that are dropped from shoulder height on to a hard surface and crack are likely not strong enough to be reused in the house walls. However, other uses for weaker bricks or pieces of brick can be found – such as using them as a durable compacted grade in site pathways and stairs.

There were no brick manufacturing facilities in any of the surveyed villages; bricks are instead brought in from the valleys. For example, clay bricks used in the villages of Kavrepalanchok are transported from Bhaktapur and are purchased from either an intermediary seller or directly from a brick manufacturing plant. This appears to discourage homeowners from using bricks, since they typically need to pay extra to cover the transportation costs. Meanwhile, stones are usually locally sourced from local quarries so their cost is significantly less then brick. Despite the difference in cost, most of the people who live in stone houses dream of constructing a house with bricks instead. Many homeowners and builders indicated that they would prefer to rebuild their homes with bricks rather than stones if they could afford to do so.

3.2.5.4 Wood

Though Nepal is rich in forest, deforestation has occurred in rural areas that has led to landslides becoming a recurring problem. In response, the government of Nepal formulated an act known as Forest Act 1993 for proper management and conservation of forests. Forest Act 1993 [6] identifies two primary kinds of forests: National and Private. Under National Forest, there are five different categories: 1. Government managed, 2. Community managed, 3. Protected Forest, 4. Leasehold forest, and 5. Religious forest. Most of the wood that was used for housing construction typically came from either government managed, community managed, or private forests.

The most common wood species used for construction in the villages were Chilaune (*Schima wallichii*), an evergreen in the tea family; Tooni (*Tonna ciliata*), a mahogany wood also called red cedar; and Salla trees. There are many different types of wood species in Nepal that are referred to as "salla" including Kote Salla (*Pinus roxburghii*, or Chir Pine), Gobre Salla (*Pinus wallichiana*, also known as Blue Pine or Himalayan Pine), and Dhupi Salla (*Cryptomeria japonica*, or Japanese Cedar). The people surveyed did not identify which type of Salla trees they used for construction. Kote Salla is commonly found in the Hilly Region at elevations of 800 to 1,600 meters (2,700 to 5,400 feet) [7] so this may be the species that is being used in the Kavrepalanchok villages. Gobre Salla is typically found in the Mountain Region at elevations of 2,200 to 3,000 meters (7,300 to 10,000 feet) [7] so the builders in the villages in Sindhupalchok may be using either this species or Kote Salla. There is a significant difference in the properties of the different types of Salla trees so further investigation into the types specifically used in the villages may be warranted. Observations indicated that the primary gravity framing system, which typically consisted of wood posts and girders that are located at the interior of the structure, performed well and displayed minimal sagging or failures.

Other types of wood that grow in the region include Sal (*Shorea robusta*), Katus (*Castanopsis indica*), Uttis (*Alnus nepalensis*), Arkhalo (*Lithocarpus elegans*) [8], Payau, and Laksi. Among these, Sal and Katus were considered as a good quality wood with no bug damage for a long term use. Sal trees are one of the dominant species in the Terai Region.

In Dhungkharka there was a wood mill located across the street from the VDC office. Dil Bahadur Shrestha is the owner of the wood mill. Though he was not available to speak with us, we talked to the staff working in the mill. There were ten workers working in the wood mill with each doing specific tasks like bringing the wood, cutting to a specific size, stacking it up, etc.

Figure 3.13. Wood mill at Dhungkharka

Figure 3.14. Stacked wood blocks and planks

The mill either buys lumber from the community forest and sells the cut sections, or people bring wood from their personal forest to the mill to cut. The mill serves as both a buyer from locals and a supplier to locals according to the need and situation. The sizes of wood available from the mill are usually 6 ft. long with these typical cross sections: 18in x 4in, 10in x 4in, 8in x 4in, and 8in x 1 in.

Bamboo is typically only used for temporary construction scaffolding. Very few houses used bamboo for structural beams or posts. The people surveyed did not think that bamboo was strong enough to use for structural supports. Their preference was to use sawn lumber instead.

3.2.5.5 Concrete Block

The people that were surveyed did not consider concrete blocks to be a reliable housing construction material. Thus their use is mostly confined to small structures such as outhouses or site walls. When they are used for houses they are in most cases combined with bricks and/or concrete frames to build the house. There were no occupied buildings in any of the surveyed villages that were built solely out of concrete blocks.

On the way to Chalal Ganeshthan there is a small concrete block making plant. There was no one at the plant at the time of our visit so it was not possible to observe how the blocks are manufactured, or if the blocks are tested for strength, or to identify the block maker's sources for the raw materials. However, our experience with concrete block manufacturing has shown that in cases where blocks produced have low strengths, that with relatively inexpensive modifications to production, much stronger blocks can be produced instead.

Figure 3.15. Concrete block making machine

Figure 3.16. Drying and stacking of concrete blocks at the plant near Chalal Ganeshthan

3.2.5.6 Aggregates

Sand and gravel aggregate for concrete were typically brought in to the villages from nearby towns. The survey team did find a rock quarry located on the road to Dhungkharka and Chalal Ganeshthan. The homeowners in Dhungkharka said that the gravel that they use for concrete was from this quarry. The homeowners in Ramche and Maneshwor said that their crushed gravel comes from a place called Sukute.

3.2.5.7 Corrugated Galvanized Iron (CGI)

There were hardware stores selling CGI sheets and fasteners in Barahabise, a small central town in Sindhupalchok district that serves many of the rural villages nearby including Ramche and Maneshwor. The cost information listed in Table 2 was obtained from one of the stores in Barahabise that was selling CGI materials.

Table 2. Materials used in roofing details

Items		Price (NRs)	Unit
CGI sheets (thick-ness)	16 mm	3800	Bundle
	17 mm	4000	Bundle
	20 mm	4200	Bundle
	26 mm	4500	Bundle
	28 mm	4800	Bundle
	32 mm	6000	Bundle
	42 mm	7000	Bundle
	45 mm	8500	Bundle
Binding Wires		130	kg
nails		100	kg
J hooks		15	set
small hook with washer		5	piece

3.2.6 Summary of Earthquake Damage

There was extensive damage to unreinforced stone masonry buildings in all of the villages that were observed. There was also extensive damage to the unreinforced brick masonry buildings. The damage ranged from localized damage to individual walls to complete collapse of the building structure. Concrete frame with brick infill buildings generally performed better than the unreinforced masonry structures in the Kavrepalanchok District, similar to what was seen in Kathmandu. However, in the Sindhupalchok District there was extensive damage to concrete frame buildings, likely because the villages in this district are located much closer to the epicenter of each of the two earthquakes. The damage found in each village is described in the subsequent sections.

3.2.6.1 Kavrepalanchok District

3.2.6.1.1 Dhungkharka VDC

Dhungkharka had a moderate level of damage. Except for 2 or 3 structures that had completely collapsed, most of the structures were standing and had suffered mostly out of plane failures and corner cracks.

Figure 3.17. Cheta Nath's house at Dhungakharka VDC

Figure 3.18. Out of plane wall failure of Cheta Nath’s house

Figure 3.19. Corner cracks of Sita Ram House (builder).

Figure 3.20. Complete collapse of Keshab Prasad's house

3.2.6.1.2 Chyasingkharka VDC

In Chyasingkharka the damage was moderate. There was one school building that was red tagged because of numerous cracks in the ground floor slab and in some of the walls. There were also a few houses that had cracks in the walls.

Figure 3.21. Damaged two story house in Mahankal Chaur

3.2.6.1.3 Mahankal Chaur VDC

Mahankal Chaur and Chyasingkharka are neighboring VDCs. They share similar types of construction material and building techniques, though Chyasingkharka has a few concrete framed structures as compared to Mahankal that has only one (a school building). The damage level at Mahankal Chaur was moderate to severe. While there were few houses that were completely collapsed most of the houses had significant amounts of cracking and localized wall failures. In Mahankal Chaur there were two houses and one temple that were constructed with brick and mortar. The temple had several cracks in the walls, but the two houses had relatively minor damage compared to the stone wall houses that were adjacent to them.

Figure 3.22. School building with cracks in Chyasingkharka.

3.2.6.1.4 Chalal Ganeshthan VDC

The damage in Chalal Ganeshthan was moderate to severe and varied by ward (local district). In Ward 9, which is on top of a mountain ridge, the damage was extensive. However, in Ward 2, which is down in a valley, the amount of damage was relatively less. There were many structures in Ward 9 that had wall cracks and out of plane wall failures. Some of the homeowners in Ward 9 have already started to demolish their partially damaged house to first floor level. Most of the households are planning to put CGI roofing on top of the ground floor after demolishing the other floors in order to continue to live in the house.

Figure 3.23. One of the houses in Chalal Ganeshthan Ward 9 where the upper floors were demolished and the ground floor level covered with CGI sheets.

3.2.6.2 Sindhupalchok District

3.2.6.2.1 Ramche VDC

The damage in Ramche was severe. Approximately 90% of the houses observed had completely collapsed and the remaining structures were partially collapsed or damaged to the extent that they were not safe for future habitation. Many people have built temporary houses and structures for food storage using stones and/or CGI sheets from their collapsed houses.

Figure 3.24. Devi Timilsina in front of her collapsed house

Figure 3.25. Shiva Prasad on the first floor level of his house.

3.2.6.2.2 Maneshwor VDC

The damage in Maneshwor was moderate to severe and appeared to be dependent on their location. Houses that were built close to the edge of the hillside suffered more damage than those that were built further back. Most of the hillside houses had completely collapsed. Houses built with concrete frames and brick infill construction were among those that were highly damaged or had collapsed. The survey team was told that the structures in Maneshwor were built without consulting or drawing approval by the VDC as it is not a requirement.

Figure 3.26. Collapsed concrete frame brick infill house in Maneshwor

3.2.7 Special Conditions

3.2.7.1 Road Access

All six villages were located in the mountain ranges at elevations between 4,000 and 6,500 feet (1,200 to 2,000 meters) and were only accessible by dirt roads and pedestrian paths cut into the hillsides. The roads are narrow, steep, and littered with ruts and sinkholes. After a rain event the roads become muddy, which combined with the steep slope and the ruts in the road make them virtually impossible to drive on. The hillsides are also prone to landslides, which according to the villagers frequently occur during rains and block the roads. There were also reports of landslides that were induced by the April earthquake that cut off access to roads. [9]

Figure 3.27. Road to Ramche

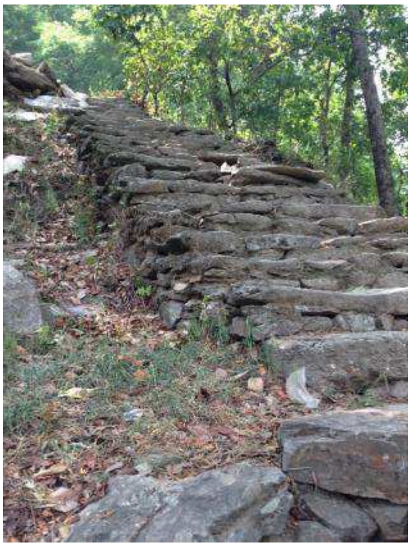

Figure 3.28. Stairs to Ramche

During dry conditions buses and small trucks are able to travel on the roads and deliver goods and supplies to the villages, including building materials. The villagers said that construction materials such as bags of cement and bricks are typically brought in from the nearest city on small trucks. Lighter building materials are often carried in by hand by the villagers themselves either on the roads or the pedestrian trails.

3.2.7.2 Wall Penetrations for Formwork

It was common for houses to have small holes in the walls. The homeowners explained that the holes were created when the walls were built to support temporary scaffolding used by the builders to construct the walls. It is standard practice for the holes to left in place, in part to allow for scaffolding to be installed to build vertical additions to the house or to make repairs to the wall. There were cases where cracks in the walls either formed in or propagated through these holes.

3.2.7.3 Wall Penetrations for Religious Purposes

In Dhungkharka and Chalal Ganeshthan it was common practice to install triangular holes in the walls at the front of the house. These holes were for religious shrines. While the survey team did not see any evidence of earthquake damage to the walls resulting from the presence of these holes, their presence within the shear walls of the houses would likely have an effect on the capacity of the walls to resist seismic loads. These holes were not seen in the other villages.

Figure 3.29. Front of house, Dhungkharka

Figure 3.30. Wall opening for shrine, Dhungkharka

3.2.7.4 Snow Loads

While the VDCs are in mountainous regions snow does not appear to be a regular occurrence at any of the six villages that the survey team visited. The Nepal Building Code does not require buildings in these areas to be designed for snow loads. There are other regions of Nepal that the building code does require snow loads to be considered. [10]

4 Conclusion

4.1 Primary Seismic Deficiencies in Stone Masonry Buildings

Stone masonry with mud mortar was the prevailing wall type for housing found in every village that was surveyed. The stone and mud are both locally sourced and the builders in each village are most familiar with this type of construction. However, stone masonry walls with mud mortar have inherent flaws and weaknesses that make them susceptible to damage or collapse in earthquakes. These flaws were exposed in the April 25 earthquake and the May 12 major aftershock. The homeowners and builders that were interviewed all acknowledged these flaws and expressed an interest in rebuilding their houses with a better system. The primary seismic deficiencies found in the prevailing building type are identified below.

4.1.1 Configuration

Large cross wall spacing – The typical floor plan had masonry exterior walls but with limited internal cross walls. Internal cross walls provide important out-of-plane support to the exterior walls and also increase the lateral strength of the house.

Insufficient wall length – Many houses had short wall piers and frequent window or door openings, particular on the front or back elevations. This reduces the lateral strength of the building and its resistance to earthquakes.

Masonry gable end walls – At the attic level, the wood framed roof is typically insufficient to brace the weight of heavy masonry walls. Triangular gables in stone masonry are particularly susceptible to failure out-of-plane and should be instead built from a lightweight material such as wood.

Two-story walls without bracing – The wood-framed floors are not specifically built stiff enough or well-connected enough to provide adequate resistance for bracing two-story walls out-of-plane. Therefore walls may be effectively unbraced over the full two-story height, leading to slender walls that are more likely to collapse.

Insufficient foundation configuration for sloping sites – In many cases, houses built on slopes did not have the appropriate configuration required to support the house during the earthquake. Special attention to the foundations of housing on sloping sites is required in order to ensure their adequacy in earthquakes.

4.1.2 Connections

Lack of ties and bands – The masonry walls were commonly missing ties and bands that help the unreinforced stone masonry span out-of-plane and transfer loads to the foundation in-plane. The absence of bands can lead to early failure of the wall in-plane and especially out-of-plane.

Lack of through stones – One of the primary failure modes for the walls was the delamination of the interior or exterior wall faces. This failure mode is due to the typical construction technique of building the walls with stone masonry on the inside and outside faces and filling the void between the two faces with rubble or debris. Through stones should be placed periodically throughout the wall construction in order to tie together the inside and outsides faces. (Also as discussed below, the walls should be built solid, without a rubble/debris layer in the center)

Inadequate connections between upper level walls and ground floor walls – In some cases, particularly in Ramche, gaps between the upper level floor and the ground level floor were observed at the level of the floor joists. This creates discontinuity in the wall at the floor level, in which it is difficult or near impossible for the lateral earthquake loads in walls above to transfer to the wall below. This may have led to early sliding or failure of the upper level walls.

4.1.3 Construction Materials

Low wall strength – Many of the walls were constructed with mud mortar as the binding between stones. Mud mortar typically has a low strength and is fairly susceptible to deterioration due to weather. In some areas, particularly in Kavrepalanchok, unshaped or round stones were used in the walls. Using stones with these characteristics limit the wall's ability to transfer load by reducing the shared interface/surfaces between adjacent stone layers.

Poorly placed masonry - Many of the stones were not placed well, for example rounded stones used instead of cut stones, or stones placed far apart, with extra mud between them, which prevents interlock and strength between the stones. Additionally, the wall composition was often composed of an interior and exterior masonry face, filled with rubble or random debris at the center, creating a weak plane in the wall.

Heavy floors and/or roofs – The heavy mud floors, and tile roofs common to these buildings add mass to the building. Earthquake loads are generated directly proportional to building mass. Lighter-weight roofs and floors would reduce the demand on these homes.

4.2 Options for Improving Performance

The Nepal building codes and standards have provisions for stone masonry construction that are typically not being used in the villages. For example, the standards call for the use of horizontal bands and through stones, etc. and have provisions for maximum openings and wall spacing. However, there was only one building in the six villages visited that had a horizontal band and there were no buildings found that had through stones in the walls. Additionally, most buildings did not respect the maximum openings or wall spacing. Many of the homeowners and builders do not appear to be aware of these provisions and there is little to no enforcement of these provisions in housing construction. If homeowners and builders were to be trained to incorporate these provisions into the construction of housing then there would likely be an improvement to the resiliency of the housing stock above the current performance.

It is worth noting that the codes and standards for stone masonry construction are generally prescriptive in nature do not identify or imply a specific performance level in a specified earthquake level. Therefore, currently there is not an effective way to estimate the probability of damage in a future earthquake or the magnitude of seismic movement that a stone masonry building following these provisions can withstand. A stone masonry building built in conformance with the standards would likely perform better in an earthquake than one that was not.

However, through the survey of homeowners, it is apparent that they are interested in constructing more modern and safer building types when possible and so below we identify not only ways to improve stone masonry construction, but also discuss other disaster-resistant building types that would be feasible to implement in these areas.

4.2.1 Stone Masonry with Mud Mortar

Implementing random stone masonry with mud mortar per the existing building code is an option for improving the performance of random stone masonry with mud mortar. In addition to recommendations identified in NBC 202 [11] and 203 [12], due to the inherent weakness in stone masonry with mud mortar walls and the difficultly of implementing it in a disaster-resistant manor, if homeowners must build in stone and mud masonry, they should limit the constructions to one-story houses only. This will reduce the earthquake demands on the walls and the required detailing, and thus the collapse potential, for this weaker building type.

However, implementing other construction types that have an established record of good seismic performance is highly recommended. For instances where implementing such construction types is not feasible due to either financial or logistical restrictions, alternative methods of homeowner support should be investigated in order to facilitate the implementation of these construction types. It is of note that stone and mud masonry was not the preferred choice for reconstruction by the people surveyed and therefore there is both a social and technical motivation to rebuild in an alternative system when desired and feasible.

4.2.2 Masonry with Cement Mortar

The mud mortars used in the stone walls have an unknown capacity to bond the stones together and strengthen the wall against seismic forces. What capacity that does exist may also vary by region since it depends on the soil and stones found within proximity of the building construction site. Cement mortar, which is commonly used for clay brick walls, should be considered for stone walls to improve the strength of the walls. Unlike mud, the type of cement can be easily controlled and mortar mix recommendations are consistent independent of geography.

There are some challenges to its use, similar to concrete, including the availability of cement in the villages and the limited experience that many of the builders have with using it. There is also a lack of available data to be able to quantify the level of strength increase in the wall that could be provided by the cement mortar, however, the observed performance of buildings with cement mortar was better than those similarly built with mud, particularly for unreinforced brick masonry buildings.

4.2.3 Concrete Frames with Brick Infill

Many homeowners indicated that they plan to build their houses using concrete frames with brick infill rather than with stone if they had the money to do so. There are, however, many challenging issues associated with building concrete frame with brick infill structures in these villages. Concrete and brick materials are more expensive than stone and mud, and thus may be beyond the financial means of most homeowners. Thus the ability to use this system may depend in part on how much financial assistance the homeowners receive from outside sources. However, if homeowners are willing, reducing the house size could help offset the increased construction cost.

Another significant challenge is that cement, aggregate, sand, bricks, and reinforcing steel are not available locally and must be brought in from the larger towns in the valleys. This presents a relative challenge since the materials would need to be brought in on trucks driving on dirt roads that are steep, narrow, and often unable to be driven on during rain storms because of mud and landslides. There is also the additional cost of transporting these materials that the homeowner would need to pay for.

While concrete frame with brick infill construction is more resistant to earthquakes than stone masonry, this type of construction can also be vulnerable to damage or collapse in earthquakes if the structure is not properly designed and constructed. For example, there were several framed infill houses in Maneshwor that sustained significant damage or collapsed. In some cases the damage was the result of inadequate strength or ductility in the concrete columns. The condition of the soil was also a contributing factor in some cases, particularly in Maneshwor. If framed infill is to be used for reconstructing houses in these villages then there would likely need to be changes to the current design and construction practices used for framed infill construction in Nepal, in addition to the social, physical and financial challenges outlined previously.

It is of note that the NBC 201, *Mandatory Rules of Thumb for Reinforced Concrete Buildings with Masonry Infill* [13] explicitly states that the design recommendations included therein are based on those appropriate for the LOWEST seismic zone in Nepal. Therefore, it is not recommended that these be directly implemented for areas of higher seismicity (majority of Nepal).

Figure 4.1. Collapsed framed infill house, Maneshwor

Figure 4.2. Damaged framed infill house, Maneshwor

4.2.4 Confined Masonry

Confined masonry construction can be considered as an alternative to reinforced concrete with infill or stone masonry. Confined masonry is similar to reinforced concrete with infill in that it consists of concrete framing and masonry walls but is constructed differently. In confined masonry construction, the masonry walls are built first and then the concrete columns and beams are poured around the masonry, whereas in framed infill construction the concrete frame is poured first and then the masonry infill is constructed inside the frame. Placing the concrete onto the masonry creates a stronger bond between the concrete frame and the masonry wall, which causes the masonry wall to be the primary lateral force resisting system instead of the concrete frame.

The benefits of this are two-fold: 1. Since the masonry wall is the primary element resisting seismic forces, the concrete strength and reinforcing requirements in the concrete frame are significantly less than what is required for an infill frame system. In turn, the presence of the concrete confining frame increases the capacity of the masonry wall to resist seismic loads above what would be the case if the frame were not there. 2. The need for costly formwork for the beams and columns is significantly reduced since the concrete is cast against the masonry surface on several sides.

Figure 4.3. Confined masonry house constructed by Build Change and Mercy Corps in Banda Aceh, Indonesia

Since there are builders in Nepal who are familiar with framed infill construction it would appear to be possible to implement confined masonry construction in Nepal since the construction of the two systems are similar. In actuality, it has been observed that in many cases outside of Kathmandu, builders are already pouring the concrete beams on top of the constructed masonry walls (although they are still building the concrete columns prior to the walls). Confined masonry construction can be implemented anywhere concrete construction is possible and bricks are readily available. However, many of the same challenges that exist for construction of framed infill houses in the rural villages also exist for confined masonry. The materials would still have to be brought in, the builders would still have to be trained, and the cost for a confined masonry house would be higher than a stone masonry house of the same size, though it would likely be less than the cost of a comparable framed infill house because of the lower requirements for the concrete and reinforcing steel.

One challenge to implementation that is unique to confined masonry versus infill masonry is the number of openings in the walls. Since confined masonry is a shear wall system the number and size of wall openings would have to be limited, like in stone or brick masonry construction, likely requiring the homeowners to accept having fewer door openings than what is currently common practice for concrete frame structures. The common practice of leaving holes in the walls for scaffolding and shrines would also likely have to be restricted.

Another challenge to implementation of confined masonry is that there are currently no explicit provisions for confined masonry in the NBC. However, confined masonry is included in building codes (ex. Colombia, Peru), guidelines and standards for high earthquake zones globally and the NBC does permit the use of alternative design methods as long as the designer can demonstrate that the finished structure will meet or exceed the requirements of NBC. The local permitting authority is responsible for evaluating if this condition has been met. Therefore, homeowners, professional organizations, and NGOs may have to make an additional effort with the local authority initially to get confined masonry design approved for construction.

4.2.5 Steel Framing

Some of the schools in the villages surveyed had steel framed roofs consisting of either light gage steel channels or trusses framed with small steel tubes. Typically the walls of these schools were built with stone masonry, though in most cases these walls did not support the roof structure. Instead the roofs were supported by steel posts embedded inside the masonry. Most of the school buildings that had this type of construction had damage to the stone walls but in every case the roof framing remained standing. Some of the residents of Ramche observed the lack of collapses of steel framed structures and advocated for using them for houses.

Constructing houses with steel framing could be a potential option since they have a good record of performance and are lightweight compared to masonry or concrete structures. The primary challenge to adopting this system would be the availability and cost of the steel material and the ability of the local builders to construct it properly. Of the school buildings that the survey team found in the villages with steel framing only the school in Dhungkharka was constructed by a local builder (though the school in Ramche was being repaired by local builders). In the other villages the school was constructed by builders from outside the village and funded either by the government or by an outside non-government organization.

Figure 4.4. School in Dhungkharka with steel framing

Figure 4.5. Steel framed school in Ramche

4.3 Capacity of Builders

All of the builders that were interviewed were born and raised in the villages where they work and typically have not received any formal training in construction. They learned by observing how other builders in their villages worked. The builders have experience in stone masonry but little to no experience in or exposure to any other type of building construction, including concrete frames. Thus if another system were to be used in these villages the builders would need to be trained in this type of construction and new quality control procedures, including inspections, would likely need to be implemented in order to insure that the houses are being built correctly. Most of the builders interviewed indicated that they were willing to take construction training courses, some suggesting that they would be willing to take time off from work to travel to a larger town and take classes.

The large number of stone masonry houses that either sustained damage or collapsed in the earthquakes strongly demonstrate the inherent seismic deficiencies of stone masonry construction and in the construction practices that are common in the rural villages that were surveyed. However, these deficiencies do not appear to be the result of deliberate attempts to circumvent good construction practices by either the builders or the homeowners. The houses appear to have been constructed as best as they could have been with the resources, materials, and skilled labor that were available.

4.4 Next Steps

Both the builders and homeowners appear to have a genuine desire to build back better, either with a stronger stone masonry system or with a structural system with a better history of performance such as framed infill, confined masonry, or steel framing. The challenges will be to develop better systems that can be built within the physical and economic constraints that each village has, and to develop training and inspection programs to ensure that these houses are properly constructed.

While the communities are waiting for formal support from the government or other agencies for supported reconstruction, key messages should be delivered to the community to help them understand the primary seismic deficiencies of the typical stone and mud construction type, such as those identified in Section 4.1, and how these can be addressed so that they do not start rebuilding themselves in the same unsafe way.

The next step is to develop guidelines, and simple design and cost estimation tools for housing reconstruction and strengthening of key building types, which can be implemented easily in the field and at scale by trained liaisons. The development of these resources should be informed by this study, the applicable national standards and the ongoing work of various agencies that are developing resources for reconstruction, such as the model house designs by DUDBC. The priority building types for new construction resources are masonry with cement mortar, concrete with masonry infill, and confined masonry. The priority building types for evaluation and retrofit resources are stone with mud mortar, unreinforced brick masonry, and concrete buildings with masonry infill.

When the updated Nepali building codes and standards are published they should be incorporated into the developed resources as appropriate. Construction costs and economic conditions, including financial subsides provided by the Nepali government and non-government organizations, should also be evaluated.

5 Appendix

5.1 Sample Survey Form: Homeowners Survey

Housing Subsector Study Survey - Home and Homeowner **Nepal**

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A. EVENT, SURVEY and LOCATION DATA

1	Earthquake Name:	4-25-15 Nepal M7.8 Earthquake						
2	Survey Date:		Time:		Survey No:			
3	Building or Owner Name		Address		Date Built			
4	City or Village		Sub-village					
5	GPS Marker No.		Latitude:		Longitude:			
6	Existing Posting Placard	☐	Red	☐ Yellow	☐	Green	☐	None
7	Survey Type	☐	Exterior Only	☐ Interior and Exterior				

B. BUILDING USE and TYPE

1	Building Use	☐ House	☐ School	☐ Religious	☐ Medical Fac
		☐ Office	☐ Commercial	☐ (mixed use) Resid-Commercial	☐ Industrial
		☐ Historic	☐ Other:		
2	Number of Floors	Plan Width (m):	Plan Length (m):	Footprint (Sq m):	
3	Sketch of Building Layout - indicate location of entrance - indicate location of toilet - indicate location of kitchen - indicate location of bathing area - if locations noted above are not located with in the home, please note the locations (exterior, backyard, shared, etc)				

4	Architectural features	Existing	Preferred
	Windows - what are the typ window sizes? - where are windows located? (in elevation, in plan, per room)		
	Ceilings - how high are the ceilings? - are the ceilings finished?		
	Doors - how many exits are there? - what are the doors made of?		
	Stairs -are the stairs interior or exterior? - what are the satirs made of?		
	Other - are there other architectural features?		
5	Take photos of the front elevation, other accessible elevations, and other relevant portions of the home and structure		

Housing Subsector Study Survey - Home and Homeowner — Nepal

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C. OWNER or WITNESS INTERVIEW

8	Interviewee Name and Position		No. Occupants at time of Earthquake	
9	No. People Uninjured	No. Minor Injuries:	No. Major Injuries:	No. Dead:
10	About the Earthquake - Ask the witness the following questions, or just listen to their story		Contact in future? Phone number?	
	Where were you at the time of the earthquake?			
	What did you do when you felt the earthquake?			
	Was the shaking up/down or side to side?			
	How long did it last?			
	What caused the injuries or deaths?			
11	MMI?			
12	About the house			
	How many people live in this home?			
	Is the home used for any other purpose?			
	Why did you chose to have your house in this location?			
	What is the most important part of the house?			
	What do you want in a new house?			

D. DESIGN AND CONSTRUCTION PROCESS

1	How old is the building				
2	Who designed the building	Paid Architect ☐	Paid Engineer ☐	Owner ☐	Other: ☐
3	Are drawings available	Yes ☐	No ☐		
4	Who built the building	Foreman ☐	Contractor ☐	Owner ☐	Other: ☐
5	Where did they get the materials				
6	Who purchased the materials				
7	Who transported the materials				
6	How much did the construction cost				
7	How was the house paid for				
8	How long did it take to build				
9	Any additions/modifications made later				
10	Has the building been retrofitted or strengthened?				
11	What was done to strengthen the building?				

BUILD CHANGE

Housing Subsector Study Survey - Home and Homeowner — Nepal

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E. STRUCTURAL SYSTEM - Use an "X" to indicate existing house and circle to indicate future preference

Wall Type

- [ ] Masonry
  - [ ] Unreinforced
  - [ ] Confined
  - [ ] Reinforced
  - [ ] Infill
  - [ ] Mud mortar
  - [ ] Cement Mortar
  - [ ] Kiln Brick
  - [ ] Stone
  - [ ] Concrete Block
  - [ ] Sun-dried Brick
- [ ] Reinforced Concrete
  - [ ] Frame (check above if also infilled)
  - [ ] Shear wall
  - [ ] Precast or Tilt-up
- [ ] Timber
  - [ ] Frame (check above if also infilled)
- [ ] Mud (adobe)
- [ ] Steel
  - [ ] Frame (check above if also infilled), covering:
  - [ ] Light gauge framing, covering:
  - [ ] Wall covering, type:
- [ ] Can't tell

Foundation Type

- [ ] Isolated RC Footing
- [ ] Masonry Strip, type:
- [ ] (Reinforced) concrete strip
- [ ] RC Mat or Slab
- [ ] Can't Tell
- [ ] Other

Floor & Roof Type (indicate which where)

- [ ] Reinforced Concrete Slab
- [ ] Timber Truss
- [ ] Timber Beams/Joists/Rafters
- [ ] Can't Tell
- [ ] Other:

Raised Floor & Roof Coverings (indicate where)

- [ ] wood sheathing
- [ ] CGI
- [ ] mud
- [ ] tile
- [ ] slate/stone
- [ ] unknown

Other:

F. FALLING HAZARDS

1	Falling Hazards	☐ Cantilever Balcony	☐ Cladding	☐ Chimney	☐ Other

G. SOILS and TOPOGRAPHY

1	Site Topography	Level	Sloping - give % Slope		Hilly or Mountainous	
2	Soil Type	☐ Hard Rock	☐ Soft Rock	☐ Dense Sand	☐ Peat/Marsh	
		☐ Loose Sand	☐ Stiff Clay	☐ Soft Clay		
3	Sand Boils	Yes ☐	No ☐	If yes, describe and draw		
4	Ground Cracks	Yes ☐	No ☐	If yes, describe and draw		
5	Settlement of Building	Yes ☐	No ☐	If yes, describe and draw		
6	Settlement of Ground	Yes ☐	No ☐	If yes, describe and draw		
7	Lateral Spreading	Yes ☐	No ☐	If yes, describe and draw		

5.2 Sample Survey Form: Homeowners Survey – Focus Study

BuildChange-Nepal

Home and homeonwer survey

A. General Information									
1. Earthqauke name:	Gorkha Earthquake M7.8 (4-25-2015)								
2. Survey date	17th July 2015								
3. District/VDC	Nuwakot/Sunkhani								
4. Latitute/Longitude									
5. Surveyer's initial									
6. Name of homeowner									
7. Ward no.		Tole							
8. Do you have internet access?	Yes		No		Email		Facebook		

B. Building Information- Existing Home

1. Are you still living in your house? Yes ☐ No ☐
2. What is the Level of damage of your house?
   Full Collapse ☐ Partial collapse ☐ Cracks ☐ No damage ☐
3. Date of house built ____________
4. Number of occupants ____________

5. Building use House ☐ House+commercial ☐ others: ____________
6. No. of floor ____________
7. Separate guest space(Pati) Yes ☐ No ☐
   if yes, specity size (LengthXBreadth) ____________

8. Is Toilet inside or outside of the house? Inside ☐ Outside ☐
9. Plan Length ____________ Plan width ____________
10. Draw plan/ elevation include plan dimension, floor heights, location of door/windows, label each room

11. What is the most important part of house? Why?

12. Structural element of existed/existing house

Name	Type		Name	Type	
a. founda-tion	stone	mud mortar	e. Column	Wood	
		cement mortar		RC	
	brick	mud mortar		stone	mud mortar
		cement mortar			cement mortar
	RC			brick	mud mortar
	Other				cement mortar
				Other	
b. wall	stone	mud mortar	e. floor	wood	mud mortar
		cement mortar			cement/brick mortar
	brick	mud mortar		RC	
		cement mortar		others	
	RC				
	Other				
c. Partition wall	Plywood		f. Roof	CGI	Wood
	woodplanks				steel truss
	stone	mud mortar		Clay tiles	Wood
		cement mortar			steel truss
	brick	mud mortar		stone tiles	Wood
		cement mortar			steel truss
	RC			other	
	Other				
			g. Doors	wood	If so, spieces
d.Stair	wood			others	
	RC				
	other		h. Windows	wood	If so, spieces
				others	

i. other structural element, if not covered:

C. Building Information- New Home
1. What type of material do you plan to rebuild with? Why? ☐ RC concrete frame and brick infill ☐ Stone mud motar ☐ stone cement mortar ☐ Brick/ Mud mortar ☐ Brick cement mortar ☐ wood ☐ Steel ☐ other
2. What type of layout do you plan to rebuild? ☐ Same number of floor ☐ same layout as before ☐ other and why?

D. General Questions				
1. How did you pay for your house? ☐ It was inherited ☐ Paid by working If so, what was your main source of income ☐ Agriculture ☐ Personal business ☐ Livestock ☐ someone working outside sending money ☐ other ☐ other				
2. Do you have access to credits?	Yes	☐	No	☐
3. Do you own the land in which your hosue is built?	Yes	☐	No	☐

4. What does a permanent house mean to you?
   - i. Is it symbol of status? ☐
   - ii. Is it just for shelter? ☐
   - iii. Is it use fot business? ☐
   - iv. others ☐

5. What is your understanding of seismic risk for your home before the earthquake?
   - i. I didn't know anything ☐
   - ii. I know some but not much ☐
   - iii. I was very aware ☐

6. What is your understanding of seismic risk for your home after the earthquake?
   - i. I didn't know anything ☐
   - ii. I know some but not much ☐
   - iii. I was very aware ☐

7. Are you ok to built house with local material like stone and mud/cement if there is good engineering design for safer house
   - Yes ☐
   - No ☐

Notes:

5.3 Summary of Homeowners Focus Study Results

Build Change-Nepal
Homeowner Survey

*Total Number of Surveys Taken in The Field: 71

Survey #:
Surveyor:

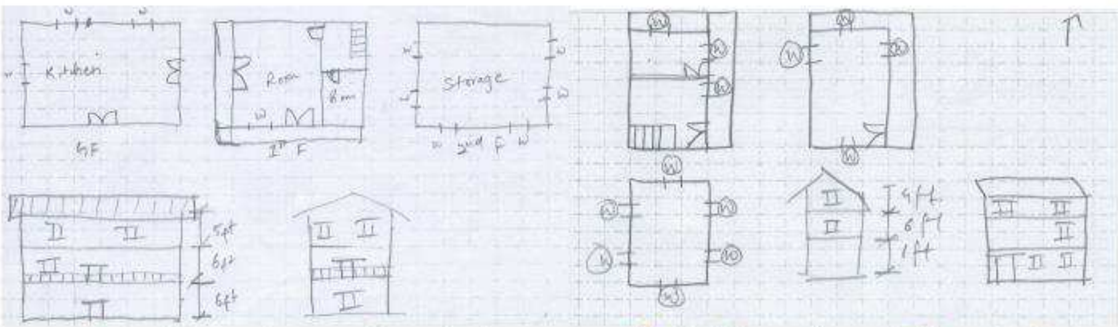
A. General Information			
1. Earthquake name:	Gorkha Earthquake M7.8 (4-25-2015)		
2. Survey date:	17th July 2015		
3. District/VDC:	Nuwakot/Sunkhani		
4. Latitude/Longitude:			
5. Name of homeowner:			
6. Ward no.:		Tole:	
7. Do you have internet access?	Yes 11	No 60	Email 11, Facebook 11

B. Building Information - Existing Home

1. Are you still living in your home? Yes 0 No 71
2. What is the level of damage of your home?
   Full collapse 50 Partial collapse 18 Cracks 3 No damage 0
3. When was your home built: Avg: 1992 A.D.
4. Number of occupants: Avg: 7

5. Use of home: Home Only 67 Home & Business 4 other:
6. Number of floors: Avg: 3
7. Is there a separate guest space (Pati)? Yes 62 No 9
   if yes, specify size (Length x Width): 15 ft x 4 ft

8. Is the toilet inside or outside the house? Inside 2 Outside 69
9. Plan Length: Avg: 15 feet Plan Width: Avg: 10 feet
10. Draw plan/elevation. Include plan dimensions, floor heights, door/window locations, and label each room



Typical House Layout: Example 1 Typical House Layout: Example 2

11. Except for the kitchen & bedroom, are there any other spaces that you need in your home?

49	Space for worshipping (puja kotha)
20	Storage
2	Other, if so specifiy: toilet

12. Who built your previous home?

21	Self, if so are you a builder?	Yes 0	No 21
50	Hired a builder		
0	Other, if so specify:		

13. Structural elements of existing house:

Element	Material Type			
Foundation	71	Stone	Mud mortar	71
			Cement mortar	
		Brick	Mud mortar	
			Cement mortar	
		RC		
		Other:		
Exterior Wall	71	Stone	Mud mortar	71
			Cement mortar	
		Brick	Mud mortar	
			Cement mortar	
		RC		
		Other:		
Partition Wall	4	Plywood		
	10	Wood planks		
	32	Stone	Mud mortar	32
			Cement mortar	
	2	Brick	Mud mortar	
			Cement mortar	
		RC		
		Other:		
	No wall : 23			
Stair	71	Wood		
		RC		
		Other:		

Element	Material Type			
Column	71	Wood		
		RC		
		Stone	Mud mortar	
			Cement mortar	
		Brick	Mud mortar	
			Cement mortar	
		Other:		
Floor	71	Wood	Mud slab	71
			Cement/brick mortar	
		RC		
		Other:		
Roof	67	CGI	Wood	64
			Steel truss	3
		Clay tiles	Wood	
			Steel truss	
	4	Stone tiles	Wood	4
			Steel truss	
		Other:		

Element	Material	Count	
Doors	Wood	71	If wood, which species?
	Other:		
Windows	Wood	71	If wood, which species?
	Other:		

14. Describe other structural elements not included above:

C. Building Information - New Home

1. What type of material do you plan to rebuild with? Why?

26	RC concrete frame with brick infill
4	Stone with mud mortar
2	Stone with cement mortar
4	Brick with mud mortar
26	Brick with cement mortar
5	Wood
3	Steel
1	Other: Pre-fab

2. What type of layout do you plan to rebuild?

Floors

20	Same number of floors as orignal home	
51	Less floors than original home, if so specify:	2 floors: 29, 1 floor: 22
0	More floors than original home, if so specify:	

Layout

29	Same layout as original home	
3	Smaller layout, if so specify (Length x Width)	
39	Larger layout, if so specify (Length x Width)	Avg: 15 x 20
0	Other, if so why?	

3. Do you intend to hire a builder to build your new home, or do you intend to build it yourself?

71 Hire a builder

If so, do you know do you know any local builders Yes 53 No 18

0 Myself

0 Other:

4. Do you want the toilet in your new home to be inside your home or outside your home?

20 Inside 51 Outside

5. Are there any new elements that you want to have in your new home that were not included in your original home? (example: the addtion of a Pati)

D. General Questions

1. How did you pay for your home?

27	It was inherited
44	I was paid by working

If so, what was your main source of income

38	Agriculture
4	Personal business
2	Livestock
0	Someone working outside of the country and sending money
0	Other

0	Other:

2. Do you have access to credit?	Yes	38	No	33
3. Do you own the land that your home is built on ?	Yes	55	No	16

4. What does a permanent home mean to you?

10	i. It's a reflection of yourself and your culture
35	ii. It's just for shelter
5	iii. It's only used for business?
1	iv. Other: Both i and ii : 20

5. What was your understanding of the seismic risk for your home before the earthquake?

12	i. I didn't know anything
48	ii. I knew about earthquakes but I didn't know my house would be damaged afterwards
11	iii. I knew about earthquakes and I knew my house would be damage
0	Other:

6. What is your understanding of the seismic risk for your home after the earthquake?

3	i. I intend to build the same way as before because of a lack of resources
34	ii. I intend to build a safer house with the amount of money I have
34	iii. I intend to build the house I want by saving additional money or taking a loan
0	iv. Other:

7. Are you comfortable rebuilding with local materials, such as stone and mud mortar, if there was an engineered solution provided to you for these material?

52	Yes
19	No

Notes:

5.4 Sample Survey Form: Builders Survey

CONSTRUCTION SECTOR SURVEY A (Active Site Information)

Surveyor: **Date:**
Address or GPS:

#	ACTIVE SITE INFORMATION	FILL OR ENCIRCLE	COMMENTS
1	Site ID (of choice):		
2	Type of activity:	New construction	
		Repair	
		Expansion	
3	# Skilled workers on site:		
4	# Laborers on-site:		
2	Contract holder on site:	Yes/No	
	Drawings/plans exist:	Yes/No	
3	Drawings/plans on site:	Yes/No	
4	Homeowner on site:	Yes/No	
5	Electricity on site:	Yes/No	
6	Water source:	River or Ravine	
		Well	
		Purchased	
		Mains	
7	Materials stored on site:	Yes/No	
8	Materials belong to:	Builder	
		Home-owner	
9	Accessible by small truck:	Yes/No	
10	Hand power tools on site:	Yes/No	
11	Cement mixer on site:	Yes/No	
12	Workers wearing safety gear	Yes/No	
13	Usual day start time:		
14	Usual day end time:		
15	Please describe the main activity underway:		

	If homeowner or contract holder available:		
16	Written contract:	Yes/No	
17	Builder paid for work in advance:	Yes/No	Percentage?
18	Estimated length of project:		
19	Full time project for contract holder:	Yes/No	
20	# Of contract holder simultaneous sites		

Please use same site ID for workers surveyed on that site

CONSTRUCTION SECTOR SURVEY B (Individual Workers on or off site)

Surveyor: **Date:**
Address or GPS:

	INDIVIDUAL INFORMATION	FILL OR ENCIRCLE	COMMENTS
1	Survey site ID (if any):		
2	Gender:	M/F	
3	Age:		
4	Born within 50km of site:	Yes/No	
5	Born within 5km of site:	Yes/No	
6	Dependents:	Yes/No	How many?
7	Read & Write:	Yes/No	
8	Qualifications:	None	
		Primary	
		Secondary	
		Vocational training	
		University	
9	English:	Yes/No	
10	Internet user:	Yes/No	
11	Telephone user:	Yes/No	
12	SMS user:	Yes/No	
Specialist means the worker is usually employed for this specific task			
13	Manages others:	Yes/No/ Specialist	
14	Reads plans:	Yes/No/ Specialist	
15	Lays Bricks/stone:	Yes/No/ Specialist	
16	Mixes cement concrete:	Yes/No/ Specialist	
17	Bends rebar:	Yes/No/ Specialist	
18	Carpentry:	Yes/No/ Specialist	
19	Logistics:	Yes/No/ Specialist	
20	Owns hand tools:	Yes/No	
21	Owns power tools:	Yes/No	
22	Owns truck:	Yes/No	
23	Independently mobile:	Yes/No	
24	Owns safety helmet, gloves and glasses	Yes/No	
25	Usual # of work hours per day		
26	Usual # of work days a week		
27	Paid:	Daily	
		Weekly	On what day?
		Monthly	
28	Salary (per above):		
29	Insurance:	Yes/No	
30	Formal Contract:	Yes/No	
31	Estimated days of employment a year:		
32	Estimated Projects a year:		

5.5 Sample Survey Form: Materials Survey

Housing Subsector Study Survey - Materials **Nepal**

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Fill this out for each source of information on materials availability and price

A. ADMINISTRATIVE INFORMATION

1	Source Name				Source ID:	
2	Owner/Contact				Time:	
3	Address				Survey Date	
4	City or Village		Sub-village			
5	GPS Marker No.		Latitude:		Longitude:	

B. SOURCE TYPE

☐ Materials Supplier ☐ Builder ☐ Homeowner ☐ Other: ______

☐ Can contact again, phone: ______

☐ Pricing info based on construction/purchase made when?

If supplier, answer following:
- Space for warehousing?
- Increase product stock for reconstruction?
- Order new materials if needed?

C. Materials Information

Material	Price	Unit	Transport Price	Unit	Notes
Cement, Ordinary Portland, Gr 33					
Cement, Ordinary Portland, Gr 43					
Cement, Ordinary Portland, Gr 53					
River Sand - washed					
River Sand - unwashed					
Crushed Pea Gravel 6-12					
Crushed Gravel 12-20					
Crushed Gravel 6-25					
Crushed Gravel 12-25					
River rock					
Limestone Rubble					
Building Stone					
Mud					
Class A Brick, 240x115x55					
Class B Brick, 240x115x55					
Class C Brick, 240x115x55					
Class D Brick, 240x115x55					
Concrete Block (Note Size)					
Concrete Block (Note Size)					
10cm Concrete Block					
Fe 415 Bars, 6mm (note length)					Deformed
Fe 415 Bars, 8mm (note length)					Deformed
Fe 415 Bars, 10mm (note length)					Deformed

Housing Subsector Study Survey - Materials — Nepal

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C. Materials Information (continued)

Material	Price	Unit	Transport Price	Unit	Notes
Fe 415 Bars, 12mm (note length)					Deformed
Fe 415 Bars, 16mm (note length)					Deformed
Fe 250 Bars, 6mm (note length)					Mild steel
Fe 250 Bars, 8mm (note length)					Mild steel
Binding wire					
Lumber,(note species and size)					
Lumber,(note species and size)					
Lumber,(note species and size)					
Lumber,(note species and size)					
Timber pole (note dia. & length)					
Plywood (note area and thickness)					
Plywood (note area and thickness)					
Plywood (note area and thickness)					
Metal strap (note gauge & width)					
Hardboard					
Wood Preservative					
Common Nails (note size and weight)					
Common Nails (note size and weight)					
4" Common Nails					
Roofing Nails					
3" Concrete Nails					
4" Concrete Nails					
CGI, 26 ga.					
CGI undulated, 29 ga.					
CGI undulated, 32 ga.					
CGI trapezoidal, 0.2mm					
CGI trapezoidal, 0.3mm					
CGI, 0.48mm					
Ridge cap					
Clay tiles					
Stone tiles					
Window frame & grill/shutter					
Door frame & door					
Paint					
Matstik for roofing sheets					
Other:					
Other:					
Other:					
Other:					
Other:					
Other:					

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Rental	Price	Unit	Transport Price	Unit	Notes (duration)
Formwork, wood boards					
Formwork, plywood					
Formwork, 2x4 lumber					
Metal shoring posts					
Other:					
Other:					
Other:					
Other:					
Other:					
Other:					

Additional Questions	
1)Where did you learn to build ?	
2) Are they using soecific nails at the roofs	
3) how are you attaching the roofing to the frame	
4)If there is a training in Kathmandu, or another nearby city, would you be able to attend	
5) If you had to rebuild your house, what materialswould you use and why?	
6)what type of work you did?	

5.6 Summary of Materials Survey Results

	Dhungkharka		Mahankal		Chalal Ganeshthan		Ramche		Maneshwor (4 years ago)	
Material	**Price (NPR)**	**Unit**	**Price (NPR)**	**Unit**	**Price (NPR)**	**Unit**	**Price (NPR)**	**Unit**	**Price (NPR)**	**Unit**
Cement	750-800	50 kg	750-800	50 kg	800	50 kg	700	50 kg	715	50 kg
Sand (washed)	125	cu. ft.	125	cu. ft.	90	cu. ft.	-	-	-	-
Sand (unwashed)	-	-	-	-	85	cu. ft.	29	cu. ft.	23	cu. ft.
Gravel	80	cu. ft.	100	cu. ft.	60	cu. ft.	17	cu. ft.	23	cu. ft.
Stone	700-800	1 cu. m	1,500	cu. m	1,600	cu. m	Uses local stones		700	cu. m
Mud Mortar	Use chimte mato (very fine clay)		Use chimte mato (very fine clay)		Use whatever is available		Use whatever is available		Use whatever is available	
Clay Bricks (Class A)	18	brick	Builders did not know the price of fired clay bricks, CMU blocks, or steel reinforcement		-	-	15	brick (before EQ)	7.8	brick
Class B					17	piece	-	-	-	-
Concrete blocks	-	-			35	block (12"x 8" x 4")	34	block (12" x 8" x 6")	40	block (12" x 8"x 6")
FE 415 bars	85	kg			95	kg	85-90	kg	84	Kg
Binding wires	120	kg			190	kg	105	kg	250	Kg
Wood (Sal)	1,000	cu. ft.			80	cu. ft.	-	-	-	-
Wood (Salla)	-	-	550	cu. ft.	-	-	2,500	cu. ft.	-	-
Wood (Chilaune)	-	-	-	-	-	-	1,700	cu. ft.	-	-
Wood (Tune)	-	-	-	-	-	-	-	-	1,200	kibi
Nails	120	kg	-		115	kg	120	Kg	130	kg
CGI (22 mm)	5,100	1 bundle	4,000	30 Kg	5,200	1 bundle 42kg	CGI is purchased from Barahabise			
CGI (29mm)	6,700	1 bundle	11,000	60-70 Kg	10,000-11,000	1 bundle 70-80kg)				

5.7 Sample Vetting Form: Demolition, Material Salvaging, and Material Reuse

Build Change - Nepal

Guideline Vetting Survey

Survey #:

Surveyor's Initials:

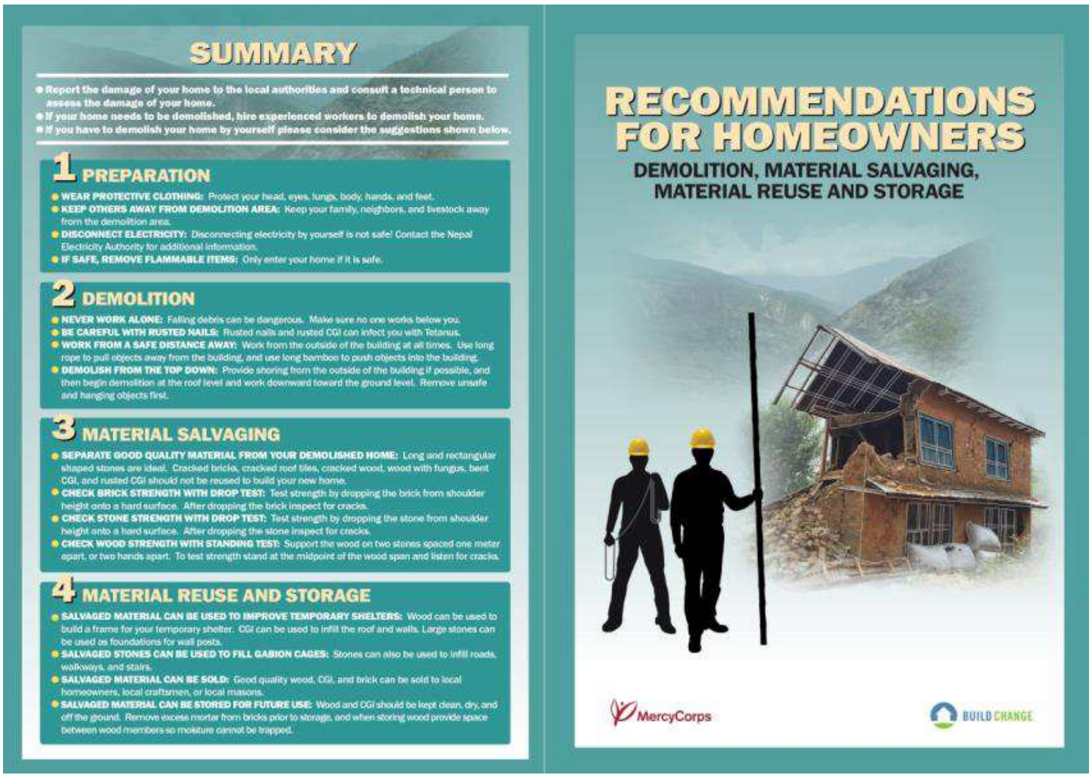
Earthquake name:	Gorkha Earthquake M7.8 (4-25-2015)
Survey date:	17th July 2015
District/VDC:	Nuwakot/Sunkhani

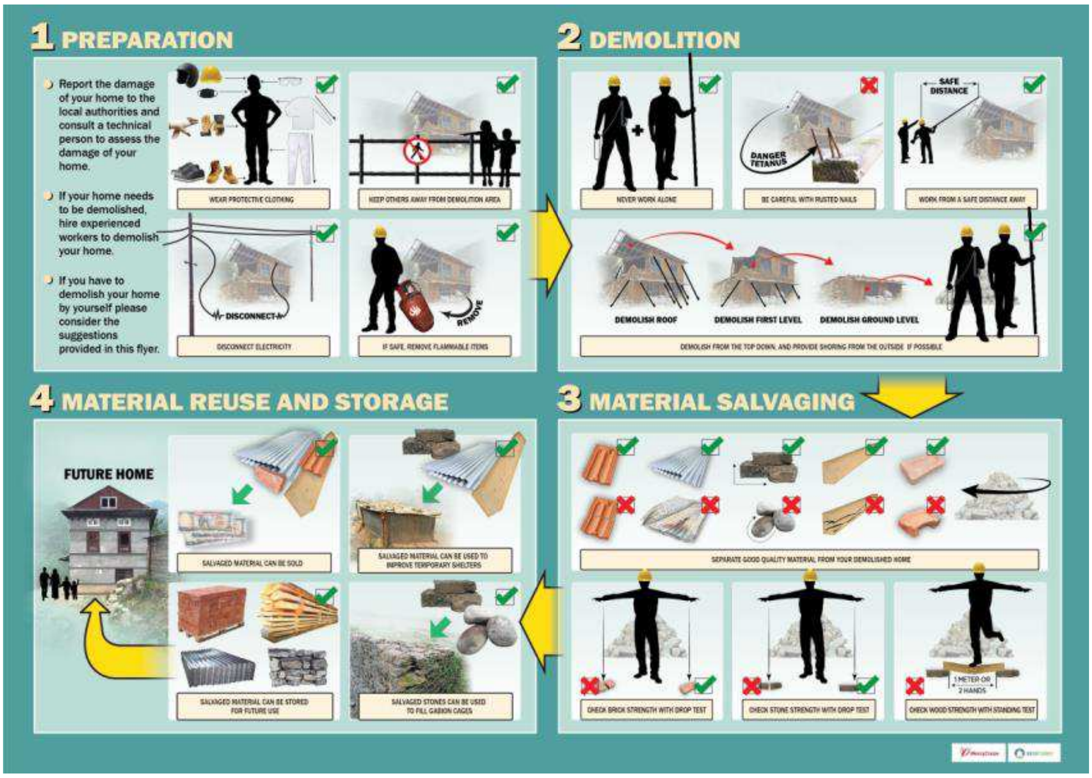
FIGURE	UNDERSTAND?				COMMENTS
A	YES		NO		
B	YES		NO		
C	YES		NO		
D	YES		NO		
E	YES		NO		
F	YES		NO		
G	YES		NO		
H	YES		NO		
I	YES		NO		
J	YES		NO		
K	YES		NO		
L	YES		NO		
M	YES		NO		

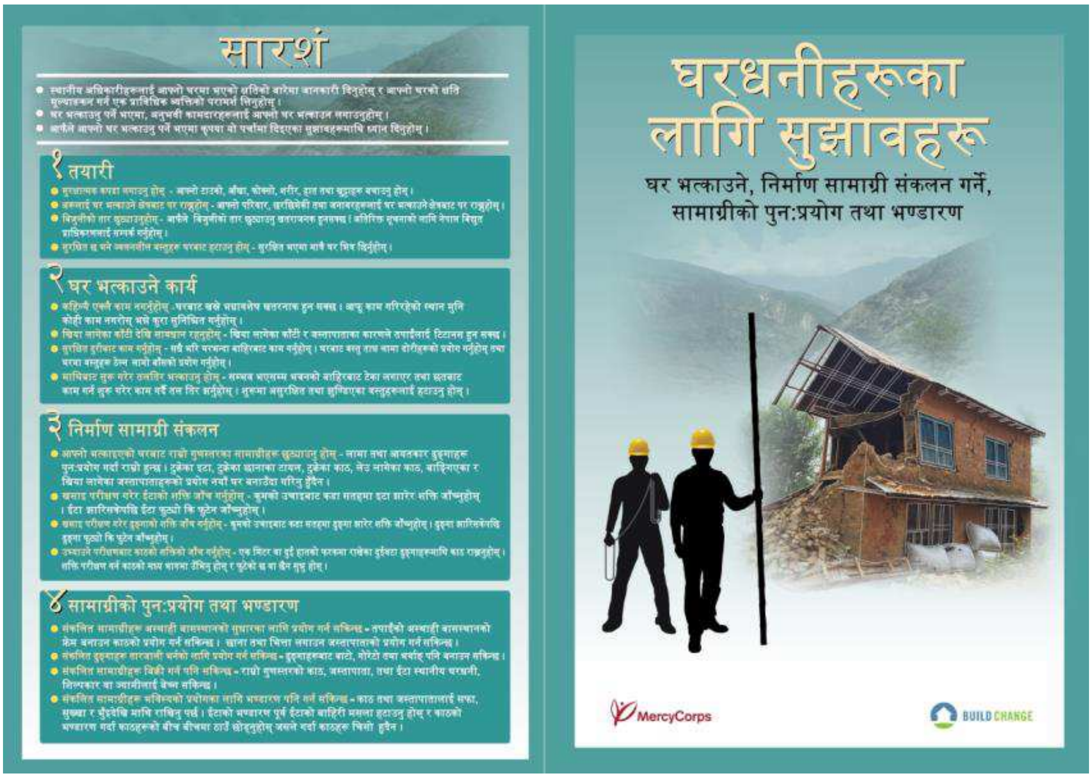
FIGURE	UNDERSTAND?				COMMENTS
A	YES		NO		
B	YES		NO		
C	YES		NO		
D	YES		NO		
E	YES		NO		
F	YES		NO		
G	YES		NO		
H	YES		NO		
I	YES		NO		
J	YES		NO		
K	YES		NO		
L	YES		NO		
M	YES		NO		

FIGURE	UNDERSTAND?				COMMENTS
A	YES		NO		
B	YES		NO		
C	YES		NO		
D	YES		NO		
E	YES		NO		
F	YES		NO		
G	YES		NO		
H	YES		NO		
I	YES		NO		
J	YES		NO		
K	YES		NO		
L	YES		NO		
M	YES		NO		

5.8 Demolition, Material Salvaging, and Material Reuse Flyer (English and Nepali)






सारांश
१ तयारी
२ घर भत्काउने कार्य
३ निर्माण सामाग्री संकलन
४ सामाग्रीको पुन:प्रयोग तथा भण्डारण
घरधनीहरूका लागि सुझावहरू
घर भत्काउने, निर्माण सामाग्री संकलन गर्ने, सामाग्रीको पुन:प्रयोग तथा भण्डारण
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BUILD CHANGE


१ तयारी
२ घर भत्काउने कार्य
४ सामाग्रीको पुन:प्रयोग तथा भण्डारण
३ निर्माण सामाग्री संकलन
भविष्यको घर

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