Case Study

Tribhuvan University
Institute of Engineering
South Asia Urban Knowledge Hub – Nepal

ADB Project Number: 46465
Regional - Capacity Development Technical Assistance (R-CDTA)

Earthquake Damage Assessment in the Traditional Town of Sankhu
Lessons for Reconstruction

December 2015
Earthquake Damage Assessment in the Traditional Town of Sankhu: Lessons for Reconstruction

**STUDY TEAM**

Sudha Shrestha, Prof., PhD  
Team Coordinator

Kirti Kusum Joshi, PhD  
Urban Specialist

Iswar Man Amatya, Assoc. Prof.  
Infrastructure Specialist

Luna Bajracharya  
Research Assistant

Tribhuvan University  
Institute of Engineering  
South Asia Urban Knowledge Hub  
Lalitpur, Nepal

Acknowledgements. Keiichi Tamaki (Senior Urban Development Specialist, ADB), Vivian Castro-Woolridge (Urban Development Specialist, ADB Nepal Resident Mission), Padma K. Mainalee (Under-Secretary, Ministry of Urban Development), Dr. Tri Ratna Bajracharya (Dean, Institute of Engineering) and Michelle Laurie (Knowledge Management Specialist/ ADB Consultant), the Office of Sankharapur Municipality, Monika Maharjan (M Sc Urban Planning Student, IOE) and student interns at Center for Urban Planning Studies (CUPS).

Cover Photo: A damaged traditional building in Sankhu (K. K. Joshi, IOE)

---

**ACRONYMS AND ABBREVIATION**

**I. BACKGROUND**

**II. SANKHU IN BRIEF**

**III. TRADITIONAL RESIDENTIAL BUILDINGS OF KATHMANDU VALLEY**

**3.1 Details**

**3.2 Resilience to Earthquakes**

**IV. EARTHQUAKE DAMAGE IN SANKHU: THE BUILDING SECTOR**

**4.1 An Overview of Building Damage**

**4.2 Building Typology and Fragility**

**4.3 Seismic Vulnerability**

**V. DO TRADITIONAL BUILDINGS HAVE FUTURE?**

**5.1 Context**

**5.2 The Economic Perspective**

**5.3 Policy Response**

**VI. CONCLUSION**

**REFERENCES**

**ANNEX A**

---

**Figure 1:** Regional map of Sankhu

**Figure 2:** Location map of Sankhu

**Figure 3:** The Sankhu settlement in late 1960’s overlaid on 1999 map

**Figure 4:** Sectional view of a typical Newar house

**Figure 5:** Section through wall, foundation and plinth

**Figure 6:** Three-layered wall construction

**Figure 7:** Assembly of posts, lintels and beams

**Figure 8:** A traditional joint used by local craftsmen for jointing on a new bottom to a post

**Figure 9:** Sections showing typical roof details

**Figure 10:** Share of buildings according to types and damage grade

**Figure 11:** Household size in surveyed households (left), number of storey (middle) and rooms per floor (right) prior to the damage

**Figure 12:** Earthquake impact on masonry buildings (left) and RC frame building (right) without base isolation

**Figure 13:** Soft storey effect due to excessive floor height floor on ground floor

**Figure 14:** Soft storey effect due to open floor

**Figure 15:** Shape and mass irregularities

**Figure 16:** Pounding during an earthquake between buildings of unequal heights (left); buildings separated by sufficient gap (right)

**Figure 17:** Desired improvement in new buildings (left), willingness to support bylaws focused on traditional construction (right)

**Figure 18:** Building types versus BC ratio

**Table 1:** Building damage in Sankhu

**Table 2:** Building typology and fragility
## ACRONYMS AND ABBREVIATION

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADB</td>
<td>Asian Development Bank</td>
</tr>
<tr>
<td>BC Ratio</td>
<td>Benefit Cost Ratio</td>
</tr>
<tr>
<td>DG</td>
<td>Damage Grade</td>
</tr>
<tr>
<td>HMG/N</td>
<td>His Majesty’s Government of Nepal</td>
</tr>
<tr>
<td>KII</td>
<td>Key Informant Interview</td>
</tr>
<tr>
<td>KVDA</td>
<td>Kathmandu Valley Development Authority</td>
</tr>
<tr>
<td>LSGA</td>
<td>Local Self-Governance Act</td>
</tr>
<tr>
<td>MMI</td>
<td>Modified Mercalli Intensity</td>
</tr>
<tr>
<td>MOHA</td>
<td>Ministry of Home Affairs</td>
</tr>
<tr>
<td>MOUD</td>
<td>Ministry of Urban Development</td>
</tr>
<tr>
<td>MRT</td>
<td>Mandatory Rule of Thumb</td>
</tr>
<tr>
<td>NPC</td>
<td>National Planning Commission</td>
</tr>
<tr>
<td>NPR</td>
<td>Nepalese Rupee</td>
</tr>
<tr>
<td>NSET</td>
<td>Nepal Society for Earthquake Technology</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operation and Maintenance</td>
</tr>
<tr>
<td>PDNA</td>
<td>Post-Disaster Needs Assessment</td>
</tr>
<tr>
<td>RC</td>
<td>Reinforced Concrete</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollar</td>
</tr>
<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
</tr>
<tr>
<td>VDC</td>
<td>Village Development Committee</td>
</tr>
</tbody>
</table>
Earthquake Damage Assessment in the Traditional Town of Sankhu: Lessons for Reconstruction

I. BACKGROUND

The 2015 April-May Nepal Earthquakes caused huge loss of lives and properties in the country – about 9,000 casualties; 22,300 injuries, 8 million directly affected people (or 1/3rd of the national population), over half a million collapsed houses, and a drop by over 1.5 percentage points in gross domestic product (NPC, 2015). Although the most affected regions were rural areas located outside the Kathmandu Valley, the latter also witnessed about 1700 casualties, 13,000 injuries, and 724,00 collapsed houses. Several traditional buildings and monuments, world-renowned for indigenous Newari architecture, in the Kathmandu Valley were literally razed to the ground, completely changing the built form of several ancient towns such as Bungamati, Khokana, Lubhu, and most notably Sankhu.

In light of the destruction caused by the recent earthquakes, the Urban Knowledge Hub (K-Hub) initiative in Nepal – based at the Institute of Engineering and supported by the Asian Development Bank and the Ministry of Urban Development – intends to contribute towards informed policymaking on risk-resilient urban development through the development and promotion of knowledge products. Urban resilience is a city’s ability to withstand and recover from unexpected shocks associated with natural hazards such as earthquakes (ADB, 2013). Building urban resilience begins with the collection, management, and dissemination of information on damage and prevailing risks. This case study takes stock of building damage in Sankhu in order to provide informed insight on how the town can be ‘built back better’.

As a town known for its heritage in the form of traditional architecture and built environment, the reconstruction of Sankhu could go either way: its historical built form could be adhered to, or there could be a departure in favor of ‘modern’ development. The complete collapse of traditional buildings has left a false impression that traditional building technology is not safe against earthquakes. However, these very buildings built with indigenous and ingenious building technology earlier survived the powerful 1934 Bihar Earthquake. The focus of investigation in this case study is to examine to what extent rebuilding of Sankhu along the traditional theme is logical from the perspective of risk-resilience, and whether such intervention makes any economic sense.

II. SANKHU IN BRIEF

Sankhu is an ancient town (12.5 hectares) populated by the Newars, the original inhabitants of the Kathmandu Valley. Situated about 20 km northeast of Kathmandu city (see Figures 1 and 2) on the bank of Sali river, Sankhu is one of the oldest settlements in the Kathmandu Valley, established by the Licchavis. The oldest inscription found in Sankhu is dated 538 AD (Shrestha, 2012). Until recently, the town was a part of the three erstwhile Village Development Committees (VDCs) – Pukhulachhi, Suntol and Vajrayogini. Sankhu now forms the historic core area of recently declared Shankharapur Municipality.

Once flourished as a trade post on the route to Tibet, Sankhu began to lose competitive advantage with the loss of this route in the late 1950s with further damage caused by the construction of Arniko Highway that now linked Kathmandu to the Tibetan border via Bhaktapur. Though most of the smaller traditional towns depended heavily on agriculture, Sankhu has historically been relatively less dependent on agriculture. Even in a survey conducted by HMG/N (1969), about 30 percent of the households reported non-agricultural occupation (e.g., commerce, wage employment or industries) as their primary occupation. The loss of trade to Tibet led to an increasing number of families seeking employment elsewhere, and even permanently migrating to other towns.

1 In this document, the 2015 April-May Nepal Earthquakes refer collectively to the 7.8 Mw Gorkha Earthquake of April 25, 2015 and 7.3 Mw earthquake of May 12, 2015.
3 The ‘Build Back Better’ or BBB implies a common approach adopted the government and development partners for the post-earthquake reconstruction in Nepal. The ‘Build Back Better’ approach basically “advocates for the restoration of communities and assets in a manner that makes them less vulnerable to disasters and strengthens their resilience.” (UN World Conference on Disaster Risk Reduction, 2015).
Figure 1: Regional map of Sankhu

Source: Ministry of Federal Affairs and Local Development, GIS and Map Center.

Figure 2: Location map of Sankhu

Source: Google map

Settlement Pattern. Like any other ancient town in the Kathmandu Valley, Sankhu is a compact settlement (Figure 3). Aside from the historic necessity for defense and the need for proximity to cultivated farmlands, the compact form of vertically oriented living in Sankhu – or any Newar town for that matter – is strongly motivated by concerns to preserve rich farmlands and minimize their use for residential purposes. With the abundance of clay in those times, houses have been uniformly built of burnt and unburnt clay bricks. The streets are mostly brick paved and the houses, of rather uniform height seldom exceeding 3 ½ stories, built on either side of the street have at least the brick walls of the compounds adjoining. Houses are closely spaced – built back to back with only a narrow lane between the two solid walls.
Figure 3: The Sankhu settlement in late 1960’s overlaid on 1999 map

Source: HMG/N, 1969 (foreground); Base map of Kathmandu Valley 1999, Kathmandu Urban Development Project, Department of Housing and Urban Development (background).
Frequently narrow lanes lead from the main road into the maze of houses. Small openings link these lanes with the courtyards lying behind the house-fronts. The high population density in the neighborhoods – characteristic of a Newar town – resulted into insufficient light and air, leading wider streets, courtyards and squares to become the scene of daily social and economic activities. Courtyards are surrounded by buildings on all sides, or sometimes on three sides with the fourth one replaced either by a pond or a wall with a gate. The enclosed courtyard, though originally designed for providing protection, also provides access to private dwellings.

III. TRADITIONAL RESIDENTIAL BUILDINGS OF KATHMANDU VALLEY

3.1 Details

Most of the traditional residential buildings that exist today in the Kathmandu Valley are from the Malla period, representing “the craft and architecture of the cultural renaissance of that period, which began around the beginning of the 15th century and survived the beginning of the Shah period, but rapidly faded during the Rana period (1845-1951 AD)” (Korn, 1977). Built, owned and resided by the Newar households, these buildings are also known as Newar houses.

The basic building unit of the traditional house is a simple rectangular space – generally 6 m in depth and 4 to 8 m in length – roofed with a gable and straight ridge line (Figure 4). The building expands by duplication and modification to become either a separate structure or a unit integrated into a main building. Independent of the house size, the need to use as little farmland as possible for residential purposes, cause the house to be vertically planned. Generally a Newar house is three-storied. The uniform depth facilitated the building of additional houses on to the existing ones forming blocks of houses.

The traditional houses are known for indigenous and ingenious construction technology using mostly locally available materials. There is a uniformity in building materials used: wood, mud, baked bricks and tiles produced locally. The Newar buildings are also appreciated for the rich brick work and wood carvings in windows. In addition, the construction technology is rich enough to allow repair or maintenance of building elements without significantly dismantling structures. But such technology has mostly lost with time although there have been some attempts to record and revive traditional techniques.

Figure 4: Sectional view of a typical Newar house

Source: Korn (1977)

Foundation. The basic foundations generally consist of a few layers of natural stone (large pebbles or broken stone) followed by brickwork which gradually attains the wall thickness of the ground floor and which continues into the superstructure without any damp proof layer (Figure 5). The foundations of one to four-storey buildings are not much deeper than 60-80 cm and wider than 70 cm.
Walls. Most houses consist of three parallel bearing walls (400 mm) with the middle wall functioning as the backbone of the house (Figure 6). Walls are built of fire burnt or sun dried bricks. Though more expensive, the burnt bricks have a better appearance and are more resistant to weathering. Thus they are used for outer wall construction while the sun dried bricks are used for the inner walls. Burnt bricks, however, are not as good as sun dried bricks in terms of adherence to the mud mortar.

The Newar house depends on its own weight for stability. But the walls bear a tremendous load. To avoid weakening of the structure, the number of ground level openings is kept to a minimum. When large openings are required, massive beams and posts are provided to bear loads (Figures 7, 8).

Floors. The flooring materials consist of packed earth and mud plaster. The floor joists are covered with narrow planks of thin bamboo reeds of various thickness. The packed earth is then carefully laid on top, leveled and a fine coat of mud plaster is applied.

Doors and windows. The door has two panels. The door frame usually carries carved motifs of flowers, serpents or dragons, done with both artistic and religious motives. Of the many types of windows, the most frequently used are the tikijhya (usually used in the bedroom or room on the first floor) and sanjhyia (used on the second floor). The tikijhya is a rectangular or square window with a decorated frame ornately designed with lotus petals, chain pieces, dragons, serpents, and so forth. The opening of the window is covered with lattice work. The main purpose of a tikijhya is to ensure privacy although its small size and design prevents much of the sunlight from entering into the room. The sanjhyia is much larger, allowing sufficient light. The window unit is divided into three panels, each creating a small window in itself. The whole frame of the window is carved with ornate designs.
The overhanging window unit is supported by struts which project from the wall at right angles to the beams and roof rafters at about one meter intervals.

**Roofs.** The roofs are usually symmetrical and owing to the rainy climate, pitched at about 30 degree (Figure 9). For roofing, flat red tiles are widely used. Tiling involves a simple procedure: the beams and roof rafters are positioned, spaced and covered with a layer of narrow wood planks over which mud is laid down to serve as a base for the tiles. The longer edge of each tile has grooves to hold the next one in position and ensure against leakage. Usually roofs have overhangs and eaves supported by wooden struts projecting obliquely from the wall at right angles to the roof edge. The projections protect the mud walls from the adverse effects of weather.

**Figure 9:** Sections showing typical roof details

### 3.2 Resilience to Earthquakes

Although most of the traditional buildings suffered severe to total damage during the recent earthquakes, the underlying technology behind the construction of such buildings is surprisingly advanced enough to ensure that buildings are able to withstand seismic shocks. The following features of a traditional building provide evidence to this:

**Configuration:** Most of the buildings are rectangular. These simple and symmetric configurations make the buildings more stable. This causes no excessive torsion because the centre of mass and center of rigidity coincide which is one of the features structural engineers ponder upon.

**Length to breadth ratio:** In most of the buildings, the length to breadth ratio is two or less, making them more stable.

---

*Based on a lecture note by Prof. Sudarshan R. Tiwari of Institute of Engineering.*
Openings: Openings are relatively small and symmetrically located. The small openings increase the length of the façade and maintain stiffness of the building.

Double framing of openings: Buildings have two complete frames of timber around the openings to strengthen them against lateral forces.

Wall Thickness: Wall thickness on the ground floor is 45 cm. Thickness decreases with every succeeding upper floor. As the horizontal thrust at the ground level develops highest at the time of an earthquake in the building, the greater thickness reduces the shear failure at that time.

Floor height and number of stories: Most of the buildings are 3 or 3 ½ stories. The storey height is found to be less than 2.5 m. This maintains stability of the building against lateral forces.

Wooden bands: Wooden bands around the building at the sill level, lintel level and at the floor level can be found carved as naga (snake). These bands protect walls from out-of-plane failures as well as provide integrity between different structural elements by connecting orthogonal walls. Also, the building acts as a monolithic structure, so that the earthquake force is resisted by the building as a complete unit rather than by individual part.

Vertical posts at corners: Vertical posts at corners act as vertical tensile reinforcements. This protects building from damage due to tensile cracks. In some cases, they provide some redundancy in the system which is very useful to withstand the earthquake force.

Wooden corner stitch: In addition to wooden bands, corner stitch can be found which connects orthogonal walls and protects from separation at the corners.

Struts: Struts are long wooden planks which support the overhanging roof of the temple. They transfer load of the roof to the vertical load bearing walls.

Wooden pegs: Proper connection of all wooden elements by wooden pegs can be seen in traditional buildings, which helps to ensure proper connection of roof and floor with the wall as well as with the different elements of roof and floor.

Boxing of openings: Boxing of openings by wooden frames, either all around or along both edges of the masonry wall provides strength around the openings.

Reducing load consecutively in upper floors: Due to lesser load carrying requirements, the wall thickness in the upper floors is reduced. The second and third floor central walls are often total timber frames. This reduces dead load of upper floors and gives more shear strength to the spine.

Plinth: Mostly in temples, foundation design for tall temples included massive multiple plinths. These improve response against wave amplification and avoid resonance with the ground.

Number of tiers: The Newari construction technique rarely uses even number of floors for constructing high buildings. Experiments with models have shown that a five-tiered temple comes to rest faster than four tiered temples when subjected to similar vibrations. Use of odd number of floors appears to have contributed to strength against earthquakes.

IV. EARTHQUAKE DAMAGE IN SANKHU: THE BUILDING SECTOR

4.1 An Overview of Building Damage

More than 90 percent of the buildings in Sankhu, mostly traditional houses, were completely damaged in the recent earthquakes. Although official figures exist for the whole Sankharapur Municipality or its wards – Sankhu is now made up of parts of ward no. 8, 9, 10 and 11, some attempts have been made to estimate losses in the core area alone.

According to a survey by NSET (August, 2015), out of about one thousand buildings in Sankhu, traditional buildings accounted for 70%, modern buildings for 24%, and the rest were neo-classical buildings (1%) and others (5%). Out of assessed 631 traditional buildings, 93% of the buildings suffered substantial damage and more, including complete destruction of 70% traditional buildings. In contrast, out of 217 assessed modern buildings, 22% suffered substantial damage and more including complete collapse of 5% (Table 1, Figure 10).
Earthquake Damage Assessment in the Traditional Town of Sankhu: Lessons for Reconstruction

Earthquake damage in Sankhu

Table 1: Building damage in Sankhu

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Damage Grade (DG)*</th>
<th>Total No. of Assessed Buildings**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern: RCC buildings</td>
<td>DG1: 1 DG2: 2 DG3: 2 DG4: 5</td>
<td>5</td>
</tr>
<tr>
<td>Others: Sheds, factory, store, mills, etc.</td>
<td>DG1: 3 DG2: 1 DG3: 1 DG4: 2 DG5: 6</td>
<td>13</td>
</tr>
</tbody>
</table>

Source: Study team’s analysis based on building damage survey map prepared by NSET. Note: DG1: negligible damage; DG2: moderate damage; DG3: substantial to heavy damage; DG4: very heavy damage; and DG5: destruction. ** There are in total about one thousand buildings in Sankhu.

Figure 10: Share of buildings according to types and damage grade

Household Sample Survey. In a survey of 80 affected households (completely damaged buildings: 68; partially damaged: 12) by Maharjan (2015), among the surveyed households of 73 traditional buildings built in mud mortar, 37% reported that damage to their buildings was caused by neighbouring buildings (possibly pounding effect), and 55% blamed old age. When asked why the buildings were not maintained, the concerned households listed replacement of jhingati roof tiles with corrugated galvanized iron sheets or plastering of walls as maintenance – there was not sufficient awareness about the structural retrofitting of the buildings.

The household sample survey indicates a significant loss of housing. Prior to the earthquake damage, most of the surveyed households had 4-storied buildings, and most buildings had at least 2 rooms per floor. The household size was large – 68% of the surveyed households had 5 or more members (Figure 11).
In order to understand the failure of traditional buildings or any other buildings during earthquakes, it is first necessary to understand how buildings of different typologies respond to seismic shocks, which is presented in the next section.

4.2 Building Typology and Fragility

The fragility of building structures during earthquakes depends on the building typology and construction technology adopted. Like in every other urbanizing areas of the country, it is common to see buildings of different types and ages (periods) standing next to one another in Sankhu although majority of the buildings are still traditional brick-in-mud mortar types. Table 2 shows probable damage to the different building structures at different intensities of earthquakes.

From Table 2, it is evident that if not built well, masonry buildings are prone to total collapse (damage grade or DG5) in the wake of strong earthquake. The same fate awaits for non-engineered reinforced concrete (RC) structures with four or more stories. This implies that a reinforced concrete structure – commonly known in public discourse as ‘pillar system’ – does not automatically ensure immunity against total collapse. The point is to construct a moment-resisting frame structure or ‘engineered’ building whereby lateral forces are resisted by the reinforced concrete frames that develop their stiffness through monolithic beam-column connections. This technical difference between an engineered and non-engineered RC structures makes all the difference during strong earthquakes as evident from complete collapse of several RC buildings in the affected districts.

However, in Sankhu, the survival of RC buildings (including non-engineered ones), though a matter of relief, may promote public bias against masonry buildings. According to Table 2 again, this need not be the case – if built well, even brick-in-mud and certainly brick-in-cement buildings can perform well against strong seismic force. This is important from the perspective of preserving or reviving traditional architecture and built environment of Sankhu which is now important for the economic resurgence of the ancient town.

It is also important to note that incremental vertical expansion of buildings is very prevalent in urban Nepal; Sankhu is also not an exception. This often results into an incompatible mix of new stories – often brick-in-cement types or even concrete structures – over old, ageing lower stories which are now forced to withstand the unintended load. In terms of seismic behavior, such buildings are the opposite of a monolithic structure, and hence very vulnerable to earthquake damages.
Table 2: Building typology and fragility

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Building Type and Description</th>
<th>Building Fragility</th>
<th>MMI*</th>
<th>Building Construction Quality and Damage Grade**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Case</td>
<td>Weak</td>
<td>Average</td>
</tr>
</tbody>
</table>
| 1     | Adobe, stone in mud, brick-in-mud (low strength masonry)  
**Adobe Buildings:** Buildings constructed in sun-dried bricks (earthen) with mud mortar for the construction of structural walls. Wall thickness usually exceeds 350 mm.  
**Stone in Mud:** Stone-masonry buildings constructed using dressed or undressed stones with mud mortar. These buildings generally have flexible floors and roof.  
**Brick in Mud:** Brick masonry buildings with fired bricks in mud mortar.  
| Adobe and field stone masonry building | VI                  | •••••••••••• | ••••• | •••• |
|     | Brick-in-mud (general) building | VI                  | ••••• | •••• | ••• |
| 2     | Brick-in-cement or stone-in-cement  
Brick masonry buildings with fired bricks in cement or lime mortar and stone-masonry buildings using dressed or undressed stones with cement mortar.  
| Brick-in-mud (well built) or brick-in-cement (ordinary) | VI                  | ••     | ••••• | •••• |
| 3     | Non-engineered reinforced concrete (RC) moment-resisting frame buildings  
Buildings with RC frames and unreinforced brick masonry infill in cement mortar. The thickness of infill walls is 230 mm (9") or even 115 mm (4½"). Column size is predominantly 9"x 9".  
| Non-engineered reinforced concrete frame buildings (≥ 4 story) | VI                  | •     | ••••• | •••• |
|     | Non-engineered RC frame buildings (≤ 3 story) or engineered RC buildings or reinforced masonry buildings | VI                  | •     | ••••• | •••• |
| 4     | Engineered RC Moment-Resisting-Frame Buildings  
Buildings consisting of frame assembly of cast-in-place concrete beams and columns, with floor and roof framing consisting of cast-in-place concrete slabs.  
**Note:** Lateral forces in these buildings are resisted by concrete moment frames that develop their stiffness through monolithic beam-column connections. These buildings are designed and construction supervised by engineers.  
| Building not falling within one of the aforementioned categories | VI                  | •     | ••••• | •••• |
| 5     | Others  
Wooden buildings or buildings using composite and mixed type of reinforced concrete, masonry units and mortar in the same building.  
| Seismic behavior depends on the inherent strength and weaknesses due to the use of composite and mixed type of concrete or masonry units. | VI                  | •     | ••••• | •••• |

Source: Improvised presentation of information based on MOUD/UNDP (2011). Note: * The Modified Mercalli Intensity (MMI) scale indicates the amount of damage observed in the affected location with the scale ranging from I to IX where VI: very strong intensity; VII: damaging intensity; VIII: highly damaging intensity; and IX: destructive intensity. The USGS ShakeMap indicates a maximum shaking intensity of "VII" or "violent" on the Modified Mercalli Intensity (MMI) scale, and moderate to heavy damage. ** The levels of damage grade (DG) are expressed graphically as follows: • (DG1: negligible), •• (DG2: moderate), ••• (DG3: substantial to heavy damage), •••• (DG4: very heavy damage) and ••••• (DG5: destruction).

http://www.gccapitalideas.com/2015/04/30/78mw-earthquake-%E2%80%93-lamjung-nepal/
Earthquake Damage Assessment in the Traditional Town of Sankhu: Lessons for Reconstruction

Salkha Tole- before (left) and after (right) (Source: Sankhu Reconstruction Committee)

Salkha tole- before (left) after (right) (Source: Sankhu Reconstruction Committee)

Pukhulachhi Tole- before (left) and after (right) (Source: Sankhu Reconstruction Committee)

Dhunla Tole- before (left) and after (right) (Source: Sankhu Reconstruction Committee)
4.3 Seismic Vulnerability

The way buildings are formed or loaded plays a vital role in increasing or decreasing seismic risks. Important factors are explained below in brief.

**Lack of base isolation.** Though highly effective against seismic forces, base isolation is not commonly practiced in Nepal. During earthquakes, buildings with base isolation respond to seismic shocks through horizontal two-and-fro motion of the entire building, thereby minimizing damages to the structures. However, buildings without base isolation struggle to transfer seismic loads to the foundation, causing damage to the weaker elements of the buildings first before impacting the whole structure (Figure 12).

**Figure 12:** Earthquake impact on masonry buildings (left) and RC frame building (right) without base isolation

![Figure 12](source: MOUD/UNDP (2011))

**Soft storey effects.** Soft-story buildings, so called for having first stories much less rigid than the stories above, are particularly susceptible to earthquake damage because of large, unreinforced openings on their ground floors. These openings often accommodate parking spaces, large windows and expansive lobbies in residential and retail buildings. Without proper design, such structures are much less able to withstand the lateral forces – forces that push a structure side to side – that earthquakes generate (Figures 13, 14). Once the first floor folds, the upper floors pancake down on top of it, crushing anything underneath.

**Figure 13:** Soft storey effect due to excessive floor height floor on ground floor

![Figure 13](source: MOUD/UNDP (2011))

---

*http://science.howstuffworks.com/engineering/structural/soft-story-seismic-retrofitting.htm*
Figure 14: Soft storey effect due to open floor

Source: MOUD/UNDP (2011)

Pancake failure of a Sankhu temple (right), soft storey on ground floor in a tall building in Sankhu (right)

Shape and mass irregularities. Many new buildings constructed in Sankhu and elsewhere display irregular shapes and forms in the name of innovative design and experimental architecture. However, shape irregularities and associated mass irregularities add vulnerability to buildings during earthquakes because of reduced stability of structures by design (Figure 15).

Figure 15: Shape and mass irregularities

Source: MOUD/UNDP (2011)
Adjacent Buildings and Pounding If buildings are built without sufficient gap and the interaction has not been considered, the buildings may pound each other during an earthquake (Figure 16). Building pounding can alter the dynamic response of both buildings, and impart additional inertial loads on both structures. Buildings that are of the same height and that have matching floors will exhibit similar dynamic behavior. In such case, when the buildings pound, floors will impact other floors, so damage due to pounding usually will be limited to non-structural components. When the floors of adjacent buildings are at different elevations, floors will impact the columns of the adjacent building and can cause structural damage.

Figure 16: Pounding during an earthquake between buildings of unequal heights (left); buildings separated by sufficient gap (right)

V. DO TRADITIONAL BUILDINGS HAVE FUTURE?

5.1 Context

Since the loss of trade route to Tibet, Sankhu has been an economically struggling town. The town has witnessed out-migration of many well-to-do families, which implies not only brain drain but also capital drain. Traditional buildings which suffered heavy damage during the recent earthquakes were already in dire needs of repair. Lack of timely maintenance could be attributed to the economic conditions of the concerned households who chose to stay in Sankhu or who could not afford to leave Sankhu.

As already discussed, the traditional building construction technology allows repair of building elements non-intrusively. The technology is known and is documented. Besides the costs of repair, it is also the issue of whether traditional buildings are compatible for modern way of living – whether the homeowners themselves would choose or decline traditional style while rebuilding their houses. According to the survey by Maharjan (2015), the households of damaged buildings wished to see
changes in building functions (e.g., use of ground floor for shops) and physical dimensions (e.g., increased floor height, room size) when they would rebuild (Figure 17, left).

Figure 17: Desired improvement in new buildings (left), willingness to support bylaws focused on traditional construction (right)

Regarding the preservation of traditional built form at the building level, Maharjan (2015) found acceptance level at almost 84% (Figure 17, right). Respondents were asked whether they would support building bylaws that would require them to preserve or rebuild buildings in traditional styles. About 16% of the surveyed households opposed rebuilding in traditional manner citing reasons such as high costs, economic inability to invest, and incompatibility of traditional houses for modern way of living. Aside from the majority of the surveyed households, participants of the key informants interviews (KIs) conducted by Maharjan (2015) strongly supported the need to preserve the traditional identity of Sankhu even if some compromises in the form of improvisation would be required to suit modern way of living and to address seismic risks.

New Construction Byelaws. Recently, the Government of Nepal endorsed Fundamental Construction Byelaws on Settlement Development, Urban Planning and Building Construction 2015 focusing on developing safer communities to deal with future disaster risks.

Accordingly, new municipalities, such as Shankharapur Municipality of which Sankhu is a part, and VDCs are required to implement the byelaws. For provisions not listed in the Fundamental Byelaws 2015, the earlier byelaws – Building Byelaws 2064 BS – will continue to be binding. As per the latter, Sankhu falls under the category of Preserved Cultural Heritage Sub-Zone and Mixed Old Residential Sub-Zone of Cultural Heritage Conservation Zone. However, now as a part of a new municipality and in the context of new Fundamental Construction Byelaws 2015, the nature of legal provisions for the (re)construction of buildings in Sankhu has become a matter of confusion for the Sankhu residents according to Maharjan (2015). The residents are concerned that if the provisions outlines in the Fundamental Construction Byelaws 2015 regarding minimum plot size of 3 aana (approx. 95 sq. m) and minimum right-of-way of 6 m are to be followed, Sankhu can no way retain any of its traditional form. Many houses in Sankhu are or were built on plots as small as 3 daam (approx. 24 sq. m). It is learnt that majority of Sankhu residents are suspicious about the so-called ‘house pooling’ approach of reconstruction – more in-depth study and perception survey is required.

5.2 The Economic Perspective

In order to retain the original built form of Sankhu to the extent practically possible, the economic benefits should be clear. Emotionally charged strategies lose their relevance over time but decisions that also make economic sense are long lasting. In any place-based planning, the strength of the place in question is first taken into consideration – for Sankhu, the strength is its cultural heritage and its physical manifestation in the form of traditional buildings, narrow alleys, temples and courtyards. In the words of Nobel Prize Laureate Robert Merton Solow (Licciardi and Amirtahmasebi, 2012):

“Over the long term, places with strong, distinctive identities are more likely to prosper than places without them. Every place must identify its strongest most distinctive features and develop them or run the risk of being all things to all persons and nothing special to
any...Livability is not a middle-class luxury. It is an economic imperative.” – Robert Merton Solow.

In some core areas of Kathmandu Valley, some ageing historic buildings have been remodeled as bed-and-breakfast inns or short-term residential rental units with impressive economic returns. According to Maharjan (2015), the survey respondents and KII participants expressed optimism that reconstruction of Sankhu in traditional style would be economically beneficial as that would create investment opportunities related to tourism and service sector – buildings can partly be rented not only for tourism-related services but also for office use by government or non-government agencies. Municipality can play the role of facilitator.

To drive the point home, a very simple economic analysis (at building level) can be performed assuming that a 4-storied building is to be built on a plot of 2 aana (684.5 sft) with 100% ground coverage. The total built-up area is therefore 2738 sft. Three alternative building styles are considered: (1) traditional, (2) semi-traditional, and (3) modern. Construction costs vary accordingly (see Annex A). Different rental areas (%) are considered. For simplicity, floor rents are assumed to increase annually at the rate equivalent to the interest rate – this way, discounted amount equals the present value. The life of building is assumed to be 20 years, which is checked against calculated payback period. The operation and maintenance (O&M) cost is supposed to be 30% of the gross rental income.

Figure 18: Building types versus BC ratio

The results are depicted in Figure 18 (see Annex A for data), which shows, for example, at a monthly gross rent of NPR 100/sft, a traditional building would provide its investor a benefit cost (BC) ratio of 1.5 in 20 years if half of its total floor area is rented at the aforementioned rate. The challenge is to ensure that the floor space are rented at expected price.

5.3 Policy Response

Most of the prevailing policies do support preservation of traditional buildings but the policies are mostly restrictive, telling homeowners what they can do or cannot do rather than addressing their economic concerns as well. If a traditional building has social value, what does its homeowner receive in lieu of preserving the building? This is an important question. Lack of interest in the maintenance of traditional buildings or their continued replacement by ‘modern’ style buildings implies that the welfare of the homeowners of traditional buildings are not being taken care of.

Some relevant policies are briefly featured below.

---

9 The rate ranges from USD 20 to 70 per night for an accommodation comprising of a living room, a bedroom and a kitchenette (approx. total area= 250 sft).
10 Social or induced benefits are not considered.
Ancient Monument Preservation Act 1956. A number of provisions are included in the Act to preserve individual elements of the cultural properties as well as to preserve the beauty and the character of groups of buildings, towns and sites which are of particular interest for historic, artistic, scientific and aesthetic reasons.

Local Self-Governance Act (LSGA) 1999. The LSGA has provisions to conserve cultural heritage within the jurisdiction of local bodies.

Guthi Corporation Act 1977. Under the provision of the Act, Guthi Corporation, a centralized government trust is entrusted to conduct rituals and to preserve the service oriented religious affairs, historical and cultural activities.

Kathmandu Valley Development Authority (KVDA) Act 2045. KVDA is empowered to divide Kathmandu Valley into different land use zones. It sets standards for physical development and formulates by-laws. It has power to demolish unauthorized constructions.

Kathmandu Valley 2035 and Beyond 20 Years Strategic Development Master Plan (2015-2035) (Draft). Objective 1: Rejuvenate the core historic cities through the preservation of the historical, cultural and social assets. Objective 2: Prohibit vertical subdivision of buildings in city core areas. Objective 3: Support the Department of Archaeology to undertake immediate reconstruction of heritage areas

Building By-laws 2064 BS. Sankhu is categorized under Preserved Cultural Heritage Sub-Zone and Mixed Old Residential Sub-Zone Of Cultural Heritage Conservation Zone.

Fundamental Construction Bylaws on Settlement Development, Urban Planning and Building Construction 2015. The by-laws outlawed, among other things, row housing (houses attached side-by-side) taller than three storeys and made it mandatory for houses to be at least 1½ m apart.

Building By-laws Model Guideline, 2015. House owners shall be responsible for the repair and maintenance of the buildings in the heritage areas. KVDA or concerned municipality has full authority to permit or prevent changes in the buildings including painting and plastering.

Nepal National Building Code 202: 1994 - Mandatory Rule of Thumb (MRT) for Load Bearing Masonry. The MRT does not cover wooden buildings, mud buildings (low-strength buildings), or adobe buildings. This MRT is valid (with certain limitations as to span, floor height, etc.) for: i) load-bearing brick masonry buildings constructed in cement mortars up to three stories, ii) load-bearing stone masonry buildings constructed in cement mortar up to two stories, and iii) load-bearing brick masonry buildings constructed in mud mortar up to two stories.

Post-Disaster Needs Assessment (PDNA) 2015. PDNA stresses that the recovery program will focus on Nepal’s cultural heritage through restoration and reconstruction of all damaged and collapsed historic buildings. It further lays emphasis on owner driven program backed up with technical support from the government.

Co-operatives Act 2048. The Act makes provisions for the formation and operation of various types of cooperative associations and societies based on the mutual support and cooperativeness for the economic and social development of the general public consumers. The spirit of cooperatives could be utilized in the reconstruction of Sankhu as the recent earthquakes did not affect a single household but an entire community.

VI. CONCLUSION

Crisis also provides opportunity. The devastation caused by the recent earthquakes has generated unprecedented public awareness on the importance of safe building construction and risk-resilient urban development. Although valuable lessons have been learnt, some myths have also crept in. The case in point is the massive destruction of traditional buildings, which may have left a false impression that traditional buildings are not safe against earthquakes. However, these same buildings have withstood earlier earthquakes including the powerful 1934 Bihar Earthquake. The traditional building construction technology is rich in terms of resilience against earthquakes as well as in terms of simplicity in the maintenance of building elements without impacting the other elements.
of the building. However, as investigated in this case study, traditional buildings failed miserably during the recent earthquakes because of their old age and lack of maintenance for a prolonged period. The underlying reasons for poor maintenance are, among others, high costs and low economic capacity of the concerned households. However, the economic opportunities associated with the preservation of traditional buildings have not been properly or fully explored. For an economically struggling town such as Sankhu, rebuilding in traditional style to bring back some of the lost glory could be an economic opportunity too rare to miss because after the loss of its status as prosperous trade post, the only strength that remains with Sankhu is its identity as a traditional town. What needs to be done is to capitalize that identity.

REFERENCES


### ANNEX A

Table A1: Calculation of payback period and benefit cost ratio for different types of buildings under varying floor rents

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Building Type</th>
<th>Construction Cost (NPR/sft)</th>
<th>Total Construction Cost (NPR)*</th>
<th>MGR (NPR/sft) **</th>
<th>Net Annual Rental Income (NPR)*** and Share of Rental Area</th>
<th>Payback Period (Years) and Share of Rental Area</th>
<th>Benefit Cost Ratio**** and Share of Rental Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Traditional</td>
<td>5500</td>
<td>15,059,000</td>
<td>100</td>
<td>2299920</td>
<td>6.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td>1839936</td>
<td>1379952</td>
<td>1149960</td>
<td>8.2</td>
<td>1.2</td>
</tr>
<tr>
<td>2</td>
<td>Semi-traditional</td>
<td>3400</td>
<td>9,309,200</td>
<td>75</td>
<td>1293705</td>
<td>7.4</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55</td>
<td>1264956</td>
<td>948717</td>
<td>632478</td>
<td>7.4</td>
<td>0.9</td>
</tr>
<tr>
<td>3</td>
<td>Modern</td>
<td>2900</td>
<td>7,940,200</td>
<td>50</td>
<td>962470</td>
<td>6.9</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
<td>689976</td>
<td>517482</td>
<td>344988</td>
<td>11.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Note: NPR: Nepalese Rupee; sft= square feet. The shaded values implies payback period of 20 years and more, and BC ratio of 1 and more.*Total floor area= 2738 sft. Monthly gross rent (MGR) is based on market information: In Bhaktapur, a B&B enterprise operating in a traditional house charges 20 to 70 USD per night for accommodation comprising of a living room, a bedroom and a small kitchenette (total area = 250 sft approx.). Similar accommodation in a semi-traditional house is charged at 20 to 30 USD per night. The floor rent in an ordinary modern house for similar space is about NPR 10,000 per month.****Operation and maintenance (O&M) costs at the rate of 30% are deducted. ****Calculated on the basis of building life=20 years.