16th World Conference on Earthquake Engineering, 16WCEE 2017
Santiago Chile, January 9th to 13th 2017
Paper N° 2591
Registration Code: S-P1474551518

STRENGTHENING BUILDING CODE IMPLEMENTATION AND COMPLIANCE IN THE DEVELOPING WORLD: A CASE STUDY OF NEPAL

L. Arendt[(1)], A. Hortacsu[(2)], K. Jaiswal[(3)], S. Shrestha[(4)], J. Bevington[(5)], F. Lanning[(6)], G. Mentor William[(7)], G. Naeem[(8)], K. Thibert[(9)]

[(1)] Professor of Management, Donald J. Schneider School of Business & Economics, St. Norbert College, De Pere, WI, USA, lucy.arendt@snc.edu
[(2)] Director of Projects, Applied Technology Council, Redwood City, California, USA, ayse@atcouncil.org
[(3)] Research Civil Engineer, U.S. Geological Survey, Golden, Colorado, USA, kjaiswal@usgs.gov
[(4)] Deputy Executive Director, National Society of Earthquake Technology (NSET), Nepal, sshrestha@nset.org.np
[(5)] Technical Director, JBA Consulting, UK, johnsbevington@gmail.com
[(6)] Associate, Miyamoto International, Inc., Costa Rica, forrest.lanning@gmail.com
[(7)] Medical Doctor, Haiti Representative, GeoHazards International (GHI), Haiti, mentor@geohaz.org
[(8)] Disaster Risk Management Consultant & Architect, Resilience Group, Pakistan, ghazala_ghq@hotmail.com
[(9)] Design Engineer, Read Jones Christoffersen Ltd., Vancouver, Canada, KThibert@rjc.ca

Abstract

The April 2015 Gorkha Nepal earthquake and subsequent aftershocks revealed the relative effectiveness of the country's National Building Code (NBC) and irregular compliance with it in different parts of Nepal. The prevalence of owner-built structures in the country meant that few residential structures, especially those outside Kathmandu Valley, were constructed with any formal professional engineering design or supervision. Tens of thousands of buildings collapsed or were severely damaged as a result of the Gorkha earthquake sequence, leading to the mammoth task of rebuilding and recovery. Such a situation underscores the need for a suitable mechanism to direct and govern construction standards and best practices of resilient construction. Ultimately, this mechanism should help to achieve the goal of reaching areas of the developing world where the majority of new construction will be built in this century. The NBC, developed following the 1988 earthquake in the Nepal-India border region and published in 1994, covers the most common building types in Nepal. The NBC has a tiered code structure that requires stringent engineering supervision for both international state-of-the-art buildings and very tall and complex buildings. For low- or mid-rise buildings and those that are located in rural areas, the NBC only states Mandatory Rules of Thumb or Guidelines to be followed by local masons and craftsmen. In this paper, we share preliminary results of a two-year project by the Earthquake Engineering Research Institute's Housner Fellows Program (a leadership and advocacy training program) focused on understanding and communicating a path toward increased building code compliance and enforcement in Nepal. We describe some issues associated with implementation of the NBC, along with global best practices for building code compliance drawn from the literature. We discuss how this information served as the foundation for workshops conducted in three municipalities in Nepal representing various levels of building code implementation. The workshops, held in February 2016, included a broad selection of stakeholders, from the ministerial level to local masons. Participants were invited to share their experiences with designing and implementing initiatives at the local level. The workshops' goals were twofold: (1) to communicate best practices from Haiti, Pakistan, and New Zealand for increasing building code compliance, and (2) to encourage and enable dialogue among the workshop participants on local conditions and potential means of increasing building code awareness and compliance. Finally, we elaborate on lessons learned and key observations for each of the participating municipalities. It is our hope that this summary of our literature review and preliminary findings from our field-based investigations will facilitate future efforts toward improving building code compliance in Nepal and other developing countries around the globe.

Keywords: building code compliance; rebuilding; building code

1. Introduction

Many countries have adopted some form of earthquake safety in building construction for new housing/infrastructure facilities dating back nearly one hundred years (Japan in 1919, the United States in 1927, New Zealand in 1935). Over the next several decades, these countries invested in multiple realms (e.g., research and development, building construction technology, code regulations, awareness) to mitigate existing vulnerabilities and to prepare for future seismic risk. Despite these and other investments in seismic mitigation in various parts of the world, as a global community we continue to face many challenges in mitigating against earthquake risk, especially when we consider the case of developed versus developing countries. We have observed, for example, that earthquakes of similar intensities and population exposure can yield significantly different impacts. To illustrate, we can compare the 2005 M7.6 earthquake in northern Pakistan, which caused 86,000 fatalities [1], to the 1994 M6.7 Northridge earthquake in California, which claimed 33 lives. In both instances, approximately one million people experienced Modified Mercalli Intensity (MMI) VIII or higher, yet the fatality rate in Pakistan was nearly 5000 times higher than the rate in California. Similarly, the 1999 M7.7 earthquake in Chi Chi, Taiwan and the 2008 M7.9 earthquake in Wenchuan, China yielded very different impacts. The Chi Chi earthquake caused 2,400 fatalities [1], with nearly 4 million people experiencing MMI VIII or higher shaking. In contrast, the Wenchuan, China earthquake caused more than 69,000 fatalities, with approximately 1.5 million people experiencing MMI VIII shaking [1]. In other words, the fatality rate in the 2008 China earthquake was several orders of magnitude higher than that observed due to the 1999 Taiwan earthquake.

While recent earthquakes in the United States, Japan, and New Zealand have been destructive in terms of physical damage and economic impact, they have yielded far fewer fatalities [2] than similar earthquakes in developing countries. One factor that appears to drive these differential impacts is the fact that buildings in California, Japan, and New Zealand are built to stringent seismic codes that target life safety as a key consideration in their design and construction. Thus, although buildings may have been damaged as a result of recent earthquakes in California, New Zealand and Japan, many of these same buildings sustained low enough damage such that occupants were able to exit safely, thanks to their seismic design and construction.

Numerous scientific and earthquake engineering advancements have taken place in the last several decades that have positively influenced the way we now design and construct newer buildings in areas of seismic hazard. Unfortunately, these advancements (both in knowledge and in building code practice) appear to have had only limited positive impact in the context of developing countries where recent earthquakes have continued to kill people and cause financial losses at an alarming rate. Recent earthquake disasters have also demonstrated that the mere existence of building codes and regulations has little influence on the safety of buildings [3], as these regulations may or may not be understood by those responsible for design and construction and may or may not be enforced to their original or intended purposes.

Seismic design and construction practices continue to evolve, as do strategies and technologies designed to minimize losses from earthquakes. Moreover, ensuring proper building code understanding and enforcement in the developing world with rapidly expanding urban centers may contribute to reducing future earthquake losses. We believe that there is a unique and timely opportunity to make a positive, lasting difference in the earthquake community by highlighting issues of building code understanding and enforcement and by identifying mechanisms for increasing adoption and enforcement of codes.

2. Building Codes

A safer built environment is the mandate of a building control authority; relevant professional groups and other stakeholders may be involved in building a safer community. Achieving the goals of building codes typically requires the development and implementation of regulations and (or) by-laws by the government organization or

agency responsible for controlling building design and construction at the Municipality, City, State, or National level.

A building code, or building control, is a set of rules that specifies the minimum standards for constructed objects such as buildings and non-building structures. The main purpose of building codes is to protect public health, safety, and general welfare as they relate to the construction and occupancy of buildings and structures. The building code becomes the law of a particular jurisdiction when formally enacted by the appropriate governmental or private authority.

Enacting a regulation, code, or law does not ensure compliance with it [4]. Any number of variables can interfere with seismic building code compliance, including stakeholders' lack of awareness or understanding of the issues, stakeholders' negative beliefs about whether they exert any control over what might happen to their buildings, stakeholders' belief that the right time to act is not now, the lack of technical solutions appropriate to the community's history and culture, and stakeholders' inadequate capacity to act (e.g., due to lack of access to knowledgeable design professionals, lack of capital to construct buildings in line with codes) [4]. Without adequate knowledge of codes, without an understanding of how to comply with them, without the means to comply with them, and without systematic building code enforcement, it may be impossible to ensure that new structures will be built according to the requisite standard and able to serve their function safely during their lifetime. While there may be many obstacles to code compliance, poor enforcement appears to pose a particular challenge, perhaps especially in developing countries where technical capacity and other enforcement enablers may be in short supply [4]. The results of noncompliance with building codes include an unsafe built environment that contributes to the loss of life, property, infrastructure, economy, and environment in the wake of a disaster.

A literature review conducted by the authors found that three factors seem to contribute significantly to building code compliance. While the lessons derived from the literature may not have always focused on the situation in developing countries, these lessons might be construed as having greater relevance in developing countries than in their more developed counterparts. The first factor, "strong leadership," considers the role and impact of community leaders, both formal and informal. In general, various scholars have suggested that the more effective and persuasive the leadership exercised in a given community, the greater the likelihood of building code compliance [5, 6]. People are more likely to listen to individuals they know and respect than they are to listen to others, including those who might be perceived as experts by virtue of their educational and other credentials.

The second factor, "awareness of and education about the need for building codes and the means to comply with them," acknowledges that awareness of codes in a given country may vary by geography, with those in rural areas tending to be less aware of codes than those in urban areas [7]. This factor also considers the role of a general "safety culture" in which individuals understand both the risks they face and how to manage them [8]. Finally, this second factor also includes the lack of knowledge and capacity on the part of local engineers and masons, those individuals most likely to be involved in building construction [9]. The third factor, "availability of improved construction materials and practices," addresses several key issues. In Southeast Asia, for example, the construction industry faces a variety of issues, including the lack of skilled labor, use of low quality materials, and regulatory barriers (or the lack of policies and incentives to encourage sustainable construction) [10]. In the Middle East, key challenges include an underdeveloped private banking sector and capacity pressures on labor and materials [11].

Contrary to what some may assume to be the case, no studies were found to show that penalties for non-compliance ensured successful implementation of building codes. One possible explanation for this non-finding is that the causes of non-compliance, such as a lack of sufficient capital, may lessen the salience and impact of potential penalties.

3. Nepal, a Case Study

The Earthquake Engineering Research Institute (EERI) is a nonprofit, technical society of engineers, geoscientists, architects, planners, public officials, and social scientists. The mission of EERI is to reduce earthquake risk by (1) advancing the science and practice of earthquake engineering, (2) improving understanding of the impact of earthquakes on the physical, social, economic, political, and cultural environment, and (3) advocating comprehensive and realistic measures for reducing the harmful effects of earthquakes. One of EERI's signature programs is the Housner Fellows Program, initiated in 2012. The Program is designed to prepare a new generation of leaders and advocates for earthquake safety. Its strategic objective is to recognize and equip promising and motivated early- to mid-career professionals with the confidence, skills, and sense of responsibility needed to become lifelong leaders and advocates of earthquake risk reduction. To achieve its objective, a new class of Housner Fellows is selected every two to three years. Each class participates in leadership training and then selects and implements a multi-year project designed to enhance the Fellows' collaborative and leadership skills while applying their technical knowledge and expertise to a real-world earthquake safety issue.

The current Housner Fellows class convened in July 2014. Its membership includes individuals living around the world with national origins in Canada, Haiti, India, Nepal, Pakistan, Turkey, the United Kingdom, and the United States. The group decided to study building code implementation in Nepal. While this developing country with high earthquake hazard has had a national building code since 1994, its mandatory building code implementation program (BCIP) has been in effect for the past decade only, since 2006. Knowing that implementation of the building code in Nepal was a work in progress, with some municipalities benefitting from a higher rate of compliance than others, the Housner Fellows group decided to study the primary factors that had encouraged or inhibited appropriate implementation of the building code and concomitant regulations. The primary goal of the group's study was therefore to identify and capture replicable successes and lessons learned from Nepal that could be shared with other developing nations with similar sociocultural, political, and seismic characteristics.

The Housner Fellows group was committed to its study of building code compliance in Nepal well before April 25, 2015, when a magnitude-7.8 earthquake occurred east of the Gorkha District at Barpak, Gorkha, approximately 80 kilometers northwest of Kathmandu, the capital of Nepal. The earthquake killed more than 8,800 people and injured more than 21,000 people. Hundreds of thousands of people were made homeless with entire villages destroyed [12, 13, 14] across many Districts of the country. Centuries-old buildings were destroyed at UNESCO World Heritage sites in the Kathmandu Valley along with thousands of residential structures. It was the worst natural disaster to strike Nepal since the 1934 Nepal–Bihar earthquake. For a country with a building code in place for twenty years, the high number of fatalities and the widespread building damage may have seemed astonishing, but in reality, the building code implementation was only in effect for approximately 11 percent of the municipalities in the country and among those municipalities only a small fraction of buildings was built to modern code [12].

The April 2015 Gorkha earthquake underscored the importance of understanding the challenges associated with obtaining high compliance rates with building codes, especially for residential structures. With this event in the forefront of people's minds, the Housner Fellows group determined that a field visit to Nepal was essential if it was to accurately describe the factors associated with non-compliance with building codes and the steps that might be taken to encourage and incentivize compliance going forward.

4. Field Work Conducted in Nepal

In order to understand non-compliance with building codes for residential structures in Nepal, the Housner Fellows completed two tasks before they visited Nepal in February 2016. First, the Fellows did a comprehensive

study of the literature on non-compliance with building codes and regulations, with a specific focus on attitudes and actions in developing countries. Second, the Fellows immersed themselves in learning as much as possible about Nepal: its history and government structure, the Gorkha earthquake, and its aftermath. Two of the Fellows participated in EERI's Learning from Earthquakes reconnaissance trip to Nepal in June of 2015 [12]. One of the Fellows is Deputy Director of the National Society for Earthquake Technology (NSET) in Nepal and was in country during and after the April 2015 earthquake. Members of NSET developed several presentations that were shared with the Housner Fellows to facilitate their understanding of the Nepali context for building code compliance during their February 2016 visit.

While in Nepal in February 2016, the Fellows coordinated and participated in three daylong workshops, all of which included a wide variety of stakeholders and interests. As noted previously, the purpose of the workshops was to engage in mutual information sharing and to discover the factors enabling and hindering building code compliance. Municipal officials and Housner Fellows gave presentations, after which the workshop attendees were organized into smaller focus groups, each facilitated by one or two Housner Fellows. Prior to the workshop's end, individuals were asked to complete short paper surveys asking about their knowledge of building codes and the factors influencing compliance with them. The surveys were drafted in English and translated into Nepali; participants completed the surveys in Nepali. Their responses were translated back into English by NSET personnel fluent in both languages.

Three municipalities were selected for the workshops based on a variety of characteristics. The Fellows selected municipalities whose characteristics were common among other municipalities, thereby enhancing the potential generalizability of their workshop findings to the full area affected by the 2015 earthquakes. Table 1 lists each of the municipalities along with key characteristics of each.

The first workshop was held in Kathmandu in the Lalitpur Municipality on February 8, 2016 with 46 participants. Workshop participants included masons, engineers, disaster management professionals, business owners, journalists, and government officials. This location was selected for the first workshop because this Municipality has been proactive with building code implementation. In 2004, Lalitpur was the first Municipality in Nepal to initiate a building code implementation program, years before the government started making it mandatory. Thus, its officials had experiences and lessons about both voluntary and compulsory building code compliance to share at the workshop. Some of the lessons learned included:

- Even though the Municipality undertook many preparations prior to beginning the building code implementation program, these preparations were deemed insufficient for an effective launch of the program by many in attendance at the workshop.

- There is a significant shortage of skilled personnel (e.g., architects, engineers, skilled masons, building inspectors) within the Lalitpur Municipality. Given ongoing construction needs, the municipal authority recognizes the necessity for training the masons quickly in earthquake-resistant construction techniques to yield safer structures. The authorities also realize the need to raise awareness about seismic safety, appropriate construction techniques, and relevant building codes within the general community. Specifically, authorities described the need to communicate to the general community about the potential danger from earthquakes in the region and the value of incorporating earthquake-resistant features when building newer residential structures. Accordingly, the Municipality has begun offering mason training courses and raising public awareness via publications and media outlets. Training of masons is considered especially important because residential structures are seldom designed or construction overseen by professional architects or engineers. Instead, local masons with deep community ties are responsible for building the vast majority of residential structures.

- Working with community social organizations, the Lalitpur Municipality has tried to ensure continuous engagement with and feedback from masons and citizens during the implementation phases of the BCIP.

The rationale for working with these organizations is that they are seen as trustworthy and focused on the community's best interests.

- The Lalitpur Municipality has successfully established relationships with international NGO's, such as JICA (Japan International Cooperation agency), Oxfam, and UNDP (United Nations Development Programme) to learn from international practices and to promote their work further through various media organizations. These relationships continue to be instrumental in encouraging earthquake-resistant construction and securing the resources and technical capacity needed to build a groundswell of support for and facilitate building code compliance.

Table 1 – Municipality profiles: Lalitpur, Bhimeshwor, and Kamalamai - Nepal

	Lalitpur	**Bhimeshwor (Dolakha District)**	**Kamalamai (Sindhuli District)**
Location (Coordinates Longitude)	27º 39' to 27º 41'	27º 36' to 27º 44'	27º 10'
Location (Coordinates Latitude)	85º 18' to 85º 21'	85º 06' to 86º 06'	85º
Location relative to Kathmandu Valley (KV)	within KV	East of KV	Southeast of KV
Total Population	226,728	23,337	41,117
No. of Households	54,748	6,092	9,320
Literacy Rate	80%	72%	74%
Total number of structures/buildings	54,581	6,076	9,304
Number of buildings with RC Frame (pillar)	22,944	775	1,148
Number of buildings with stone/brick and cement mortar	18,359	646	1,464
Number of buildings with stone/brick and mud mortar	10,413	4,462	692
Number of buildings with wooden pillars	280	157	5,925
Number of buildings with unstated/other construction	2,585	26	52
Number of new buildings with permit	N/A	40	200
Number of new buildings without permit	N/A	12	100
	Municipality Building Permit System		
Sections/Provisions Applicable	Professionally engineered and Mandatory Rule of Thumb (MRT)	Mandatory Rule of Thumb (MRT) and Guidelines for Rural Construction	Mandatory Rule of Thumb (MRT) and Guidelines for Rural Construction
	Municipality Office Capacity		
Building Permit Unit Exists	Yes	Yes	Yes
	Building Code Implementation (BCI) Status		
Initiated since	2004	2014	Planning to declare
General Overview of Compliance	Good in permits	Just started	Not yet
	Impact of April 2015 Earthquake		
Impact of April 2015 earthquake	Highly Affected	Highly Affected	Highly Affected
Number of destroyed/damaged buildings	25,508[1]	52,000[2]	28,225[3]
Number of deaths	180	177	15

	Lalitpur	Bhimeshwor (Dolakha District)	Kamalamai (Sindhuli District)
Number of injured people	3051	662	230

[1] Impact numbers for Lalitpur are for the entire Lalitpur District (http://drrportal.gov.np/ndrrip/main.html?id=2)
[2] Impact numbers for Bhimeshwor are for the entire Dolakha District (http://drrportal.gov.np/ndrrip/main.html?id=2)
[3] Impact numbers for Kamalamai are for the entire Sindhuli District (http://drrportal.gov.np/ndrrip/main.html?id=2)

Lalitpur Municipality is situated on the southern part of the Kathmandu Valley. It is located approximately 150 kilometers from the April 2015 epicentral region and dozens of kilometers away from the earthquake rupture zone. This distance likely contributed to the limited amount of damage in Lalitpur. To date, only about a quarter of the buildings in the Municipality are in compliance with the building code. Numerous challenges to increasing compliance in Lalitpur were articulated by workshop participants and observed by the Housner Fellows group. First, there appears to be a relative dearth of good quality building materials and the financial capacity to purchase the same. Second, there is a lack of general awareness about the potential negative consequences associated with improper building plan/floor alterations that are neither reviewed nor approved by municipal officials, e.g., illegally adding upper floors to existing buildings. Third, workshop participants and individuals with various NGOs (e.g., JICA, UNDP) and NSET commented at length about inconsistencies in mason training and other capacity building programs. Finally, workshop participants observed that there is limited institutional capacity to enforce the building permitting process. Workshop participants stated that raising awareness about these issues and potential solutions will be critical to the future success of the building code implementation program.

A second workshop was held in Charikot, Bhimeshwor Municipality in the Dolakha District on February 11, 2016 that was attended by approximately 59 participants. Workshop participants included members of the media, Municipality staff, representatives from local political parties, individuals representing a local citizens action group, homeowners, farmers, and trained masons. This location was selected because the Bhimeshwor Municipality started implementing building codes following the introduction of government regulation in 2005. The Municipality has taken several steps to improve building code compliance. First, the Municipality has introduced new courses and provided more rigorous training to local masons. Next, the Municipality created and implemented a new program in which the owner of a code-compliant residential structure can reclaim up to 50 percent of the original permit cost after obtaining a completion certificate. The Municipality also developed and publicly distributed simplified guidelines that explain the process for obtaining a building permit. In addition, the Municipality has engaged in multiple public awareness campaigns. For example, in one of the campaigns, they developed a large visible poster that was signed by citizens pledging their commitment to earthquake safety. Similarly, municipal officials worked closely with local prosocial organizations to create and deliver street dramas to get the word out about earthquake safety as it pertains to residential construction.

The Bhimeshwor Municipality is now working on additional enhancements to their building permitting program, all of which are intended to ease the bureaucratic process for users and, ultimately, increase code compliance. The Municipality has instituted text-messaging to inform applicants of their building permit application status while also enhancing their application tracking process. They have also committed to resolving issues related to lost documentation, a source of significant frustration for users. Despite their numerous achievements, several challenges continue to inhibit the code compliance process in the Bhimeshwor Municipality. Among these is an ongoing shortage of skilled staff within the Municipality to perform field inspections and ensure a smooth permitting process. Following the April 2015 Gorkha earthquake sequence, there was exceptionally high demand for skilled masons, qualified engineers, and architects within the Municipality for evaluation and reconstruction activities. One of the workshop participants noted that there weren't enough skilled personnel available to meet this increased demand in the immediate aftermath or nearly a year after the event. Another workshop participant noted that the availability of demonstration houses would be very helpful to educate both masons and the public on issues of seismic safety and the construction practices associated with more earthquake-resistant construction.

The third workshop was held in the Kamalamai Municipality in the Sindhuli District on February 11, 2016. It was attended by more than 40 participants. Kamalamai was selected for several reasons, most notably because it is similar to several new developing municipalities in Nepal and has just started the process of building code implementation. While the number of buildings being constructed per year in Kamalamai is increasing with urbanization, its Municipality office has only a small number of technical staff members skilled in the building permit process and familiar with the building code. This gap in staffing and capacity was noted as an impediment to building code compliance by workshop participants. Finally, Kamalamai was selected for the third workshop because the damage to residential structures during the April 2015 earthquake was relatively high.

The workshop held in the Kamalamai Municipality was attended by large numbers of masons and building contractors who also had significant work experience in the Municipality. This group shared several important observations in regards to the state of building code compliance. According to them, only a small fraction (perhaps 5 to 10 percent) of recently built residential structures were designed and constructed to withstand earthquakes in the Kamalamai Municipality. The masons and building contractors recognized that this was not acceptable. In order to address the issue of needing better design and construction in the future, with an eye toward building code compliance, the masons and contractors made several key suggestions. First, they indicated the strong need for an individualized training program for masons focused on contemporary construction methods consistent with the building code. They stated that too many working masons remain unfamiliar with particular aspects of the code and the means to comply with it. The results are predictable: too many newer residential structures have proved incapable of withstanding earthquakes. Next, they suggested the development and implementation of a mechanism or process enabling trained masons to train other untrained masons in construction techniques that comply with the building code. This suggestion was rooted in the need for training and construction solutions to be as local as possible, increasing the perceived trustworthiness of trainers (since they are local and well-known masons) and therefore increasing the likelihood that the training would “stick” and masons would use the new techniques rather than fall back on more traditional techniques out of sync with the building code.

Workshop participants in the Kamalamai Municipality also suggested that training on the building code itself be offered to a wide range of stakeholders, including local politicians and municipal officials. They suggested that such training would help these individuals understand the need for earthquake-resistant construction, how to achieve it, and their role in the construction process as building code proponents and enforcers. According to the workshop participants, targeted training exercises for local politicians and elected officials are essential because these individuals are critical to the creation and adoption of new regulations and the development and implementation of new strategies for effective monitoring and widespread building code compliance. Workshop participants noted that the Municipality has few staff members with the proper engineering background and time to rigorously inspect engineering designs and drawings and to monitor the actual construction. In addition, workshop participants suggested that construction/labor rates in the Municipality needed to be standardized and mandated as such to account for the additional costs and efforts associated with building an earthquake-resistant structure. Without this step, according to some participants, an untrained mason could (and very probably would) charge less in the current system than a skilled and trained mason, leaving homeowners in a situation where their lack of awareness could yield new construction that may not be built in line with governing earthquake-resistant construction practices.

4.1 Workshop Survey Results

Results from the paper surveys distributed during the three workshops were consistent with the information shared with the Housner Fellows during the workshop presentations and smaller focus group discussions. A total of 67 surveys were completed, and results analyzed for similarities and differences between the municipalities. When asked to indicate their familiarity with the building code, it was only in Bhimeshwor that the majority of

respondents (59 percent) indicated that they were highly familiar with the code. In Lalitpur and Kamalamai, only 27 percent and 14 percent (respectively) reported high familiarity with the code. While not all workshop attendees were directly involved in building construction, virtually all (excluding a small number of attendees in the media) have cause to be at least moderately knowledgeable about the building code. The results from the Kamalamai were especially notable as the majority of attendees were masons or individuals otherwise directly involved in building construction. These results suggest that a lack of awareness and familiarity may be one reason for a lack of action directed toward code compliance.

Sixty percent of the total survey respondents from Bhimeshwor Municipality indicated that the sections of the Nepal Building Code applicable to professionally engineered buildings have been highly effective in their intent and implementation. In comparison, only 40 percent of the survey respondents from Lalitpur Municipality and 32 percent from Kamalamai Municipality felt that the provisions applicable to professionally engineered buildings have been effective. The survey results highlighted that a sizable percentage of the respondents in Bhimeshwor and Kamalamai did not find the current code provisions to be sufficiently clear and exhaustive in either their explanation or implementation. With respect to the portions of the Nepal Building Code applicable for seismic design and construction of non-engineered buildings (also known as the "Mandatory Rules of Thumb"), relatively few respondents thought that the provisions were appropriate and effective. Specifically, only 27 percent of the respondents from Lalitpur said that the Mandatory Rules of Thumb were highly effective, while 40 percent of the respondents from Bhimeshwor and 20 percent of the respondents from Kamalamai thought that the Mandatory Rules of Thumb were highly effective. The survey results suggested a potential disconnect between the usage of the Mandatory Rules of Thumbs and peoples' confidence in their efficacy.

When asked whether their Municipality had sufficient numbers of qualified staff to effectively conduct building inspections, the resulting response was "no" for the majority of respondents in each of the three municipalities. In Lalitpur, 80 percent of the respondents responded "no" to this question, while 63 percent responded "no" in Bhimeshwor and 52 percent responded "no" in Kamalamai. Our survey responses point to clear issues with technical and oversight capacity; without these in place, trying to ensure earthquake-resistant construction is virtually impossible. When asked about the timing of inspections, 33 percent of the respondents from Lalitpur indicated that inspections occurred during building construction, while 30 percent of the respondents from Bhimeshwor and 56 percent of the respondents from Kamalamai indicated the same. When asked whether inspections occurred after construction was completed, only 43 percent of all respondents from the three municipalities indicated that inspections were performed after construction was completed. In general, according to survey respondents, there seems to be a large variation between different municipalities and considerable uncertainty in terms of whether inspections do occur when they should, and whether the inspections were performed both during and after construction was completed. These survey results align well with verbal statements made to the Housner Fellows by workshop participants about the perceived lack of sufficient staffing and technical capacity for conducting timely inspections.

One of the principal areas of interest for the paper survey was to identify key reasons for limited use of earthquake-resistant construction materials and techniques. Respondents were asked to identify the relative importance of five potential causal factors, as follows:

- Greater cost of building structures in order to make them more earthquake resistant
- Low probability of earthquakes
- Greater time needed to build structures that are more earthquake resistant
- Lack of enforcement of building code
- Lack of awareness that structures can be built to be more earthquake resistant

Of the five factors, the two having the greatest importance were "lack of enforcement of building code" and "lack of awareness that structures can be built to be more earthquake resistant." A significant number of survey respondents also associated high importance with the "greater cost of building structures in order to make them more earthquake resistant." This choice was described by some survey respondents as being more salient for individuals with lower socioeconomic status and those whose ability to pay more for the construction was limited. As a complement to these survey results, we note that during small group discussions, workshop attendees indicated that they were generally supportive of efforts undertaken by their municipalities to enhance peoples' awareness of seismic risk and to build the locally-based technical and oversight capacity.

Finally, survey respondents were asked to consider potential obstacles to building code compliance. The following options were listed:

- Lack of awareness and perception among stakeholders
- Lack of infrastructure and personnel available to enforce
- Lack of legal/statutory structure
- Corruption

In general, the first three reasons were cited most frequently by the respondents as contributing greatly to failures in building code compliance. Once again, lack of awareness and lack of infrastructure and personnel available to enforce were the top two factors to have the greatest negative influence. A positive takeaway from the consensus between what people consider important causal factors and what people observe as obstacles to building code compliance is that leaders hoping to achieve greater compliance with building codes may be more likely to find success if they are able to build awareness among key stakeholders (e.g., homeowners, masons, municipal officials) about the building code and about the means of construction most likely to yield earthquake-resistant building structures. In addition, the feedback from the respondents highlighted the need for providing rigorous training both to individuals who have engineering and construction skills (e.g., engineers, architects, masons) and to the individuals who have inspection responsibilities (i.e., municipal officials, building inspectors).

5. Observations and Conclusions

The development of new state-of-the-art seismic design codes and standards for a community or a country and their effective implementation (putting the standards into use in reality) are two distinct challenges, each of which demands potentially unique region-specific solutions in order to achieve sustainable seismic resilience. Recent destructive earthquakes, both in terms of societal losses and economic damages in different parts of the world, underscore the enormity of this problem. Historically, much of the advice and (or) solutions and strategies proposed for the proper implementation of building codes in developing countries appear to have come from the larger scientific and engineering community, which may or may not have had the requisite knowledge of affected countries' governance and culture. As described earlier in the brief summary of the literature, effective implementation and enforcement of codes depends on strong leadership and governance [5, 6] – something that those in the scientific and engineering communities should note and plan for when proposing codes and code changes. For example, when proposing new code implementation strategies, developers and compliance advocates should assess and acknowledge the potential limits of existing institutional mechanisms, i.e., the strengths and the weaknesses of the existing system along with the system's ability to define and measure implementation successes and failures. Factors such as a failure to foresee bottlenecks, recognizing within- or between-institutions information flow, and an overemphasis on certain elements (e.g., strong reliance on a paper-based permitting/certification model in regulation processes) may have added to the challenges associated with building code implementation.

The Housner Fellows' work in Nepal suggests that the challenges to enabling code compliance may be even greater in developing countries. For example, when examining the three municipalities described in this

case study, we observed that existing institutions (e.g., municipal government, construction industry) appeared to be stretched to the maximum of their capacity to meet the rising construction demands, in part due to rapid growth in urban areas. In conversations with workshop participants and other individuals, the Fellows learned that this attenuation of capacity appears to have caused and encouraged extensive construction delays, potential negligence, complacency, corruption, political influence, and systemic resistance/rebuttal to adopt or implement new building and building code solutions. Workshop participants also shared their frustrations with factors such as a lack of accountability, lack of budget for training and capacity building, and the limited expertise available on technical subject matter (such as proper techniques for designing and building with attention to seismic risk). Illustrating this latter point, participants noted that in many parts of Nepal the contractors, builders, and masons are not trained or certified through any formal programs. It was recognized by workshop participants that the majority of small buildings in developing countries, especially those in the housing sector, are owner-built through the personal hiring of masons and small contractors. These structures are typically built with little to no engineering oversight. At present, there appears to be no formal licensing/registration mechanism to bring these masons and small contractors into the mainstream of understanding building codes and the means to comply with them. As discussed earlier, there are a number of other important impediments to proper enforcement of building codes, for example, a limited number of skilled staff to perform site inspections and a lack of technical knowledge to critically evaluate code compliance and corruption. Our workshop surveys also highlighted the need to enhance technical and oversight capacity within each Municipality. Survey and verbal comments about this topic suggested that without enough people who are trained and available to perform both construction and inspection activities, building codes have little hope of being properly or widely enforced.

Given the fast pace of urban development in developing countries, a large portion of the existing residential building stock may be replaced in the coming decades, providing an excellent opportunity to introduce systemic change. Developing a new code document from scratch is a mammoth task that requires the availability of subject matter expertise and institutional capacity to meet the demands of keeping it current with the latest scientific and engineering developments. There are many countries where such expertise or resources may not be available. In response to this reality, adapting other model codes to a specific country's context may be a viable option. For example, Jamaica developed a local code, which is largely based on the International Code Council (ICC) family of codes, but which also incorporated necessary adaptations to its local context [15]. This approach has allowed Jamaica to drastically reduce the burden of keeping up with the developments of new model codes, while also enabling the local engineering community to directly benefit from the latest code developments and use practices that are vetted by the international community. With codes in place, rigorous training and capacity building exercises could then be employed to train members of the local engineering community to facilitate knowledge transfer. To illustrate this idea, workshop participants in Kamalamai advocated for a "train the trainer" model, thereby supporting the masons and building national capacity at the fastest rate possible and in such a way that the general population could be aware of their enhanced capability and locate them in the community. We see potential to tie engineering licensing procedures or their renewal to mandatory design and training exercises as a means of aiding continued and proper implementation of building codes.

Nepal's National Building Code was introduced in 1994 but it took more than 20 years to make the provisions mandatory. The mere existence of a building code or its formal adoption does not ensure usage for effective earthquake risk reduction. The World Bank study highlighted the need for a strong legal framework to support building code compliance at the local level [15]. Existence of a strong legal framework helps to send a clear message to all stakeholders about the consequences associated with inaction or inappropriate actions. Feedback from our workshops in three municipalities identified the need to engage community leaders to facilitate the adoption and implementation of such a strong legal framework. According to workshop participants, community leaders must identify and make provision for the financial and human resources needed to support the various means of ensuring accountability. Strong collaboration with private sector experts can strengthen the ability of building regulatory authorities to protect public health and safety and enhance resilience [15]. The building permit application process may need to be simplified (e.g., a cell phone app or a web-based electronic application, or a text messaging facility as in case of the Bhimeshwor Municipality) by setting some

predefined time limit for obtaining permits to minimize bureaucratic hurdles. Finally, both financial (e.g., lower interest rates on mortgages and construction loans) and nonfinancial (e.g., permitted mixed-use development) incentives could encourage building code compliance.

6. Acknowledgments

The authors of this paper are affiliated with the Housner Fellows Program funded by the Earthquake Engineering Research Institute (EERI), the Federal Emergency Management Agency, and the Global Facility for Disaster Risk Reduction of the World Bank. The first author is the program's lead trainer; the remaining authors are the members of the 2014 class. The authors are indebted to the time and logistical support from EERI staff including Jay Berger, Marjorie Greene, Maggie Ortiz, and Heidi Tremayne and the staff of the National Society of Earthquake Technology (NSET), particularly Amod Dixit, Suman Pradhan, Kapil Bhattarai, Pavitra K.C., and Rita Thakuri. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

7. References

[1] USGS (2106): "Earthquakes with 1,000 or more deaths 1900-2014." USGS website, available at http://earthquake.usgs.gov/earthquakes/world/world_deaths.php. Retrieved 30 May 2016.

[2] Applied Technology Council (2014): *Building Safety Evaluation after the February 22, 2011 Christchurch, New Zealand Earthquake: Observations by the ATC Reconnaissance Team*. ATC-109 report. Redwood City, California, USA.

[3] Organisation for Economic Co-operation and Development (OECD) 2004. Keeping schools safe in earthquakes, *Proceedings of the Ad Hoc Experts' Group Meeting on Earthquake Safety in Schools*, Paris, Feb 9-11, 2004.

[4] Alesch DJ, Arendt LA, Petak WJ (2012): *Natural Hazard Mitigation Policy: Implementation, Organizational Choice, and Contextual Dynamics*. Springer.

[5] Meres R, Sigmon J, DeWein M, Garrett K, Brown JH (2012): Successful strategies for improving compliance with building energy codes. *ACEE Summer Study on Energy Efficiency in Buildings*, 4-275. Available at: http://aceee.org/files/proceedings/2012/data/papers/0193-000112.pdf

[6] Burby RJ, May PJ, Paterson RC (2007): Improving compliance with regulations: Choices and outcomes for local government. *Journal of the American Planning Association*, **64** (3), 324-334.

[7] Chamlagain D (2009): Earthquake scenario and recent efforts toward earthquake risk reduction in Nepal. *Journal of South Asia Disaster Studies*, **2** (1), 57-80.

[8] Spence R (2004): Risk and regulation: Can improved government action reduce the impacts of natural disasters? *Building Research & Information*, **32**, 391-402.

[9] Dixit AM (2004): Promoting safer building construction in Nepal. *13th World Conference on Earthquake Engineering*, Vancouver, British Columbia, Canada.

[10] Shafii F, Ali ZA, Othman MZ (2006): Achieving sustainable construction in the developing countries of Southeast Asia. *Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference*, Kuala Lumpur, Malaysia.

[11] AECOM (2013): *Middle East Construction Hand*book. AECOM.

[12] EERI (2016): *EERI Earthquake Reconnaissance Team Report: M7.8 Gorkha, Nepal Earthquake on April 25, 2015, and its Aftershocks*. Developed by the Earthquake Engineering Research Institute, Oakland, USA.

[13] Shrestha S (1 May 2015): Langtang is gone. *Nepali Times*. Retrieved 29 May 2016.

[14] Kaini S (29 April 2015): Great earthquake wipes out Barpak. *The Kathmandu Post*. Retrieved 29 May 2016.

[15] World Bank Group (2016): *Building regulation for resilience: Managing risks for safer cities*. Developed by the World Bank Group, Washington D.C., USA.