18TH WORLD CONFERENCE ON EARTHQUAKE ENGINEERING
WCEE2024
MILAN

MILAN, ITALY
30TH JUNE - 5TH JULY 2024
www.wcee2024.it

CAUSES OF DEATHS AND INJURIES IN THE 2015 GORKHA EARTHQUAKE

B. Pandey [1], M. Petal [2] & R. Paci-Green[3]

[1] *British Columbia Institute of Technology, Burnaby, Canada, bpandey@bcit.ca*

[2] *Save the Children Australia, Melbourne, Australia*

[3] *Western Washington University, Bellingham, USA*

Abstract: *The main shock of April 25th and its major aftershock on May 12th of the 2015 Gorkha Earthquake killed more than 9,000 people and injured more than 22,000 people in Nepal. These daytime earthquake events impacted semi-urban and rural hilly areas of the country. This provided an opportunity to study the particular causes of deaths and injuries to better understand effective protective actions and determine proper public education messaging. A study was carried out using a purposive approach with randomized elements, selecting 500 households in 10 hardest-hit communities within 5 of the 14 hardest-hit districts of Nepal. The households surveyed had 1,855 members present at the time of the earthquake: 88% were uninjured, 10% were injured, and 2% died. Based on previous earthquake epidemiology a wide range of variables were examined including the seismic event itself, individual and behavioural, built environment, mitigation actions and response variables. The earthquake characteristics were atypical, the built environment included two major types of structures (stone and brick masonry construction – gārowālā vs. reinforced concrete or masonry with a frame or columns – pillarwālāas) as well as the role of non-structural items and response behaviours in relation to the casualties. Based on findings, key recommendations were developed for individuals and households covering: situational risk awareness, assessment and planning, risk reduction, and response preparedness, as well as recommendations for the scientific and advocacy community for public discussion and consensus-building.*

1 Introduction

1.1 Overview

Following the Gorkha, Nepal Earthquake of 2015, a study was carried out to identify the causes of injuries and deaths\. The goal was to review and update the scientific basis for education and training in earthquake preparedness and mitigation from the perspective of earthquake epidemiology. In Nepal, several global and national agencies working in the field of earthquake awareness, preparedness, and trainings follow a set of public education messages for individual and collective actions in the event of an earthquake, based on past studies and recommendations. This research study seeks to provide evidence to validate, and, where needed, offer refinements and changes, to support a renewed process of consensus-building for public education for safety from earthquakes and other hazards in the region.

1.2 The 2015 Gorkha Nepal earthquake and seismicity of the country

An earthquake of M_W7.8 struck the central hilly region of Nepal on 25 April, 2015 at 11:56 am. Two major aftershocks that occurred on the same day and the next day were greater than M_W6.0, and a major aftershock of M_w7.3 occurred on 12 May 2015. These events resulted in more than 9,000 deaths and more than 22,000 reported injuries [Government of Nepal, 2015].

Deaths were heavily concentrated in several populous districts. The Government of Nepal declared 14 districts as 'worst-hit'. There the total population was 5.37 million at the time of the 2011 census; 8,775 deaths and 21,161 injuries were recorded. The seven most heavily impacted districts accounted for 91% of the deaths. These were: Sinhupalchowk (3,531), Kathmandu (1,222), Nuwakot (1,125) Dhading (676), Rasuwa (656) Gorkha (449), and Bhaktapur (333).

In addition to the huge number of lives lost and people injured, more than 458,000 buildings were heavily damaged or totally collapsed, and 3.5 million people were made homeless. The earthquake resulted in widespread damage to public and private buildings, schools and health centers, heritage sites, and trekking routes. More than 8 million people (about 1/3 of Nepal's population) were affected in 31 of 75 districts. A total of 850,000 houses were damaged by the earthquake. Overall, 2,649 public buildings and 510,762 private dwellings collapsed, while 3,617 public buildings and 291,707 private dwellings suffered partial damage.

Even before the 2015 earthquake, Nepal was well known as an earthquake hotspot, a country at high risk owing to its geological setting, its past events, and the high fragility of its built environment. The country has a long history of destructive earthquakes. About ten episodes of large earthquake shaking have been reported in Kathmandu in the past 750 years. The 2015 Gorkha earthquake was the largest earthquake event in Nepal since 1934, when a devastating earthquake with Mw of 8.1 severely affected the country. The earthquake of 1934, and more recent 1988 earthquake are still in the active memory of Nepalese people.

1.3 Earthquake epidemiology and construction

Public education messages about protective action during earthquakes draws heavily upon earthquake epidemiology. Earthquake epidemiology is defined as "the study of the distribution of death and injury in earthquakes and the causes of fatal or nonfatal injury (Jones et. al., 1994). In the short history of the field that has depended upon post-disaster research, conventional wisdom has yielded the simplistic conclusion that "earthquakes don't cause deaths, buildings do." However, both the public and researchers often recognize a more nuanced reality. Major differences in construction type between wood, and other light-weight frame structures, heavy adobe and stone, and confined masonry, reinforced concrete, and steel-frame buildings, as well as the quality of their design and construction can have significant implications for both causes and prevention of casualties.

Damage to buildings is considered the most important factor causing injury and death in earthquake events worldwide, and it was no different in the case of the 25 April 2015 Gorkha Earthquake. The potential for devastation is very serious in low-resource countries due to both lack of building codes, limited access or understanding of these, poor capacity for compliance, and lack of enforcement. All of these make structural collapse and resulting casualties more likely to happen. Dramatically smaller numbers of earthquake casualties are seen in developed countries like Japan and New Zealand which have implemented strict seismic building codes and invested heavily in enhancing community preparedness. In comparison, other countries like China, Turkey, India, and Haiti have experienced devastating casualties particularly due to building collapse (Paton, 2010; Elliott, 2012). In the Christchurch, New Zealand earthquake in 2011, 115 of 185 total fatalities took place in one multi-storey office building, not built to code (Wikipedia, 2016).

The basic variables associated with deaths and injuries of interest are the severity of injury, as well as the type and mechanisms of injury and death. Petal (2012) listed basic variables associated with deaths and injuries in earthquake epidemiological research from literature study [Tang et. al. 2017; Doocy et. al. 2013; Petal, 2012; Wood, 2014.] as :

- **Hazard level variables:** earthquake source characteristics, local site hazard characteristics (including post-impact data as well as environmental factors such as temperature), time of year, time of day, shaking intensity, and duration.
- **Individual and behaviour level variables:** age, gender, physical/mobility disabilities, injury characteristics, physical and social location, activity, occupant behaviour.
- **Injury level variables:** type of injury, injury severity, part of body affected, treatment sought.

- **Built environment level variables:** construction type, quality of construction, storey height, building damage, collapse pattern, volume loss, extrication difficulty, non-structural risks, infrastructure risks, hazardous materials exposure.
- **Mitigation level variables:** household preparedness, fastening tall and heavy furniture, having fire suppression tools and knowledge, first response skills, and response provisions.
- **Response level variables:** availability of professional rescuers, length of time entrapped, response effectiveness, and presence of trained community emergency response volunteers.

These variables can be broadly classified into two groups: (i) natural and exposure variables and (ii) intervention variables. The first group includes those factors that are related to natural phenomena and exposure of population that individual, community, or state have no or minimal control over whereas the second group includes variables that depend on preparedness and mitigation actions by the population and states. This paper focuses on the intervention variable group that includes the built environment, mitigation, and response level variables. This also provides a perspective in causes of deaths and injuries in the context of building typology, construction practice, building code implementation, and other mitigation and preparedness works in the country leading up to the event of 2015. The impacts of natural variables are also discussed when they are coupled with intervention variables in ways that impact the severity of injuries and number of deaths.

2 Built environment and preparedness variables

Several researchers have studied the impact of built environment and preparedness on injuries and deaths in earthquakes [Tang et. al. 2017; Doocy et. al. 2013; Petal, 2012; Wood, 2014]. Their findings are discussed below, first considering building construction, mitigation actions, and then response preparedness.

2.1 Buildings, construction and mitigation actions

- **Construction type:** Until recently, most of the earthquake studies have occurred in rural areas, and therefore early studies focused on the vernacular stone masonry and adobe construction that had been responsible for most of the deaths (e.g. Guatemala 100%; Chile 86.9%). The documented lethality rates for stone-rubble and stone-masonry buildings have varied (Spitak 2.8%-12%; Bingol 5.3%; Erzurum 8.3%; Caldiran 11.1%) With the shift to a greater urban than rural population globally, there have been more data recorded on both wood-frame and reinforced concrete buildings. In several earthquakes with predominantly urban impacts, the overwhelming number of deaths were in poorly constructed reinforced concrete buildings (Bucharest 70%; Mexico City 89%). Lighter-weight construction and lighter-weight roofs were associated with much lower lethality from building damage (Guatemala, Northridge). There are higher lethality rates due to fire risk associated with wooden buildings (Hanshin-Awaji).
- **Building damage:** Building damage is the single variable that correlates most frequently to deaths and injuries across earthquake locations. The use of standard building damage classification schemes (e.g. ATC-13) would enhance the comparability of data. Recently, poorly-built reinforced concrete multi-family buildings have been studied. A lethality rate of 1.5% in heavily damaged reinforced concrete buildings, compared to 10.7% in totally collapsed RC buildings in Kocaeli, further demonstrated the great potential for incremental and minimum retrofit measures to prevent collapse and save lives.
- **Occupancy of buildings:** A number of very high occupancy buildings of various construction types (confined masonry, frame panel, pre-cast concrete, reinforced concrete) have failed catastrophically and are associated with very high lethality rates (Spitak, Gorkha, El Asnam, Mexico City, Luzon); these include the more common multi-family reinforced concrete buildings (Kocaeli).
- **Building height and floor:** In several earthquakes, the odds of injury appeared to be greater the taller the building (Armenia, S. Italy, Spitak, Kocaeli, Chile). The relatively greater motion on higher floors may restrict people from taking protective action. The exception to this seems to be in low-rise buildings where the upper floor may be safer (Hanshin-Awaji). Content-related injuries seem to be higher in concrete and metal structures and lower in wood buildings (Loma Prieta), which is hypothesized to be an effect related to the height of these buildings.
- **Structural hazards**: In both California and Turkey, deaths were predominantly associated with structural hazards (98.5% in Loma Prieta, 75.8% in Northridge, and 61% in Kocaeli). Collapse patterns, as well as the size and number of void spaces or the void-to-volume ratio, are key factors in survivability, including time to extrication . However, high rates of entrapment limit the success of rapid extrication

efforts (Taiwan 1999). Life-saving first aid, in situ, has been suggested as a way to increase survival until extrication .

- **Non-structural hazards**: Building non-structural elements and building contents are also highly associated with injuries, especially slight and moderate; however, non-structural elements also are associated with serious and critical injuries (Northridge, Hanshin-Awaji, Kocaeli). In Loma Prieta and Northridge, 22% and 44% of hospitalized injuries, respectively, were attributed to non-structural hazards. In California, where buildings themselves contain more hazardous contents that can topple, slide, or break, the ratio of injuries to deaths is high, and non-structural building hazards are implicated in many moderate and less serious injuries. In earthquakes in areas with heavier construction types, more serious injuries have been associated with being struck, crushed, or pinned by heavier objects. In Kocaeli, Turkey, where reinforced concrete buildings in urban settings predominated, 69% of non-fatal injuries were associated with non-structural building components (including unreinforced infill walls) and building contents, 22% with structural components, and 11% with both. Tall and heavy furnishings, windows, and other glass objects, and other household equipment and objects were identified as having hurt people. In Turkey in 1999, 33% of injuries were attributed to being struck by a falling object, 24% to being under a falling object, 11% to being cut or pierced, 8% to falling, 20% to multiple, and 3% other (Petal, 2009). In Imperial County, the ratio of building contents-related injuries to other non-structural injuries was 3:1.
- **Structural and non-structural mitigation actions**: It is now clear from the enormous differential impacts of similar-sized earthquakes in the U.S., Japan, and New Zealand vs. similar events in Iran, Pakistan, Turkey, and elsewhere, that measures taken to prevent structural and infrastructural collapse have been successful in mitigating the enormous potential for serious injuries and deaths. Building code adoption, implementation, and enforcement has, in many high-income countries have integrated findings from earthquake damage. However, it has been extremely challenging to measure the deaths and injuries that have not happened, especially around non-structural mitigation. The efficacy and potential efficacy of securing non-structural hazards and building contents have been demonstrated through shake table research in Japan and California (Youtube, 2008), and noted in photographic and video evidence (YouTube, 2016), but in the absence of widespread adoption of non-structural mitigation measures, these have not yet been systematically studied in situ.

2.2 Response actions

Until large numbers of people systematically adopt specific protective actions, the efficacy of these actions in reducing casualties is difficult to measure. A study in Iceland confirmed that whilst taking protective action worked well for some people in areas with lower-intensity shaking, residents who experienced strong shaking reported being unable to move to safer places within their homes, and that poorly fastened household contents posed a significant threat (Akason et. al. 2006).

Movement, and in particular exiting during shaking has been found to be dangerous. In the 1994 Northridge earthquake those who reported moving during the earthquake were twice as likely to have been injured as those who remained in place (Shoaf, et. al., 1996). In the Kocaeli earthquake, those who stayed in bed were safer than those who did anything else (Petal, 2009).

The severity of injuries, the time taken to rescue, and the length of time until medical treatment are also important factors in survival when buildings collapse in earthquakes. In most of earthquakes, the vast majority of live rescues are performed by household members and neighbours, during the first 24 hours. Thus, beyond a few outliers, the efforts of international search and rescue response are known to be largely ineffective in extracting survivors alive. In spite of the significant drop-off rate in live rescues, the moral imperative is to continue search and rescue until all survival void spaces have been uncovered; body recovery is also important for grief and death ritual completion (Rao, 2006; Suwalowska *et* al, 2021). One study that directly assessed health sector preparedness found that low-prepared regions had five times more fatalities than high-prepared regions (Bissell et. al. 2004).

Findings from these studies were used in the development of sampling and the questionnaire for the epidemiological study on causes of deaths and injuries from the 2015 Gorkha (Nepal) earthquake, described in the next section.

3 Epidemiological Research Design and Methodology

3.1 Epidemiological survey

The primary research methodology used in this study was an epidemiological survey of earthquake survivors. Epidemiological research using standardized surveys across a wide number of disaster events allows the development of a body of knowledge, and the potential for comparing results across a range of variables. This comparison facilitates both the validation of results and the crystallization of salient questions. There is an emerging standard template through which the differential impacts of particular earthquakes can be fruitfully compared (Shoaf et. Al. 2002; Petal, 2009; Petal, 2012).

Epidemiological survey research is found to be an efficient way to reach a sizeable number of respondents – enough to form a reliable sample of the impacted population. Surveys that include both closed and open-ended questions can be administered quickly and efficiently.

The major drawback of structured surveys is that they limit access to spontaneous responses and information. Ideally, a combination of structured and unstructured methods provides an opportunity to pick up on important inputs that enter from off the researcher's radar screen.

This study follows a descriptive cross-sectional study design. It was implemented in five districts identified as highly affected due to the 25 April 2015 Nepal earthquake. A quantitative research technique using a structured interview questionnaire was implemented for the data collection, as described in more detail below.

3.2 Study Tools and Techniques

The household survey questionnaire was based on findings of studies done over the last 20 years in U.S., China, and Turkey (Shoaf, 1996; Petal, 2009), and adapted and localized with support from a global expert reference group, including Nepali public health and earthquake engineering specialists, prior to and after translation (see Acknowledgements). The questions were programmed into a tablet-based application for data collection using Open Data Kit. Pre-testing of the data collection tool was done prior to the field supervisors'/researchers' training. Paper-based data collection forms, too, were provided to the field researchers/supervisors for backup in case the tablet was not functional. Portable flipcharts were produced for use by each field researcher to identify the damage levels of the building and injury severity. Household visits were timed to maximize when most family members could be expected to be home.

3.3 Sampling

Cluster sampling using a purposive method was adopted to select the study sample. Five of the seven hardest-hit districts with the highest number of fatalities, and highest numbers of damaged buildings were selected in order to cover a range of urban, peri-urban, and rural settings. Figure 1 provides a graphic illustration of the overall sampling frame.

The selected districts were: Bhaktapur, Kathmandu, Kavrepalanchok Nuwakot, and Sindhupalachowk. In each of these five districts, the team first selected the 10 local government units (e,g. Village Development Committees(VDCs)/Municipalities/Metropolitan Cities) that were hardest hit, based on number of fatalities. Then, one ward from each local government unit was purposively selected. Outliers caused by very high fatalities in 1-2 buildings were eliminated. The criteria for selection of wards were: accessibility (by road), and sufficient density for efficient data collection from at least three households per day per field researcher. Social mapping with key informants was used to generate a full list of accessible households with a sampling frame of at least 100 households. From this list, every second household was selected until 50 households were identified. Substitutions of 'next building' were made where the building was uninhabited, or when no inhabitants could be found after a third visit. In multi-family buildings, units were counted from top down, clockwise on each floor. The target was to interview or obtain survey responses from all members of the household who were in the local government unit at the time of the 25 April earthquake. Each home was visited up to three times. Proxy reporters were requested for children under 18, and other unavailable or deceased persons. Figure 2 illustrates the process of sample selection for this study.

A sample size of 500 households was purposively selected considering the time and resources. A total of 1,855 household members from the sampled households were present in the local government unit during 25 April 2015 Nepal Earthquake and were eligible respondents for the study. Individual surveys were obtained for 1,403 members (815 self-interviews and 588 proxy interviews). Surveys were not completed for the remaining

25% (469) household members who were present in the local government unit at the time of the earthquake, because they were not available, and none were present who felt they had sufficient knowledge to respond on their behalf. This included 23 dead and 16 injured individuals. The districts were selected to represent a variety of construction types and terrains. Most of the households sampled were stone and brick masonry construction, referred to as *gārowālā* in Nepal.

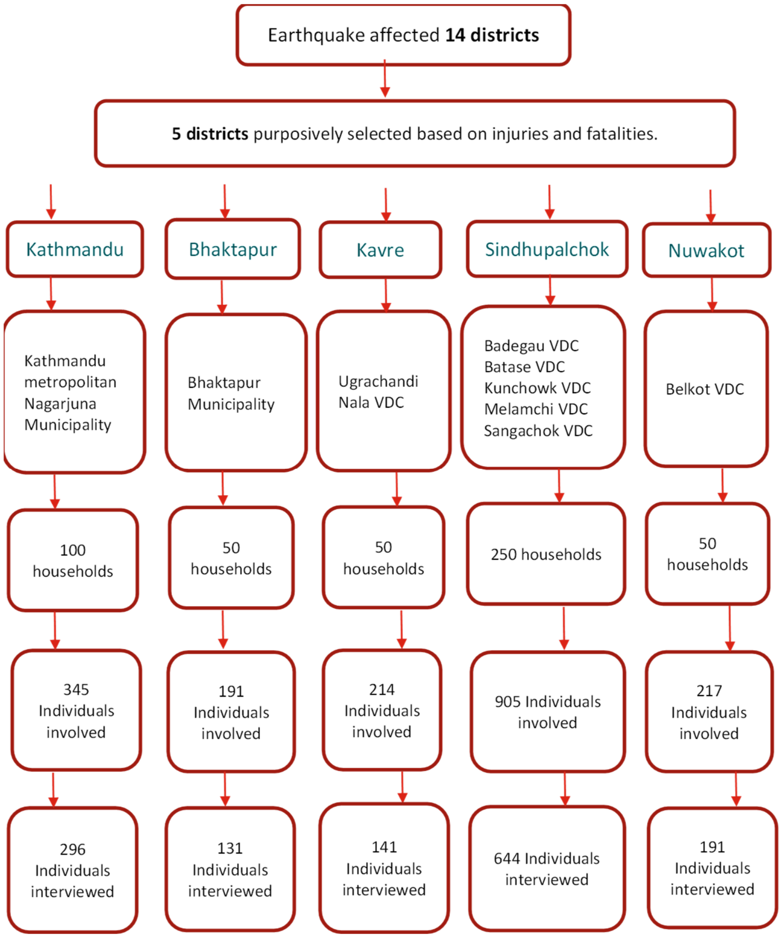

Figure 1. Sample frame for the study

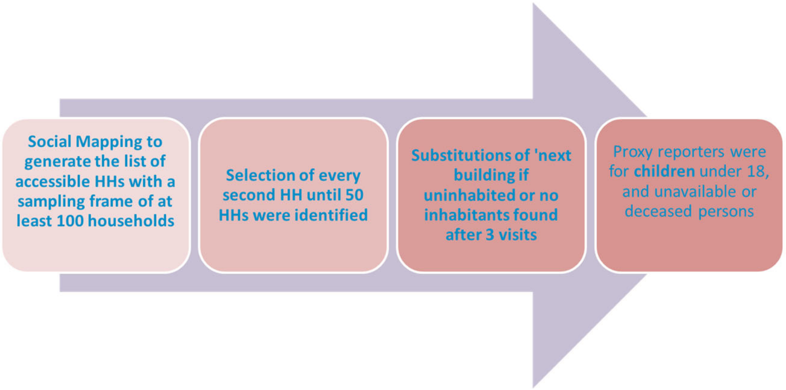

Figure 2. Sample selection process of households (HHs)

3.4 Potential Biases and Limitations

Surveying was conducted over a two-week period in the early spring of 2016. Whilst recall bias might have occurred as this study captured the earthquake-related experiences of people after a period of almost one year, other studies have reported little degradation of memory over time. Proxy interviews were also carried out for the unavailable/deceased person, which may lower the accuracy of the data. The study was limited to only five districts based on the high impact of the earthquake, and only 500 households (1403 completed interviews/surveys out of 1855 household members) were purposively selected. As such, findings may not represent all of the districts. Particularly unrepresented in this survey are people in larger and taller urban buildings and people who were in the most lethal buildings, as households with fewer survivors would be less likely to stay in the same households, or there may be no survivors to report at all.

4 Findings and discussions

4.1 Hazards

The25 April 2015 Mw7.8 Gorkha mega-thrust earthquake occurred in an anticipated location, 80 km NW of Kathmandu at a depth of 15 km, yet all other seismological considerations defied expectations (Molnar and Adhikari, 2018). The shaking intensities and resulting damage in Kathmandu were generally lower than expected, resulting from the culmination of lower-than-expected acceleration, source frequency content, and blind-thrust rupture. Few strong-motion instruments were operating in Nepal at the time of the Gorkha earthquake. The mainshock peak ground acceleration (PGA) values at the station operating in central Kathmandu was only 0.16 g (USGS KATNP station; www.strongmotioncenter.org). As the PGA recorded in Kathmandu was higher than 0.1g, a typical acceleration level that adobe and stone buildings start experiencing damaged, these buildings were heavily damaged. However, the recorded PGA of the earthquake in Kathmandu was very low when compared to more typical earthquakes of similar magnitude and depth. Because of this, damage to well-constructed buildings was not observed. Even poorly constructed reinforced concrete buildings did not sustain much damage. The displacement of the ground, from shaking, was as much as 95cm (Figure 3). This was sufficient to cause damage to flexible structures like older buildings with mud brick walls and wooden floors, as well as tall slender temples. This also caused people indoors on higher floors to feel substantial swaying.

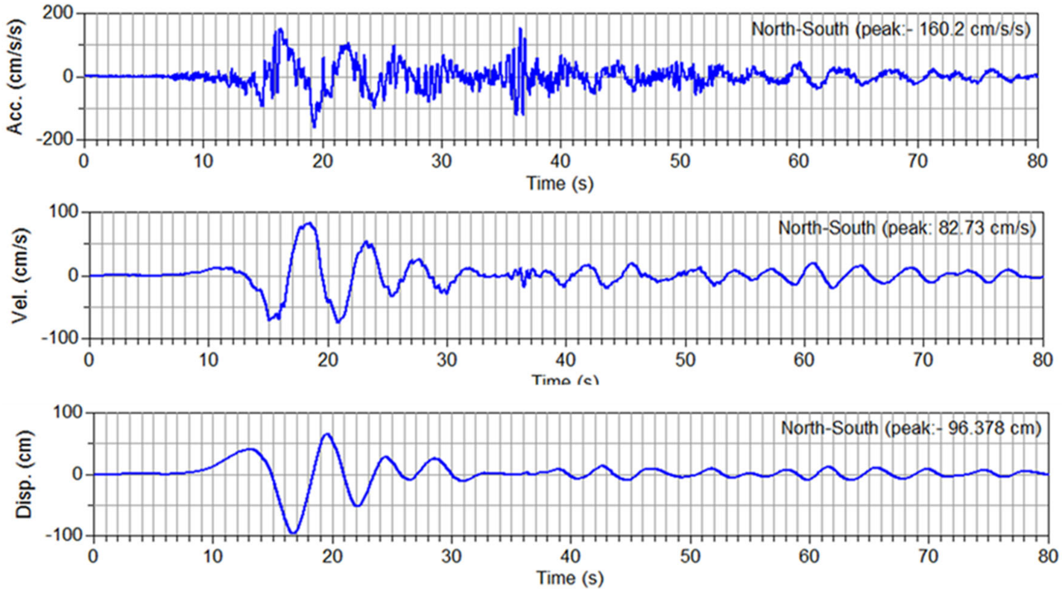

Figure 3. Acceleration, velocity, and displacement time histories of the recoded motion at KATNP station

4.2 Deaths and injuries in the sample population

In both the full sample of 1,855 individuals present in the local government units during the earthquake and the smaller number of 1,403 individuals for whom full survey responses were completed, injury rates exceed government statistics. Specifically, of the 1,403 individuals, 87% (1,213) were uninjured and alive, 13% (175) were injured, and 1% (15) died. The rate of injuries in the sample population is significantly higher than government statistics, which estimated an injury rate of 32 per 10,000 across all 14 most effected districts and 405 per 10,000 in the most heavily impacted district of Nuwakot. This difference is expected because the survey under this study captures the impacts of minor and self- or locally treated injuries, which government data typically does not. Of the 187 people in our sample for whom extent of injury was obtained, 63% (118) sustained minor injuries, and 37% (69) were seriously or critically injured.

Of the 190 for whom full survey responses were completed and who were injured or killed, 78% (148) were in a building, 11% (20) were outdoors near a building, 3% (6) were outdoors near another structure, and 8% (16) were not near any structure (Figure 4). As expected, deaths and injuries are significantly associated with being in or near a building.

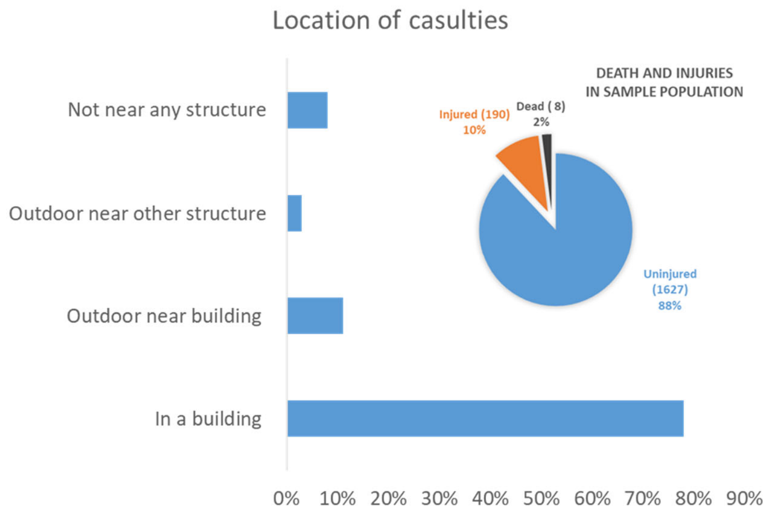

Figure 4. Death and injuries and their location during the earthquake in the sample population

4.3 Causes of death and injuries from the built environment

In the earthquake-affected area, types of building construction can be broadly classified into two major groups: adobe or stone masonry with mud mortar (Gārowālā) and reinforced concrete with masonry infill or confined masonry with reinforced concrete (RC) tie-columns (Pillarwālā). Figure 5 shows typical buildings of these construction types as well as representative damages.

Gārowālā Buildings: rubble stone with mud mortar

Pillarwālā Buildings: confined masonry or reinforced concrete with infill walls

Figure 5. Predominant Construction Types in 14 Hardest-hit Districts in Gorkha Earthquake

Stone masonry or adobe building is a predominant building type when it comes to the location of earthquake victims. Of the 156 who were injured and for whom type of building was determined, a total of 89% (139) were associated with stone or brick masonry buildings, 9% (14) with RC construction, and 2% (3) with wooden houses. Of the 14 dead, all were associated with stone or brick masonry buildings.

Death rates were higher when people were a in or near gārowālā (stone or brick masonry) buildings, compared to RC tie-column (pillarwālā) construction.

4.4 Damage to structural and non-structural elements causing injuries

The severity of injuries was observed against types of building elements that hit the victims: structural, non-structural, or both. Figure 6 presents the source and severity of injury from either structural or non-structural or a combination of both. Structural damage inflicted more injuries but it should also be noted that more structural damage leads to more damage to building contents as well.

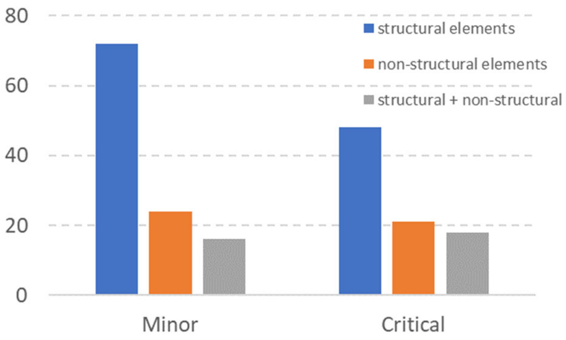

Figure 6. Injuries in the sample population

The level of damage was another major factor in the injury and death. The most deadly buildings were those that were totally collapsed, or heavily damaged. In our sample, all deaths were in totally collapsed buildings. No one died in buildings that were slightly, moderately, or even heavily damaged. As expected, rates of injury increase with building damage level. The rate of injuries in buildings that sustained slight, light, and moderate damage is relatively stable at <10%, whereas the rate of deaths and injuries in very heavily damaged buildings is at least 18%, and in totally collapsed buildings it can be 23% and more.

This is a clear indication that the prevention of the worst levels of building damage is a priority for the reduction of casualties. Collapse avoidance is the most obvious remedy to reduce the majority of deaths and injuries. As expected, the rates of injury and death are highly correlated with the damage level of the building. By far the most hazardous buildings are those uninhabitable and irreparably damaged (every heavily damaged or totally collapsed).

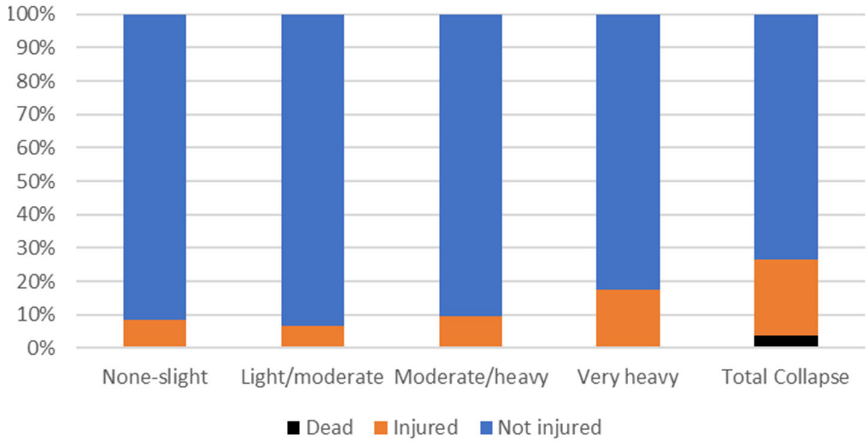

Figure 7. Injuries and death by building damage

Structural elements were implicated in 71% of casualties, non-structural building elements in 26% of casualties, building contents in 16% of casualties, and outdoor objects in 27% of casualties. Structural elements were implicated in 100% of deaths, non-structural building elements in 67%, building contents in 25%, and outdoor objects (such as stones, wood pile, and other agricultural equipment) in 8%. Whether the striking object was structural or non-structural did not make a significant difference to the severity of injuries. Of the 15 deaths recorded by the survey and for whom a full survey response was completed, most were caused by being trapped and crushed under a falling object 92% (11), struck by a falling object 58% (7), or by a cutting or piercing object 33% (4). These objects may have been building structural or non-structural elements or building contents.

Of the 175 people injured and for whom a full survey response was completed, many were caused by being struck by a falling object 49% (85), falling 26% (46), trapped and crushed under a falling object 19% (33), by a cutting or piercing object 17% (30), and by jumping from a window or balcony 4% (7). The building components most clearly associated with serious and critical injury were walls and roofs, and, to a lesser extent, columns, staircases, doors, and tall furniture. Figure 8 presents findings with major contributors to injuries and deaths.

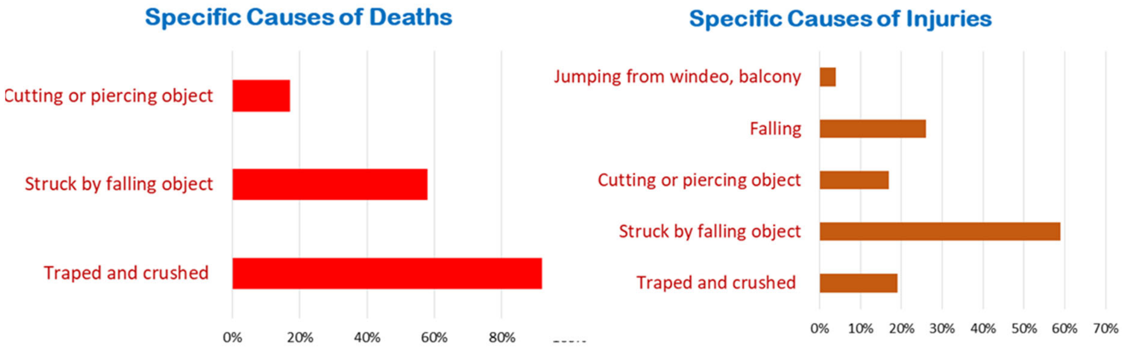

Figure 8. specific causes of deaths and injuries

4.5 Protective actions, mitigation, and preparedness variables

We studied the impact of protective actions taken by 1521 individual for whom first actions could be identified and related it to injuries and deaths. In the sample population, we found that 96% of injuries and 100% of deaths took place during the main shaking rather than afterward or while awaiting or during search and rescue. Of the 88 in the survey population who took cover, 91% (80) were not injured, 9% (8) were injured, and none died. Similarly, of the 631 in the survey who stayed in place, 87% (550) were not injured, 12% (73) were injured, and 1% (8) died. Of the 802 in the survey who moved, 84% (671) were not injured, 15% (122) were injured, and 1% (9) died. From these, it can be inferred that the safest action is taking cover. Staying in place is safer than exiting the building during the earthquake. Figure 9 presents the relationship between response action and casualties.

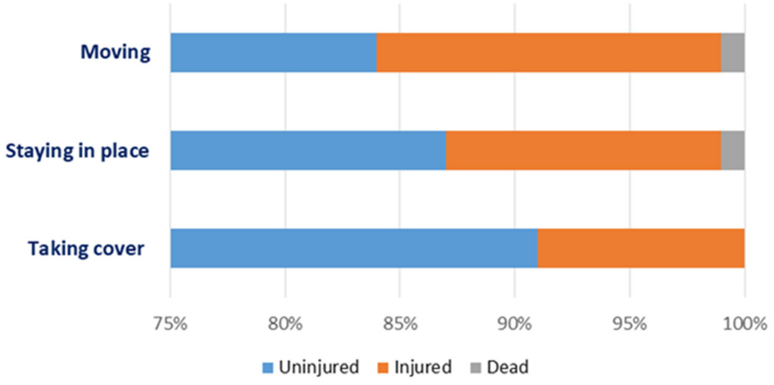

Figure 8. Response action and casualties

The questionnaire also asked participants about the household risk reduction and preparedness measures before the earthquake. Only 3% of the sample population said they had a family safety plan, only 1% had an emergency plan at work, 3% said they had furniture and equipment secured whereas less than 1% had emergency kits and tools in place. The most frequently cited reason for not taking preparedness measures was "not knowing what to do" (53%) and "being too busy" (15%). Only 4% of our sample reported that their households had been exposed to awareness programs in schools or in their community.

5 Conclusions

The findings from this earthquake are mostly of relevance to people occupying stone/ adobe and brick masonry buildings in Nepal. The greater the degree of stone/adobe and brick masonry building damage, much greater is the likelihood of death. Totally collapsed buildings are the most lethal of all. Heavily damaged buildings that do not collapse are much less lethal, and buildings that have minor and/or even moderate levels of damage, are much less dangerous still. As a result, any and all well-considered measures to strengthen construction, including 'minimum retrofit' in order to prevent collapse, are the single most important thing that can be done to reduce earthquake deaths and injuries. The evidence for building and maintaining earthquake-resistant buildings is overwhelming. Indeed, poorly built buildings do kill people, and minimum retrofit and replacement are important solutions that are only incrementally costly if done during the normal course of construction, rather than an enormous burden in the context of disaster recovery. Building non-structural elements and building contents are implicated in deaths and injuries. Public education can usefully emphasize knowledge and skills to identify and mitigate items that can slide and fall, to secure tall and heavy furniture, electronics, and appliances, to keep exit pathways clear, fasten hanging objects, store heavy objects lower down, place beds away from windows, and use tempered glass and window coverings in high traffic areas.

6 References

Akason, J.B., Olafsson, S., & Sigbjornsson, R. (2006). Perception and observation of safety during earthquake exposure: A case study, Safety Science 44; 913-933.

Bissell, R.A., Pinet, L., Nelson, M., Levy, M. (2004). Evidence of the effectiveness of health sector preparedness in disaster response, the sample of four earthquakes. Fam Community Health 27: 193-203.

Doocy, S., Daniels, A., Packer, C., Dick, A., & Kirsch, T. (2013). The Human Impacts of Earthquakes: a Historic Review of Events 1980-2009 and Systematic Literature Review. PloS Currents: Disasters. http://currents.plos.org/disasters/article/the-human-impact-of-earthquakes-from-1980-2009-a-historical-review-of-events-1980-2009-and-systematic-literature-review/ [Accessed June 9, 2016]

Elliott J. (2012). Earthquake disasters and resilience in the global North: lessons from New Zealand and Japan. The Geographical Journal. 2012 Sep 1;178(3):208-15.

Government of Nepal (2015). Nepal Earthquake 2015 Post Disaster Needs Assessment. Kathmandu: National Planning Commission. www.preventionweb.net/publications/view/44973

Jones, N.P. et al. (Ed.) (1990). Proceedings, International Workshop on Earthquake Injury Epidemiology for Mitigation and Response (pp. 71-76). Baltimore, MD: U.S. Geological Survey, Reston, VA.

Molnar,S. and Adhikari, S. (2017). Report on earthquake reconnaissance of The M7.8 Gorkha, Nepal earthquake on April 25, 2015 and its aftershocks- pg18:, ISBN: 978-0-9685376-2-6

Paton D, Bajek R, Okada N, McIvor D. (2010). Predicting community earthquake preparedness: a cross-cultural comparison of Japan and New Zealand. Natural Hazards. 2010 Sep 1;54(3):765-81.

Petal, M. (2012). Ch 3. Earthquake Casualties Research and Public Education in Robin J. Spence, Emily So and Charles Scawthorn Eds. Human Casualties in Natural Disasters: Progress in Modelling and Mitigation, Springer.

Petal, M. (2009). Evidence-based Public Education for Disaster Prevention: The Causes of Deaths and Injuries in the 1999 Kocaeli Earthquake, VDM. Doctoral dissertation, UCLA, 2004.

Rao, K. N. (2006). Lessons learnt in mental health and psychosocial care in india after disasters. International Review of Psychiatry, 18(6), 547-552. https://doi.org/10.1080/09540260601037961

Suwalowska, H., Amara, F., Roberts, N., & Kingori, P. (2021). Ethical and sociocultural challenges in managing dead bodies during epidemics and natural disasters. BMJ Global Health, 6(11).

Shoaf,K.I.(2002). Standardized Earthquake Injury Classification Scheme from www.ph.ucla.edu/cphdr/scheme.pdf [Accessed June 6, 2016]

Shoaf, K. I., Bourque, L. B., & Nguyen, L.H. (1996). Injuries sustained in the January 17, 1994 Northridge Earthquake. Paper presented at the American Public Health Association, New York NY.

Tang, B.; Chen, Q.; Chen, X.; Glik, D.; Liu, X.; Liu, Y.; Zhang, L. (2017). Earthquake-related injuries among survivors: A systematic review and qualitative synthesis of the literature, IJDRR V21 p.159-167

Wikipedia (2016) CTV Building https://en.wikipedia.org/wiki/CTV_Building [Accessed Dec. 15, 2016]

Wood, M. (2014). Epidemiology of Deaths and Injuries During Earthquakes, GeoHazards International.

YouTube (2008). Earthquake Simulator #1, https://www.youtube.com/watch?v=rIn0q_hSbAM

YouTube (2016). Earthquake Non-Structural Damage, https://www.youtube.com/watch?v=vUH76D5D3xs