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Structural performance and associated lessons to be learned from world earthquakes in Nepal after 25 April 2015 (M_W 7.8) Gorkha earthquake

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ABSTRACT

Gorkha earthquake (M_W 7.8) occurred in Nepal on 25 April 2015 at 11:56 local time. This earthquake is the most devastating event after the 1934 great Bihar-Nepal earthquake (M_W 8.1) in terms of damages. In that earthquake, 498,852 buildings were completely collapsed and other 256,697 were partially damaged. Structural and non-structural damages were occurred in all types of prevalent structural systems in affected areas. This paper outlines the structural performance during Turkey, Bhuj, Kashmir, Haiti, Chile and L'Aquila earthquakes from past two decades worldwide and comparisons are made in terms of structural forms, regulations to infer the lessons to be learnt by Nepal in the aftermath of Gorkha earthquake. Apart from this, review of structural performance during two major earthquakes of 1934 (M_W 8.1) and 1988 (M_W 6.5) in Nepal is presented to draw insights in terms of changing structural forms, technology and housing units. Insights are presented in terms of codal provisions and distribution of structures in Nepal. With due account of major world earthquake paradigms and historical earthquakes from Nepal and detailed field reconnaissance after the Gorkha earthquake, interpretations are disseminated in terms of lessons to be learned by Nepal in the aftermath of Gorkha earthquake. Comparative analyses have highlighted the urgent need of building code revision and development of proper strengthening techniques for the affected structures.

1. Introduction

On 25th April 2015, a strong earthquake of M_W 7.8 hit central Nepal and neighboring areas including the capital city at 11:56 local time. The epicenter was located near the Barpak village of Gorkha districts, around 77 km NW from the capital city, Kathmandu and the focal depth was about 15 km depth. The devastating main shock event was followed by more than 400 aftershocks as of November 2015. Three major aftershocks after Gorkha earthquake 2015 also accelerated the damage in already jolted structures. The aftershock of May 12 (M_W 7.3) which occurred in the border between Dolakha and Sindhupalchowk districts was largely responsible for the aggravated damage scenario in Sindhupalchowk and Dolakha districts. Out of 75 administrative districts, 31 were affected by Gorkha earthquake and 14 out of 31 districts in central Nepal were the worst affected in terms of casualties, infrastructural losses and lifeline damages. Distribution of earthquake effects as per categories endorsed by Government of Nepal for the affected 31 districts is reported in Fig. 1. In particular, the impacts of earthquake are congregated only

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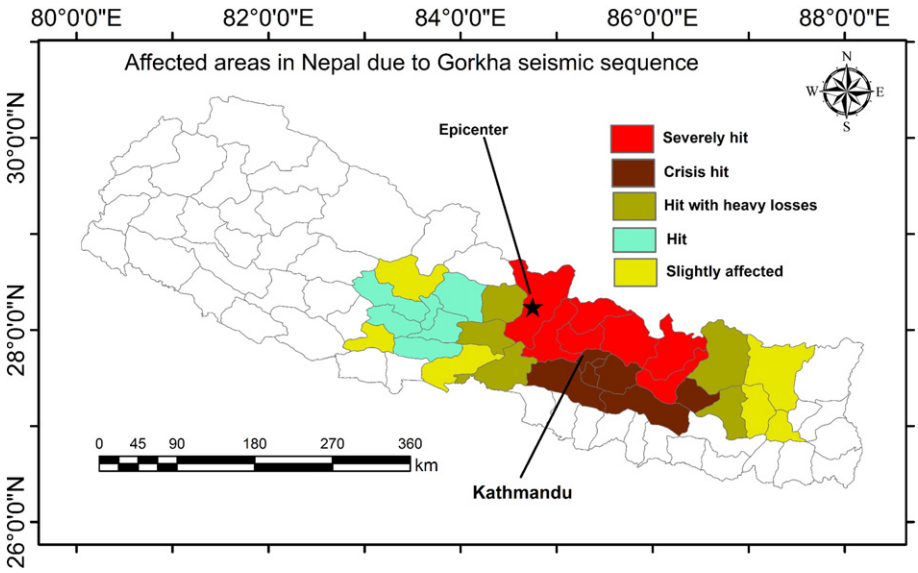

Fig. 1. Affected areas in Nepal due to Gorkha seismic sequence and categorization of earthquake impact.

towards east and south east of the epicenter and interestingly, no damage is cases were recorded even in neighboring districts towards west of epicenter. Details regarding the seismological reconnaissance and directivity effects are reported in several contributions (e.g. [3,9,26]). The official death toll was 8790, with 22,300 injured, almost eight million people were affected and millions were homeless [49]. Due to directivity effects and site conditions of settlements, the damage was primarily concentrated in central Nepal. In terms of structural damages, four major events M_W 7.8 (25th April), (M_W 6.7 (25th April), M_W 6.8 (26th April) and M_W 7.3 (12th May) governed almost all fraction of major structural collapse and minor to severe damage. The preliminary intensity distribution map prepared by Martin et al. [75] designates the near-field regions at around 8 in 1988 European Macroseismic Scale (EMS-98) and for the case of capital city districts; the intensity is designated to be 6–7. The severe losses in near-field regions of the April 25 main shock and 12 May aftershock is largely attributed by the flattened rubble stone masonry buildings ranging from recent constructions to centuries old unrepaired houses continuously used for several generations. For all of these events till May 12, the Post Disaster Need Assessment (PDNA) conducted by government of Nepal depicts the overall loss of around US$ 7 billion and there is no any case of strong shaking after the May 12 event till date, however aftershocks of magnitude 4–5.5 are occurring until April 2016 exactly one year after the main shock event.

Nepal, being situated in one of the most active seismic zone in the world, and continuously hit by strong earthquakes, still lacks proper framework in structural preparedness to strengthening measures. In addition to this, the lessons and preventive measures after every earthquake events are not accounted in policies and planning, thus the losses in case of earthquakes are always devastating. Moreover, lessons of the each earthquake events are not well documented till date, so it is imperative to document the causes behind the damage, lessons to be learned and improvement scenario for possible replication in case of future planning. Some contributions are made regarding various aspects of Gorkha earthquake, however exhaustive coverage in affected areas, comparative analysis of structural performance with past major earthquakes in from last century and comparative structural performance in terms of structural performance and associated lessons to be learned were not disseminated. This contribution covers the scenario of 21 affected districts including the entire crisis hit and severely hit districts in central Nepal. In particular, this paper outlines the brief summaries of significant world earthquakes and 1934 and 1988 earthquakes in Nepal with special focus on structural performance and associated casualties and draws comparisons with significant world earthquakes to infer the lessons to be learned by Nepal for improving the performance of structures in case of future earthquakes in Nepal. Reviews regarding the state-of-the art of building construction and possible improvement measures are discussed in light of prevalent guidelines along with the sufficiency of guidelines.

2. Seismicity and occurrence of earthquakes in Nepal

Nepal Himalaya is characterized by the frequent occurrence of earthquakes of varying magnitudes from east to west. In general, strong earthquakes in Nepal occur within every 60–80 years (Table 1) causing enormous loss of life and properties in terms

Table 1
Earthquake recurrence in Nepal Himalaya and the surrounding region between 1911 and 1991 [7].

Earthquake magnitude (M_L)	5–6	6–7	7–7.5	7.5–8	>8
No. of events	41	17	10	2	1
Approximate recurrence interval (years)	2	5	8	40	81