EFFECTS OF THE 2015 APRIL 25 Mw 7.8 NEPAL GORKHA EARTHQUAKE ON THE BUILT ENVIRONMENT

Efthymios LEKKAS1, Spyridon MAVROULIS2, Panayotis CARYDIS3, Ioannis TAFLAMPAS4, Emmanuel SKOURTSOS5

ABSTRACT

An Mw 7.8 earthquake struck Nepal on April 25, 2015 at 11:56 local time. The shock was felt throughout Nepal and in India, Bangladesh and Tibet. Along with its largest Mw 7.3 aftershock on May 12, the central Part of Nepal was severely affected resulting in 8891 fatalities, 22303 injuries, millions of homeless, environmental effects, damage on buildings and infrastructures and great economic losses. Based on field reconnaissance in the affected area immediately after the main shock, the dominant building types were recognized and their response on this earthquake was observed and analyzed. The dominant building types include reinforced concrete (R/C) buildings, unreinforced buildings with masonry load-bearing walls, wooden frame buildings, old cultural heritage structures and industrial structures. As far as the induced damage is concerned, masonry and cultural heritage structures suffered most damage due to inadequate construction and poor maintenance. In case of sounder construction, such buildings remained intact. Most of R/C buildings weathered the earthquake without damage despite of possessing high seismic vulnerability in most cases. The earthquake response of buildings was discontinuously nonlinear. It was observed that either partial or total collapse or no horizontal motion, no cracks, no breaking of glass window panels occurred. This fact is a key characteristic of the local domination of vertical excitation and the respective response of structures.

Keywords: 2015 Nepal earthquake; seismic response; structural damage; heritage structures

1. INTRODUCTION

The Himalayan range foreland basins are among the fastest growing in the last decades and most dense areas in the world. Nepal located in the central Himalaya (Fig. 1) is the 11th most earthquake-prone country and the fastest urbanizing country in the world according to the United Nations Development Programme (UNDP) in 2009. Kathmandu valley constitutes the cultural, economic and political capital of the country and presents a highly dynamic spatial pattern of urbanization, while Kathmandu city ranks first among the most earthquake-prone cities of the world. Ever since the first recorded earthquake of 1255 that killed the one-third of the local population of Kathmandu valley and its King Abhaya Malla, the major earthquakes in Nepal and Kathmandu valley are generated in regular time cycles of 75-80

1 Professor of Dynamic Tectonic Applied Geology and Disaster Management, Department of Dynamic Tectonic Applied Geology, Faculty of Geology and Geoenvironment, School of Sciences, National and Kapodistrian University of Athens, Greece, elekkas@geol.uoa.gr
2 Geologist MSc, PhD Candidate, Department of Dynamic Tectonic Applied Geology, Faculty of Geology and Geoenvironment, School of Sciences, National and Kapodistrian University of Athens, Greece, smavroulis@geol.uoa.gr
3 Professor of Earthquake Engineering, Professor Emeritus of the National Technical University of Athens, Greece, Member of the European Academy of Sciences and Arts, Panagouli 5a str., Kifissia, Greece, pkary@tee.gr
4 Civil Engineer PhD, Laboratory of Earthquake Engineering, National Technical University of Athens, Greece, taflan@central.ntua.gr
5 Geologist PhD, Laboratory Teaching Staff, Department of Dynamic Tectonic Applied Geology, Faculty of Geology and Geoenvironment, School of Sciences, National and Kapodistrian University of Athens, Greece, eskourt@geol.uoa.gr
years. The last great earthquake in Nepal was the 1934 Nepal-Bihar Mw 8.1 event resulted in more than 10000 fatalities in Kathmandu valley and damage to about 60% of the valley buildings (Pandey and Molnar, 1988). Similarly, a large Mw 7.8 earthquake struck Nepal on April 25, 2015 and along with its largest aftershock of Mw 7.3 on May 12 (Fig. 1) caused numerous fatalities and significant effects on the natural environment and the social, productive, infrastructure and cross-cutting sectors.

The main shock is a typical Himalayan-type low-angle thrusting earthquake with very wide slipping area and consequently widespread damage on the natural and built environment of the affected area. Seismic history shows that this event occurred in a seismic gap on a major shear zone marking the underthrusting of the Indian Plate beneath Asia, the Main Himalayan Thrust (MHT) fault in Central Nepal, where no large magnitude earthquakes have been recorded over the past 300 years (Ader et al., 2012).

This study is structured as follows. An overview upon the 2015 Nepal earthquake comprising its basic parameters is given in the second section. The dominant building types in the affected area are described in the third section. Their seismic response comprising non-structural and structural damage is presented in the following section based solely on field macroseismic observations recorded during field reconnaissance conducted by the authors that visited the earthquake-affected area immediately after the occurrence of the devastating earthquake. Finally, a brief summary of lessons learnt is found in the conclusions section.

2. THE 2015 NEPAL, GORKHA EARTHQUAKE

The Nepal, Gorkha earthquake occurred on April 25, 2015 at 11:56 local time and was assessed as 7.8 (USGS, GFZ, IPGP) or 7.9 (HARV). It caused intense ground shaking throughout Nepal and parts of India, Bangladesh and Tibet. The main shock and its largest aftershocks severely affected districts of Central Nepal resulting in over 8891 fatalities, 22303 severe injured, nearly half a million homes destroyed and a quarter million partially damaged that left over 280000 people homeless (OCHA, 2015). They also induced extensive environmental effects including numerous slope movements, ground cracks and liquefaction phenomena, damage on buildings and infrastructures as well as great economic losses in the order of US$7 billion (PDNA, 2015). Nearly 8 million people were affected by the earthquake sequence.

The earthquake epicenter was located near the Barpak Village of Gorkha district which is 81 km northwest of Kathmandu (Fig. 1a) and its focal depth was approximately 10-15 km. All focal mechanisms provided by seismological institutes and observatories (Fig. 1a) indicated a low-angle fault plane with NW-SE strike parallel to the Himalayan Belt and dip to NE at 7°-12° (Fig. 1a, b). The aftershock sequence within the first 45 days after the main shock included about 3000 events recorded by the permanent network of the National Seismological Centre (NSC) in Kathmandu with most hypocentral depths in the range between 2 and 25 km (Adhikari et al, 2015). The aftershocks occurred in a narrow zone with width of about 40 km, along the southern slope of the high Himalayan range (Adhikari et al, 2015) (Fig. 1c). This spatial distribution is consistent with the focal mechanisms provided for the main shock. The aftershocks in the western part of this distribution were concentrated close to a topographic high, while in the eastern part two clusters were defined: a large cluster observed immediately after the main event in Kathmandu area and coincided with the main ruptured fault segment and a smaller one located at the eastern end of the seismic cluster that occurred after the largest Mw 7.3 aftershock of May 12 (Adhikari et al, 2015) (Fig. 1c) and coincided with a deeper rupture to the east (Fig. 1b, c). The first aftershocks occurred in an area located in a distance of 120 km east of the main shock epicenter. More than 120 aftershocks with magnitude $M_l > 4.0$ followed the main shock in the first 12 hours. The number of aftershocks was decreased until the generation of the Mw 7.3 largest aftershock on May 12 with epicenter in Sunkhani of Dolkha district located 76 km northeast of Kathmandu (Fig. 1) and similar focal mechanism with the main shock (Fig. 1). This aftershock was located in the easternmost part of the aftershocks distribution and followed by a large number of aftershocks, 70 of which had magnitude $ML > 4.0$ (Adhikari et al, 2015).
Figure 1. (a) Geological map of Nepal after Upreti et al. (1999) with the epicenters of the April 25, 2015 Nepal, Gorkha earthquake and its largest aftershock. (b) Generalized N-S cross section through the Central Himalaya. The southern flat along the MHT is locked during the inter-seismic period resulting in elastic stress accumulation, which is released through microseismicity in Nepal Himalaya. The great earthquakes are generally originated along the northern flat just front of the Higher Himalaya (Chamlagain and Gautan, 2015). (c) The epicenters, the aftershock sequences and the focal mechanisms of the main shock on April 25, 2015 and of its largest aftershock on May 12, 2015 respectively based on USGS (2015).

Initial finite fault models show slip ranging from 2 to 4 meters at a depth of about 15 km over a zone...
extending about 150 km ESE of hypocenter (Lindsey et al., 2015). Based on Angster et al. (2015) and Moss et al. (2015), no surface rupture occurred from this earthquake or any of the subsequent aftershocks. However, a highly disrupted zone in Araniko Highway could be attributed to thrust faulting directly located under the Kathmandu basin. As far as the recorded ground motion is concerned, the maximum horizontal peak ground acceleration (PGA) of the earthquake recorded at the KATNP (USGS, 2015) strong motion station in central Kathmandu was 0.164g with a vertical component of 0.186g, maximum velocity of 0.86 cm/s and maximum displacement of 139 cm. This PGA is very low despite of the large earthquake magnitude and the small epicentral distance of central Kathmandu. Based on interferometric data and the derived surface deformation measurements, it is concluded that no major discontinuities in phase near the surface trace of the MHT are detected (Lindsey et al., 2015). Most of the displacement from the May 12 aftershock was observed close to the eastern tip of the displacement induced by the April 25 main shock indicating that stress interaction is the most possible explanation for the occurrence mode of these earthquakes in the Nepal Himalaya (Galetzka et al., 2015). The main shock produced changes in the state of stress of sufficient magnitude to trigger the largest aftershock on May 12.

3. DOMINANT BUILDINGS TYPES IN THE AFFECTED AREA

The dominant building types in the affected area are the following:

(a) **Reinforced concrete (R/C) buildings.** About 10% of buildings in Nepal are R/C buildings (Central Bureau of Statistics, 2012). They are frequently constructed in urban and suburban city areas (Marhatta et al., 2014) with R/C column and beam frames (R/C frames), concrete floors and roofs, and unreinforced masonry infill walls of solid clay bricks with cement mortar with width of one solid brick (Fig. 2a-f). The reinforcement comprises four deformed longitudinal bars in columns and beams, with widely spaced ties.

R/C buildings are classified in low- (1-3 storeys), mid- (4-7 storeys) and high-rise (> 7 storeys) buildings (Fig. 2d-f). The ground floor in almost 90% R/C buildings is used for commercial purposes and provided with shutters (Gautam et al., 2016) hence facing the undesirable consequences of the soft ground storey in case of ground shaking. However, the upper stories of such buildings are provided with infill brick masonry walls. Reinforcement in infill walls were not found to be provided in residential buildings with exception to some apartments. In case of high-rise buildings, the ground floor are also left open for parking or sometimes basement parking is also provided without infill walls. Moreover, most of residential buildings were found to be practicing “weak column-strong beam” as depicted by the massive beams and smaller columns (Gautam et al., 2016).

R/C buildings are constructed in two phases. During the first phase, the concrete floor slabs, columns, and beams are formed, poured, and allowed to cure, during the second phase unreinforced masonry infill bricks are then laid in between exterior columns, and bound using cement mortar, to form thin non-structural walls the width of one solid brick (McGowan et al., 2017). However, the majority of R/C buildings in Nepal are constructed in phase (Gautam et al., 2016) resulting in wide variations in quality of construction materials and practices and subsequent non-homogenous and non-monolithic construction characterized by wide variation in terms of seismic response and structural performance during earthquakes.

As far as the age is concerned, the R/C buildings can be further divided in two categories: The first category comprises buildings constructed before 1996, after the implementation of the first Nepal Building Code (1994). These buildings are less than 7-8 stories high. In general, their load-bearing system comprises reinforced concrete filled with solid fired clay brick walls. The dimensions of the concrete elements are very small, remaining constant along the height of the building. For example, the central columns of a 5-6-storey building are 0.25 m x 0.25 m ÷ 0.30 m x 0.30 m at distances of 4-5 m. The quality of concrete and the workmanship is poor. Moreover, problems with the well-known results of unconsolidation of the concrete mass due to lack or inadequate vibration are also observed. The reinforcement is sparse and small in diameter. Shear walls were not used. Their flexibility is augmented due to soft soil conditions, small plan dimensions and many stories.

The second category comprises buildings constructed after 1996 according to the Nepal Building Code (Nepal Building Code, 1994) and are much safer than those of the first category. Those buildings have
a height of up to 20 storeys, are of stiffer and sounder design, material and workmanship quality compared to the previous category. Nevertheless, even this category of buildings appears to have suffered damage.

R/C buildings in Nepal have some negative characteristics affecting their response and structural performance during the earthquakes. These characteristics include the construction of floating columns commonly observed in residential structures in order to increase the built up area from upper stories and the construction of asymmetrical structures in terms of plan as well as elevation attributed to unavailability of spaces for construction (Gautam et al., 2016). Due to the presence of such discontinuities in the load path during earthquakes, the forces are not effectively transferred to the foundation and the overturning forces can result buckling of columns of the ground floor and related damage. Moreover, the unavailability of spaces for construction have resulted in buildings in close proximity or abutting each other that can oscillate at different frequencies, phases, and modes during earthquakes and suffered significant damage.

### (b) Unreinforced buildings with masonry load-bearing walls

They have rectangular shape in plan and 1-5 storeys (Fig. 2g-i). Their foundation comprises bricks or stones. Different types of masonry were observed including solid bricks, concrete blocks, adobe and stones with cement, lime or mud mortar as well as mixed types. The masonry walls are often exposed without external or internal plasters. Wooden or masonry lintels are used to span over openings such as doors and windows. Wooden frames support heavy mud floors and roof of various types such as roof slabs, sloped wooden-framed roofs, canopies with corrugated galvanized iron and clay or stone tile finishes. The construction types vary based on location (urban, semi-urban and rural) and construction age (old and recent).

McGowan et al. (2017) further classified the unreinforced buildings in Kathmandu valley into two categories: (a) unreinforced buildings with masonry load-bearing walls and reinforced concrete slabs (URM-slab structures) and (b) unreinforced buildings with masonry load-bearing walls with some timber framing and/or timber flooring (URM-timber structures).

The URM-slab structures are constructed as follows (McGowan et al., 2017): the unreinforced masonry walls of one story are placed using courses of manufactured solid rectangular bricks bound together by cement mortar. Since these are load-bearing walls, they are generally thicker with width of two solid bricks than the non-structural infill walls incorporated into R/C-frame structures. A reinforced concrete floor slab is then placed across the entire footprint of the enclosed area. This process is repeated for each story of the building. The thick and brittle unreinforced masonry bearing walls remain the primary structural system resisting horizontal earthquake shaking (Sinha and Brzev, 2014).

The URM-timber are constructed as follows (McGowan et al., 2017): The load-bearing unreinforced masonry walls of these buildings comprise rectangular bricks bound together by mud mortar. They have width of two solid bricks. Once each story is laid, wooden joists are inserted to span between walls and support the wooden plank floors. Timber elements are also used to support the roof and to maintain the integrity of door and window openings. While the timber elements contribute to the overall flexibility of the structure, they are not seismically tied together to form an earthquake-resisting structural system. The thick unreinforced masonry bearing walls remain the only significant structural elements used to withstand horizontal earthquake shaking.

The URM buildings in Nepal have also some considerable disadvantages affecting their seismic response. These comprise the lack of proper bonding in masonry load bearing walls and the poor quality of binding materials, the lack of integration of several members within the structural components and weak connections between walls, walls and floor and wall and roof and lack of corner post or stone, the mixed up system of construction and the addition of reinforced concrete portions in upper stories along with cantilevered constructions, the foundation of buildings on inclined foundations as well as the very old construction age as many masonry buildings in Nepal were up to of 100 years age used by at least three generations (Gautam et al., 2016).

It is worth mentioned that entire villages and settlements of the affected area are characterized by the same pattern of URM constructions. There are plenty of structures in which there are no bonds between mortar and bricks. The mortar observed in the debris resulted from building collapse was disintegrated and almost powdered, while bricks were clean without any sing of mortar around them. Moreover, the fallen bricks in the collapsed sites were undamaged, indicating the very good construction quality of bricks. Based on these observations, it is concluded that earthquake resistant structural measures were not implemented despite of the frequent occurrence of major earthquakes.
(c) **Adobe structures.** They consist of adobe usually sun dried bricks made of earth found near the construction site. The earth is left to season for a few days. Then, it is mixed and put in wooden brick shaped molds in order to dry in the outdoors. The same earth material is used for constructing mortar. Adobe structures are not usually laid directly on the ground, but on foundation of stones found in adjacent fields or within nearby river beds. The adobe walls are composed of two leaves: the external, visible leaf is usually built with good quality bricks or has a special finish, while the internal leaf has simple rendered finish. The cavity between the external and the internal leaves is filled with the same earth material used for making the bricks and the binding mortar. The total thickness of the walls is never less than 50 cm. The two brick leaves are laid with one header followed by a stretcher, in order to create cohesion with the filling material and a strong link between the two brick leaves. In many buildings, the external leaf is often covered with a fine colored earth plaster in order to be protected from the undesirable effect of severe monsoon rains and the humidity causing erosion of the finest parts of the plaster leaving the bricks intact.

As regards their general seismic response, traditional adobe construction responds very poorly to earthquake ground shaking, suffering serious structural damage or collapse, and causing a significant loss of life and property (Shrestha et al., 2016). Seismic deficiencies of adobe construction are caused by the heavy weight of the structures, their low strength, and brittle behavior. During strong earthquakes, due to their heavy weight, these structures develop high levels of seismic forces that they are unable to resist, and therefore fail abruptly (Shrestha et al., 2016). However, they can exhibit a satisfactory resistance capacity to seismic movements when the building has an adapted morphology, does not exceed two floors above the ground floor and has adequate links between the vertical and horizontal structural elements (Bonapace and Sestini, 2003). In comparison to R/C and masonry buildings, adobe buildings, which are widespread in the affected area, are probably the most vulnerable structural system.

(d) **Wooden frame buildings.** They comprise post and beam frame up to 3 storeys, timber floors and roofs made of galvanized iron sheets. The infill walls are composed of wooden planks or galvanized iron sheets or bamboo with mud plaster on either side. The wooden parts are of good quality. This is deduced from the fact that the beams were safely standing after the 2015 Nepal earthquake in spite of the rather long openings and heavy beam loading compared to the cross sections of the respective bearing beams.

(e) **Industrial structures** including typical steel structures with truss and steel columns and composite steel structures with steel truss and R/C columns.

(f) **Old cultural heritage structures.** They are classified as buildings with traditional brick masonry and timber frame structures, brick masonry structures in lime or mud mortar and buildings made from stones. Three styles of architectural design are observed in the affected area: Tiered/Pagoda, Chaitya/Stupa and Shikhara style (Fig. 2j-l). Despite many differences within each style, the main load-bearing system of the traditional temples comprises multi-layered brick walls. The outer layer is made of good quality (fired clay) bricks, the middle layer of brick fragments and mud and the inner layer of poor quality materials (sun dried bricks).

In buildings of the affected area, the wooden structural parts were prevailing. Taking into account the debris induced by collapse of buildings of this type, it is concluded that the timber parts of the timber frame structures and the bricks of the brick masonry structures are of good quality, while the mortar was disintegrated and almost powdered without any bonds with the bricks indicating a rather poor quality.

4. **RESPONSE OF STRUCTURES TO THE 2015 NEPAL, GORKHA EARTHQUAKE**

Well-constructed R/C buildings sustained no damage at all or negligible to slight damage including fine cracks in plaster over frame members, in walls at the base and fine cracks in partition and infill walls. Poorly built and non-engineered R/C buildings suffered minor, moderate and severe damage not only to non-structural but also to structural elements. Non-structural damage included cracks with multiple patterns in infill walls (e.g. diagonal cracks, horizontal cracks at the beam interface and vertical cracks at the column interface), detachment of large pieces of plaster from infill walls, detachment of infill walls from the surrounding R/C frame and partial or total collapse of infill walls. Damage to structural elements of low- and mid-rise buildings comprised cracks and fracturing in beam and columns, shear failure or compression crushing of the supporting columns along with the elastic
behavior of beams, tilting (Fig. 3a, b), foundation failure resulting in overturning and partial or total collapse (Fig. 3b), soft story failure due to absence of infill walls and stirrups at the beam-column joint location, pounding of adjacent buildings resulting in partial collapse or tilting as well as pan-cake type collapse (Fig. 3c) due to heavy loads from the upper storeys and insufficient column sizes. Damage to high-rise buildings was observed to non-structural elements and comprised cracks in infill walls and detachment of large pieces of plaster in the lower storeys (first and second) followed by the medium storeys (Fig. 3d).

Damage to R/C buildings is attributed to poor geometric configuration (too long in one direction, extension of masonry wall beyond column line), poor quality of construction materials and concrete with comprehensive strength lower than the expected, non-seismic detailing and absence of earthquake resistant features, lack of implementation of proper ductile detailing of reinforcement even in recent constructions, lack of geotechnical provision and inappropriate foundation on slopes.
Unreinforced masonry buildings suffered the most by the 2015 Nepal earthquake. Damage to masonry buildings included diagonal cracks often originating from the openings in the masonry load-bearing walls (doors and windows), vertical corner cracks along the mortar joints of the brick walls, partial collapse of multi-layered walls (Fig. 3e-f), collapse of the upper storeys of the buildings and roofs, while the lower storeys remained intact (Fig. 3g-h), out-of-plane failure of roof gable due to its location at the top of the building and to its vibration as a free standing unit, tilting due to foundation failure, damage due to pounding with heavier adjacent buildings and partial or total collapse of the building (Fig. 3i-l). Damage to unreinforced masonry buildings is attributed to the placement of construction materials in a random manner, the large thickness of the load-bearing walls along with heavy floors and roofs resulting in heavy structures attracting large inertial forces during large shocks, lack of interlocking connection between main and cross walls, poor connection between the wall and the diaphragm and absence of continuous horizontal bands for developing confining box action of walls.

Major destruction was observed at various square complexes, world heritage sites and many other historical structures of cultural and archaeological significance in Kathmandu valley (Fig. 3m-p). The observed damage varied significantly based on the construction age and the structural systems. It mainly comprised residual deformation of the ground floor level of the temple, cracks in masonry walls, partial or total collapse of masonry walls (Fig. 3m-p), sway of the timber frame and partial or total collapse of the structure. Damage to old cultural heritage structures were due to old construction age, unusual structural systems, fatigue of monuments from past earthquakes, lack of maintenance and poor quality restoration after the 1934 Nepal-Bihar earthquake.

The industrial structures were slightly or no damaged by the 2015 Nepal, Gorkha earthquake sequence. The detected damage was limited to infill walls and included their cracking and partial collapse.

![Figure 3. The first row illustrates damage on RC buildings: (a) Tilting close to ground cracks strongly related to liquefaction-induced lateral spreading, (b, c) near total or total collapse, (d) moderate damage to non-structural elements of high-rise apartment building. The second and the third row illustrate damage to unreinforced masonry buildings with masonry load-bearing walls: (e-f) failure of side walls, (g-h) failure of the upper parts of the structures, (i-j) total or near total collapse of URM buildings. The forth row illustrates damage to old cultural](image-url)
heritage buildings of various construction types and especially partial (m) and total collapse of temples (n, o, p).

5. CONCLUSIONS

The 2015 Nepal, Gorkha earthquake is considered as one of the most destructive earthquakes of Nepal Himalaya since the great 1934 Nepal-Bihar earthquake as it severely affected 13 Nepal districts (Sindhupalchok, Kathmandu, Dolakha, Kahrupalanchok, Lalitpur, Dhading, Gorkha, Bhaktapur, Nuwakot, Rasuwa, Sinduli, Kaski, Parbat) (Fig. 4) in terms of earthquake environmental effects, fatalities, injuries, governmental and public building damage. The other districts were slightly or moderately affected. Because Nepal had not experienced earthquakes of this magnitude for more than 80 years, people and state authorities were less prepared for such an incident.

The well-designed R/C buildings show good performance sustaining minor reparable damage in structural elements but considerable damage to non-structural elements. Poor construction of non-engineered R/C buildings resulted in their collapse. The majority of masonry constructions lack proper seismic design and consequently they sustained heavy damage. The dominant type of the observed damage included corner cracks, diagonal cracks, multi-layered wall collapse, gable failure and partial or total collapse. Old cultural heritage structures suffered varying levels of damage based on construction age and structural system. Industrial buildings sustained minor to moderate damage limited to non-structural elements. Infrastructure sectors suffered minor damage except from electricity generation and distribution networks and communication systems.

It is significant to note that relative lateral motion between adjacent buildings was not detected in numerous cases all over the affected area, where partial or total collapse of buildings, lack of horizontal motion, vertical or horizontal cracks and no damage to glass window panels were observed. Diagonal cracks were also not detected. This observation is a key characteristic of the predominance of vertical component of the earthquake ground motion in the epicentral region and of the respective response of structures.

Figure 4. Distribution of (a) total fatalities, (b) injuries, (c) damaged governmental buildings and (d) damaged public buildings induced by the 2015 Nepal, Gorkha earthquake and its largest aftershocks to the Nepal districts (Lekkas et al., 2017; modified). The used data came from reports of the Government of Nepal, Ministry of Home Affairs (2015).
Taking into account the numerous fatalities, the injuries, the extensive effects on the natural environment, buildings and infrastructures and the societal aftermath of the seismic sequence of spring 2015, it is concluded that the 2015 Nepal, Gorkha earthquake is the most destructive generated in Central Himalaya since the 1934 Nepal-Bihal earthquake with a long-term effect on different aspects of the life of Nepalese people. The most significant lesson Nepal learnt from this earthquake is that the best way to mitigate the disastrous earthquake effects is the strengthening and retrofitting of the existing structures to better standards, the construction of earthquake resistant structures and the increase of preparedness at all levels of administration.

6. REFERENCES


