Academic Voices
A Multidisciplinary Journal
Volume 5, No. 1, 2015
ISSN 2091-1106

EARTHQUAKE IN NEPAL: A MISERABLE ENVIRONMENTAL HAZARD VISITED BY NATURE

Shiva Kant Dube
Department of Geography, TU, Thakur Ram Multiple Campus, Birgunj, Nepal
E-mail: shivakant.dube@gmail.com

Abstract

The federal democratic republic of Nepal is located at the boundary between Indian and Tibetan tectonic plates and therefore lies in a seismically active region. Historical data evidence the occurrence of destructive great earthquakes in the past. Earthquakes are caused mainly due to disequilibrium in any part of the crust of the earth. If we look at the world distribution of earthquake, it appears that the earthquake belts are closely associated with the weaker zones of the globe. Microseismic monitoring is a very fast and efficient tool to understand the seismotectonics of the region. It is an instrument for seismic surveillance allowing a fast post-earthquake rescue operation. This paper incorporates a case of earthquake occurred in April, 2015 as one of the environmental hazards visited by nature which proved disastrous causing massive loss of lives and properties to the vulnerable regions. It can be taken as a lesson to mitigate massive loss of lives and properties selecting isostatically proper land structure and constructing safe settlements for habitat in Nepalese context.

Key words

Seismic; tectonic plates; environmental hazard; vulnerable; massive loss

Introduction

Those events or accidents, whether caused by natural processes or human factors, are called extreme events which occur very rarely and aggravate natural environmental processes to cause disaster for human society such as sudden tectonic movements leading to earthquake and volcanic eruption, continued dry conditions leading to prolonged droughts, floods, atmospheric disturbances, glacial lake outburst floods, collision of celestial bodies etc. Environmental hazards may be defined as those extreme events either natural or man-induced, which exceed the tolerable magnitude within or beyond certain time limits, make adjustment difficult, result in catastrophic losses of property, income and lives and become the headlines of different news media at world level (Strahler & Strahler, 1976).

Singh describes that hazards are generally taken to be the processes, both natural and anthropogenic, which cause an accident/ extreme event or danger whereas 'disaster' is a sudden adverse or unfortunate extreme event which causes great damage to human beings as well as plants and animals. Disasters occur rapidly, instantaneously and indiscriminately. It, therefore, becomes obvious that environmental hazards are the processes whereas the environmental disasters are the results or responses of environmental hazards. It may be mentioned that environmental disasters are always viewed in terms of human beings. The intensity of environmental disaster is weighed in terms of the quantum of damages done to the human society (as cited by Dube, 2014).

Earthquake is one of those extreme events caused due to natural or anthropogenic or by both factors. This paper incorporates the introduction of environmental hazard, environmental disaster, earthquake, definition, causes, classification, effects, size & occurrence, mitigation measures, preparedness, a case of earthquake in Nepal-2015 and history including conclusion.

Earthquake

Geographically, Nepal is situated on the lap of the Himalayas in southern Asia, sandwiched between two large countries, China in north and India in south, east and west, occupy an area of 1,47,181 sq. kilometers which is about 0.3 percent of Asia continent and 0.03 percent of world land mass. Situated on the southern slope of the Himalayas, it stretches in between the latitudes26° 22' and 30° 27' north and the longitude 80° 04' and 88° 12' East (Chaudhary, 1998). According to recent population census report, out of the total 2,64,94,504 population, Himalayan region habituates with 6.73 percent, Hilly region 43 percent and Terai region habituates with 50.27 percent population of Nepal (CBS, 2011). Among these, Himalayan and Hilly regions are more vulnerable from the point view of earthquakes because many fault-lines/zones are located in these isostatically weaker zones.

Strahler & Strahler define earthquake is a major demonstration of the power of tectonic forces caused by endogenetic thermal condition of the interior. An earthquake is a motion of the ground surface ranging from a faint tremor to a wild motion capable of shaking building a part and gapping fissures to open in the ground. The earthquake is a form of energy of wave motion transmitted through the surface layer of the earth in widening circles from a point of sudden energy release, the focus (as cited by Singh, 1999).

The word 'earthquake' has been composed of two words 'earth' and 'quake' which means 'quaking or shaking' of the earth (Sharma & Bhatta, 2011). An earthquake (also known as a quake, tremor or temblor) is the perceptible shaking of the surface of the Earth, which can be violent enough to destroy major buildings and kill thousands of people. The severity of the shaking can range from barely felt to violent enough to toss people around. Earthquakes have destroyed whole cities. They result from the sudden release of energy in the Earth's crust that creates seismic waves. The seismicity, seismism or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time (Wikipedia).

The place of origin of the earthquake is called focus or hypocenter which is always hidden inside the earth. The place on the ground surface, which is perpendicular to the buried hypocenter is called epicenter (Gurung, 2064 BS). The magnitude or intensity of energy released by an earthquake is measured by "Richter scale" which was devised by Charles F. Richter. The waves generated by earthquakes are called seismic waves which are recorded by an instrument called 'seismograph or seismometer'. The science which deals with the seismic waves is known as 'seismology. The tremors which are frequently coming in an area affected by earthquake are called "After-

shocks". An aftershock is an earthquake that occurs after a previous earthquake, the main-shock. An aftershock is in the same region of the main shock but always of a smaller magnitude. If an aftershock is larger than the main shock, the aftershock is re-designated as the main shock and the original main shock is re-designated as a foreshock. Aftershocks are formed as the crust around the displaced fault plane adjusts to the effects of the main shock (Singh, 1999).

Magnitude 3 or lower earthquakes are mostly almost imperceptible or weak and magnitude 7 and over potentially causes serious damage over larger areas, depending on their depth. The largest earthquakes in historic times have been of magnitude slightly over 9, although there is no limit to the possible magnitude. The most recent large earthquake of magnitude 9.0 or larger was a 9.0 magnitude earthquake in Japan in 2011 (as of March 2014), and it was the largest Japanese earthquake since records began. Accordingly some of the greatest hazardous earthquakes of the world are Russia (1952) having magnitude of 9.0 richter scale, Chile (1960) having magnitude 9.5 richter scale, Alaska (1964) having magnitude of 9.2 richter scale, Indonesia (2004) having magnitude of 9.1 richter scale and one very recent earthquake of Chile (16th September, 2015) having magnitude of 8.3 richter scale which occurred during the preparation of this manuscript. Intensity of shaking is measured on the modified Mercalli scale. The shallower an earthquake, the more damage to structures it causes, all else being equal (Wikipedia).

The most devastating earthquakes visited in Nepal are Bihar-Nepal earthquake on 16th January, 1934 with magnitude 8.4 richter scale, Nepal-Sikkim earthquake on 18th September, 2011 having 6.8 richter scale magnitude and the most recent shocking earthquake of 25th April, 2015 with the magnitude 7.9 richter scale hit Nepal in the area near Barpak, a mountain village between capital Kathmandu and tourist town Pokhara. The earthquake was followed by many powerful aftershocks and a very powerful one (6.7) hit Nepal on Sunday April 26. The earthquake caused extensive damage to buildings and thousands of deaths and injuries and was even felt in Pakistan, India and Bangladesh. Many historic monuments and buildings collapsed, temples have been ruined, roads destroyed, nearly 10,000 deaths in Nepal and hundreds of deaths in India and Tibet. The quake was followed by more than 600 aftershocks and another overwhelming earthquake of 6.8 Richter scale on May 12, 2015 (The Kantipur Daily on 28th April, 2015).

Causes of earthquake

Earthquakes are caused mainly due to disequilibrium in any part of the crust of the earth. If we look at the world distribution of earthquake, it appears that the earthquake belts are closely associated with the weaker zones of the globe (Singh, 2003). In its most general sense, the word earthquake is used to describe any seismic event - whether natural or caused by humans - that generates seismic waves. Earthquakes are caused mostly by rupture of geological faults, but also by other events such as volcanic activity, landslides, mine blasts, and nuclear tests. The major causes of earthquakes are;

- Gaseous expansion beneath the earth surface
- Volcanic eruption
- Crustal adjustment; faulting/ folding
- Hydraulic action
- Anthropogenic causes
- Nuclear testing
- Plate tectonics

Recently, plate tectonic theory has been accepted as the most plausible explanation of the causes of earthquakes. There are three main types of fault, all of which may cause an interpolate earthquake: normal, reverse (thrust) and strike-slip. Normal faults occur mainly in areas where the crust is being extended such as a Divergent boundary. Reverse faults occur in areas where the crust

is being shortened such as at a Convergent boundary. Strike-slip faults are steep structures where the two sides of the fault slip horizontally past each other; Transform boundaries are a particular type of strike-slip fault. Many earthquakes are caused by movement on faults that have components of both dip-slip and strike-slip; this is known as oblique slip.

The plate boundaries/zones constitute the major earthquake areas of the world. Three well-defined seismic belts i.e. isostatically weaker zones of the world are;

- Circum-Pacific zone
- Mid-Continental belt
- Mid-Atlantic ridge

Classification of earthquake

Singh (1999) emphasizes that there is wide range of variation in the nature and magnitude of earthquakes. Each earthquake differs from the other and thus it becomes difficult to classify all the earthquakes into certain categories. In spite of these limitations earthquakes are classified on the basis of common characteristics as given below.

1) Classification on the basis of causative factors

A. Natural earthquakes

   I. Volcanic earthquakes
   II. Tectonic earthquakes
   III. Isostatic earthquakes
   IV. Plutonic earthquakes

B. Artificial or man-induced earthquakes

2) Classification on the basis of focus

Guttenberg has divided the world seismic centers on the basis of the depths of their foci into three types

   I. Moderate earthquakes - 0 to 50 km. depth
   II. Intermediate earthquakes - 50 to 250 km. depth
   III. Deep focus earthquakes - 250 to 700 km. depth

3) Classification on the basis of human causalities'

   I. Moderately hazardous earthquakes - below 50,000 deaths
   II. Highly hazardous earthquakes
      - 51,000- 1,00,000 deaths
   III. Most hazardous earthquakes - above 1,00,000 deaths

Environmental effects of earthquake

At the earth's surface, earthquakes manifest themselves by shaking and sometimes displacement of the ground. When the epicenter of a large earthquake is located offshore, the sea-bed may be displaced sufficiently to cause a tsunami. Earthquakes can also trigger landslides and occasionally volcanic activity. Some of the overwhelming effects of this natural hazard are;

- Ground shaking and ground displacement along a fault
- Slope instability and failures
- Land and mud slides
- Soil liquefaction.
- Avalanches.
- Floods from dam and levee failure and subsidence.
- Structural collapse
- Falling objects
- Damages to towns and cities
- Massive loss of lives and property
- Fires
- Flash flood

- Volcanoes
- Tsunami
- Epidemics and diseases

It is estimated that only 10 percent or less of an earthquake's total energy is radiated as seismic energy. Most of the earthquake's energy is used to power the earthquake fracture growth or is converted into heat generated by friction (William et al., 1989). The effects of earthquakes include, but are not limited to, the following:

Shaking and ground rupture

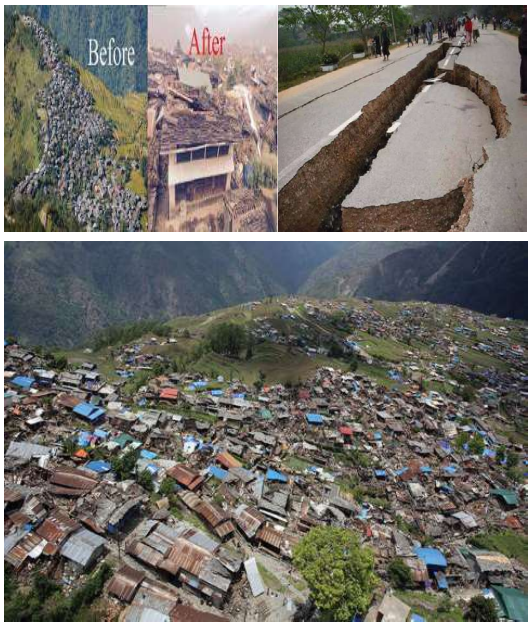

Fig. 1 Damaged buildings and ground in (Barpak and Kathmandu) Nepal, April, 2015

Shaking and ground rupture are the main effects created by earthquakes, principally resulting in more or less severe damage to buildings and other rigid structures. The severity of the local effects depends on the complex combination of the earthquake magnitude, the distance from the epicenter, and the local geological and geomorphological conditions, which may amplify or reduce wave propagation. The ground-shaking is measured by ground acceleration.

Ground rupture is a visible breaking and displacement of the earth's surface along the trace of the fault, which may be of the order of several meters in the case of major earthquakes. Ground rupture is a major risk for large engineering structures such as dams, bridges and nuclear power stations and requires careful mapping of existing faults to identify any which are likely to break the ground surface within the life of the structure (Wikipedia).

Landslides and avalanches

Fig. 2 Landslide of a) El Salvador earthquake, 2001, (b, c) Kaligandaki which blocked the river d) avalanche of Mt. Everest after earthquake of 2015 in Nepal

Landslides became a symbol of the devastation the 2001 El Salvador earthquakes left, killing hundreds in its wake. Earthquakes, along with severe storms, volcanic activity, coastal wave attack and wildfires can produce slope instability leading to landslides, a major geological hazard. Landslide danger may persist while emergency personnel are attempting rescue (Wikipedia).

Fires

Earthquakes can cause fires by damaging electrical power or gas lines. In the event of water mains rupturing and a loss of pressure, it may also become difficult to stop the spread of a fire once it has started. For example, more deaths in the 1906 San Francisco earthquake were caused by fire than by the earthquake itself (Wikipedia).

Soil liquefaction

Soil liquefaction occurs when, because of the shaking, water-saturated granular material (such as sand) temporarily loses its strength and transforms from a solid to a liquid. Soil liquefaction may cause rigid structures, like buildings and bridges, to tilt or sink into the liquefied deposits. For example, in the 1964 Alaska earthquake, soil liquefaction caused many buildings to sink into the ground, eventually collapsing upon them (Wikipedia).

Tsunami

Fig. 3 The tsunami of the 2004 Indian Ocean earthquake

A large ferry boat rests inland amidst destroyed houses after a 9.0 earthquake and subsequent tsunami struck Japan in March 2011. Tsunamis are long-wavelength, long-period sea waves produced by the sudden or abrupt movement of large volumes of water. In the open ocean the distance between wave crests can surpass 100 kilometers, and the wave periods can vary from five minutes to one hour. Such tsunamis travel 600-800 kilometers per hour, depending on water depth. Large waves produced by an earthquake or a submarine landslide can overrun nearby coastal areas in a matter of minutes. Tsunamis can also travel thousands of kilometers across open Ocean and wreak destruction on far shores hours after the earthquake that generated them (Noson *et al.*, 1988).

Floods

A flood is an overflow of any amount of water that reaches land. Floods occur usually when the volume of water within a body of water, such as a river or lake, exceeds the total capacity of the formation, and as a result some of the water flows or sits outside of the normal perimeter of the body. However, floods may be secondary effects of earthquakes, if dams are damaged. Earthquakes may cause landslips to dam rivers, which collapse and cause floods (Wikipedia).

Human impacts

An earthquake may cause injury and loss of life, road and bridge damage, general property damage, and collapse or destabilization (potentially leading to future collapse) of buildings. The aftermath may bring disease, lack of basic necessities, and higher insurance premiums. District-wise human causalities done by the shocking earthquake of 2015 in Nepal is presented in the following map (MoHA, 2015).

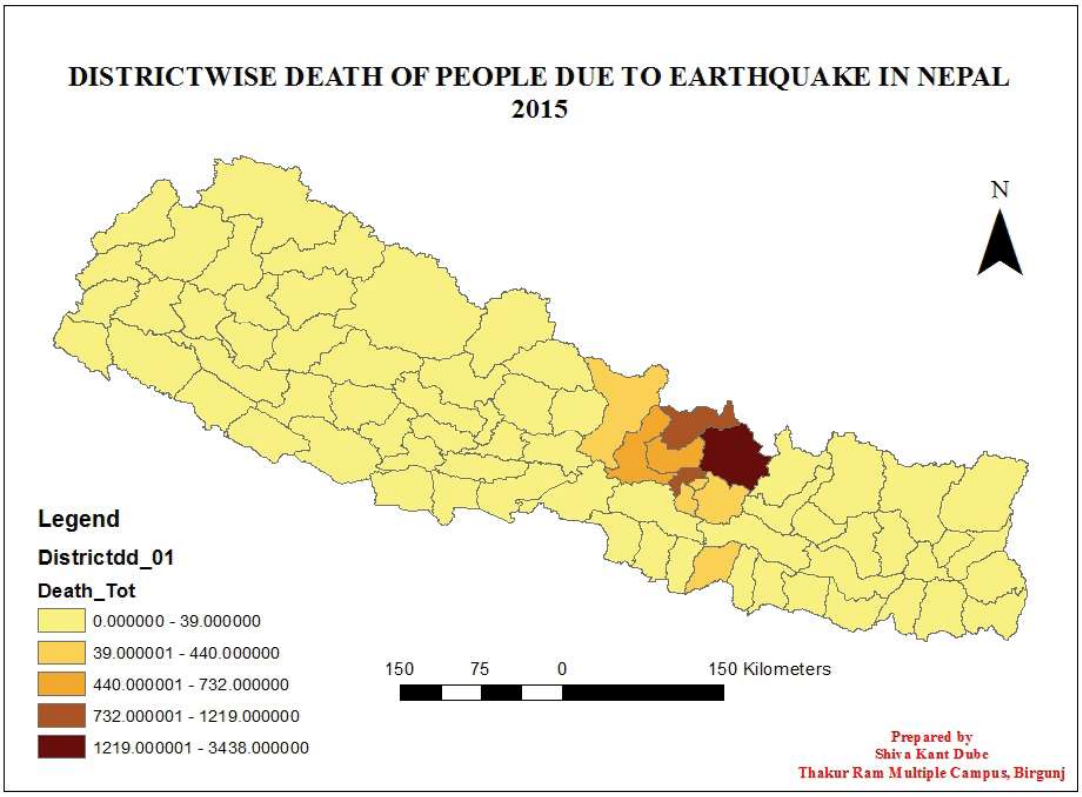

Fig. 4 District-wise loss of life due to earthquake 2015

Size and frequency of occurrence

It is estimated that around 500,000 earthquakes occur each year, detectable with current instrumentation. About 100,000 of these can be felt. Minor earthquakes occur nearly constantly around the world and larger earthquakes occur less frequently, the relationship being exponential; for example, roughly ten times as many earthquakes larger than magnitude 4 occur in a particular time period than earthquakes larger than magnitude 5. In the (low seismicity) United Kingdom, for example, it has been calculated that the average recurrences are: an earthquake of 3.7–4.6 every year, an earthquake of 4.7–5.5 every 10 years, and an earthquake of 5.6 or larger every 100 years. This is an example of the Gutenberg-Richter law.

Most of the world's earthquakes (90%, and 81% of the largest) take place in the 40,000 km long, horse shoe-shaped zone called the Circum-Pacific seismic belt, known as the Pacific Ring of Fire, which for the most part bounds the Pacific Plate. Massive earthquakes tend to occur along other plate boundaries, too, such as along the Himalayan Mountains (James, 2006).

Earthquake prediction

Many methods have been developed for predicting the time and place in which earthquakes will occur. Despite considerable research efforts by seismologists, scientifically reproducible predictions cannot yet be made to a specific day or month. However, for well-understood faults the probability that a segment may rupture during the next few decades can be estimated. Earthquake Warning System have been developed that can

provide regional notification of an earthquake in progress, but before the ground surface has begun to move, potentially allowing people within the system›s range to seek shelter before the earthquake›s impact is felt (Wikipedia) .

Preparedness

The objective of earthquake engineering is to foresee the impact of earthquakes on buildings and other structures and to design such structures to minimize the risk of damage. Existing structures can be modified by seismic retrofitting to improve their resistance to earthquakes. Earthquake insurance can provide building owners with financial protection against losses resulting from earthquakes. Emergency management strategies can be employed by a government or organization to mitigate risks and prepare for consequences (Wikipedia). Table 1 shows the preparedness techniques to be adopted at different stages of earthquake to minimize potential loss.

Table 1: Preparedness of earthquake

How	Before an earthquake	At the time of an earthquake	After earthquake
Be prepared for coming earthquakes.	Construct earthquake resistant buildings and other structures.	Don't get panic. Panic kills you rather than the earthquake itself.	Be prepared for aftershocks.
Learn how to be prepared for earthquakes.	Retrofit old houses.	Take shelter (if it is close) under strong furniture (tables, beds) close to walls under door frame.	Stop gas, electricity supply.
Learn what we should do before earthquakes occur.	If possible, avoid areas that are sensitive to earthquakes, where earthquake waves get amplified.	Keep away from High Tension lines of electricity.	Know the condition of your family and then go to safe places outside.
Learn what we should do at the time of earthquakes.	Identify safe places in your house, office and outside.	Keep away from windows.	Don't use telephone (rescue team may want to use it).
Learn what should we do after an earthquake.	Prepare first aid kit, torch, radio, food and water for at least three-four days.	Keep away from high rise buildings.	Rescue your family members first then your neighbors.
	Educate students on how to protect ourselves at the time of earthquake.	Keep away from tall structures. Stop your vehicle if you are on drive.	If you are trapped, believe and wait rescue teams will come to rescue you.
	Put important documents (passport, citizenship, insurance) in safe place.	If you are walking, stop now!! Keep away from very congested places.	

Nepalese context

The federal democratic republic of Nepal is located at the boundary between Indian and Tibetan tectonic plates and therefore lies in a seismically active region. Historical data evidence the occurrence of destructive great earthquakes in the past. Mitigation of earthquake risk can be made only with adequate assessment of seismic hazard which should be based on the evaluation of seismo-tectonic and geological process prevailing in this part of the world.

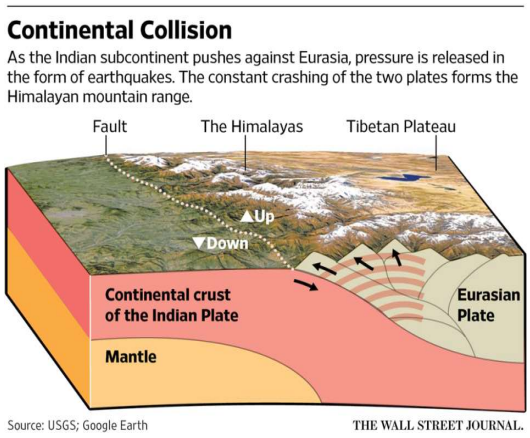

Fig. 5 Collision of Eurasian and Indian Plates

Microseismic monitoring is a very fast and efficient tool to understand the seismotectonics of the region. It is an instrument for seismic surveillance allowing a fast post-earthquake rescue operation. For regional and global earthquake location and related seismological studies it provides a valuable database.

Microseimic monitoring in Nepal started in November, 1978 by Department of Mines and Geology (DMG), Ministry of Industry, government of federal democratic republic of Nepal in collaboration with Laboratoire de Geophysique Appliquee, Paris University, France with the installation of first short period vertical seismic station Phulchoki (PKI) hilltop in the south of Kathmandu. The numbers of stations were augmented gradually to create the National Network consisting of 21 short period seismic stations in 1998 and 7 accelerometer stations in 2012. The network is operated in collaboration with Department of Analysis & Surveillance of Environment (DASE), France. The 21 short period seismic stations and 7 accelerometer stations occupy the Lesser Himalaya and Sub Himalayan terrain of Nepal Himalaya uniformly.

The recording is carried out at two centers Birendranagar Regional Seismological Centre (RSC), Surkhet and National Seismological Centre (NSC), Lainchour, Kathmandu. RSC records 9 stations of mid-western and far-western Nepal while NSC records the remaining 12 stations from Pyuthan to Taplejung. The stations are operated in two sensitivity channels allowing a dynamic range of 110 db. The signals are digitized centrally acquired using JADE software of DASE. The location is made with ONYX software of DASE since April, 2001. Before this ISIS software of DASE was used for acquisition & processing.

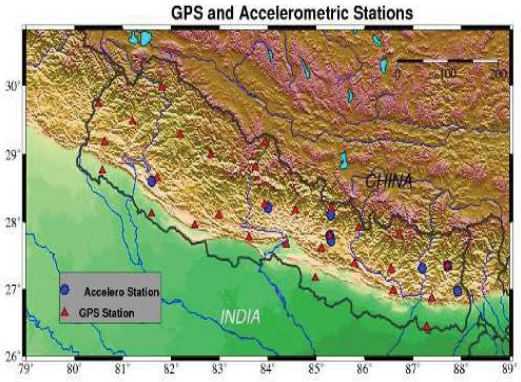

Fig. 6 GPS and Accelerometric Stations in Nepal

Since, earthquake is caused by sudden release of elastic energy stored in the active geological faults inside the earth which causes movement in the crust. In order to monitor the crustal shortening because of continuous movement of Indian Plate towards the north, NSC/DMG installed 29 GPS Stations in technical collaboration with Caltech/USA and

DASE/France across the Nepal Himalaya. By the end of 2012, 151667 earthquakes have been recorded by the Centre out of which 51053 are local and regional and 100814 are teleseisms.

Historical Earthquakes

Historical seismicity is the historical records of earthquakes preserved in different form such as written history, chronicles, inscription etc. which plays an important role in the seismic hazard assessment because instrumentally recorded earthquakes are lacking before the current century. Historical events must be available for a long period of human civilization which should throw light on the extent of damage besides the date and place of occurrence.

Chitrakar & Pandey (1986) conclude that the earthquake of 1255 AD has been reported to destroy many houses and temples and killing one third to one fourth population of the Kathmandu Valley. The assigned intensity is about X in MM scale. The earthquake of 1408 AD has been reported to destroy the Machhendra Nath temple of Patan. Similarly the earthquake of 1681 AD and 1810 AD have been reported to occur but the exact locations of these earthquakes are not known.

Bilham (1995) acclaimes that recent research on historical data has well constrained on the source, size, magnitude and possible location of 1833 AD event which devastated Kathmandu valley. Its magnitude is reported to be of Mb=7.8 with possible rupture length of more than 70 km and the event is located at 50 km North - North East of Kathmandu.

Molnar and Pandey (1994) finalize that the human casualties are reported to be less than 500, which may be due to occurrence of two large foreshocks. The earthquake of 1934 AD is the most devastating earthquake ever occurred in the territory of Nepal with casualties of more than 16000 people including from Nepal and India put together. The rupture length is estimated to be 200 Km 100 Km . The great earthquake, which occurred in Nepal, was Bihar-Nepal earthquake of 1934 AD Assam great earthquake of 1897, Kangra earthquake 1905, and Assam earthquake 1950 were felt in Nepal. The earthquake of 1833 also affected the Kathmandu Valley. The record of historical earthquake is not complete which poses a problem in assessing the recurrence period of great earthquakes. From the available data there has been no great earthquakes of magnitude >8.0 in the gap between the earthquakes of 1905 A. D and 1934 A. D. and there is a real threat that a major earthquake may occur in this gap that will affect Western Nepal (NGS, 1986).

Conclusion

Earthquake is one of those extreme events caused due to natural or anthropogenic or by both factors. It is demonstration of the power of tectonic forces caused by endogenetic thermal condition of the interior. An earthquake is the perceptible shaking of the surface of the earth which can be violent enough to destroy major buildings and killing thousands of people. The severity of the shaking can range from barely felt to violent enough to toss people around. They result from the sudden release of energy in the Earth's crust that creates seismic waves. The seismicity, seismism or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time. Earthquakes are caused mainly due to disequilibrium in any part of the crust of the earth and are associated with isostatically weaker zones of the world. Earthquakes trigger overwhelming environmental effects and prove miserable to human society.

The recent earthquakes of Nepal-2015 proved devastating and miserable causing extensive damage historic monuments, buildings, temples, roads and nearly 10000 deaths and thousands of injuries in Nepal and the neighboring territories. Thus, preparedness about earthquake, seismically suitable structure and scientifically proper settlements may support to minimize

potential loss because neither it is predictable nor controllable.

References

California Department of Conservation. (2002). Guidelines for evaluating the hazard of surface fault rupture, *California Geological Survey*. Retrieved on 21st November, 2015 from http://www.consrv.ca.gov/cgs.

CBS. (2011). *National population and housing census 2011, National report (2012)*. Kathmandu: Central Bureau of Statistics.

Chaudhary, R. P. (1998). *Biodiversity in Nepal*. Retrieved on September 25, 2015, from http://unfccc.int/resource/docs/cop7/13a02.pdf.

Dube, S. K. (2014). Glacial lake outburst flood in Nepal: A challenging environmental hazard and disaster. *Academic Voices A Multidisciplinary Journal*, vol. 4, no. 1, 2014, 56-67.

Gurung, J. B. (2064). *Concept of environmental education for grade XII*. Kathmandu: MK Publishers and Distributors.

James, J. (2006). Fatal attraction: living with earthquakes, the growth of villages into megacities and earthquake vulnerability in the modern world, *Philosophical Transactions of the Royal Society,* 15 August 2006, vol. 364, no. 1845.

MoHA. (2015). *Death and injuries of people due to earthquake hazard-2015*. Kathmandu: Ministry of Home Affairs, GoN.

MSN Encarta Dictionary. (2006). *Flood*. Retrieved on 5th November, 2015 from http://encarta.msn.com/encnet/features/dictionary.

Nepal Geological Society. (1986). Historical earthquakes. *Bulletin of Nepal Geological Society*, Vol. 4. Retrieved on 21st September, 2015 from http://www.seismonepal.gov.np/index.php?linkId=56 .

Noson, Qamar, & Thorsen (1988). *Washington Division of Geology and Earth Resources Information Circular 85*. Washington State Earthquake Hazards.

Sharma, P. K. & Bhatta, B. (2011). *Environmental Education.* Kathmandu: Bhundipuran Publication.

Singh, S. (1999). *Physical Geography*. Allahabad: Prayag Pustak Bhawan, India.

---------- (1999). *Environmental Geography*. Allahabad: Prayag Pustak Bhawan, India.

Strahler, A. N. & Strahler, A. H. (1976). *Geography and Man's Environment*. New York: John Willey.

The Kantipur Daily. (28th April, 2015). Mulukkai dosro thulo bhukamp. Kathmandu.

USGS. (2006). *Visual glossary- Ring of fire*. Retrieved on 5th September, 2015 from http:// United States Geological Survey.

---------- (2008). *Natural hazards- landslide*. Retrieved on 1st November, 2015 from http:// United States Geological Survey.

---------- (2008). *The great 1906 San Francisco earthquake of 1906*. Retrieved on 5th November, 2015 from http://United States Geological Survey.

---------- (2008). *Historic earthquakes-1946, Anchorage earthquake*. Retrieved on 5th November, 2015 from http://United States Geological Survey.

William, S., Sipkin, S. A. & Choy, G. L. (1989). *Measuring size of earthquake*. Retrieved on 15th November, 2015 from http://United States Geological Survey.

Working group on California earthquake probabilities in the San Francisco Bay region, 2003 to 2032. (2003). Retrieved on 15th November, 2015 from http://earthquake.usgs.gov/regional/nca/wg02/index.php.