EARTHQUKAES : SHIVERING NEPAL

Research Report by Atul Adhikari

Contact : 9849424498 / atuladhikari345423@gmail.com

Research Methodology

I'm Atul Adhikari, a high school student currently studying at Khwopa Secondary School. I do not have advanced knowledge or experience in Geology, which is why I have referenced a lot of data throughout this report. However, my passion and deep interest in earthquakes inspired me to write it. Any critical reviews or citations are warmly welcomed.

The systematic theoretical analysis of methods applied to a field of study is generally known as methodology. It deals with the methods adopted in the study which contains selection of study area, nature and source of data , methods of data collection and analysis and so on.

This research report mainly is based on secondary sources of data and information. It has tried to evaluate the secondary data available. The data in this report is collected from different daily newspapers of Nepal including Kantipur, Majdur Daily, and Gorkhapatra, books related to the geology of Nepal and India, online articles, research articles available on the Internet, Disaster assessment books, and so on.

This research report has used all the above mentioned secondary data modes and used a research based AI tool named, Perplexity for the comparison and validation of the data.

Table of Contents

CASE STUDIES

List of Abbreviations

K/a	Known as
Fig	figure
Km	kilometer
M	meter
Cm	centimeter
S	seconds
Mi	miles
$	dollar
Mm	millimeters
P-waves	Primary Waves
S-waves	Secondary Waves
L-waves	Long Waves
V	Velocity
EQ	Earthquake
MMI	Modern Mercalli Intensity
~	Approximately
Dr	Doctor
TU	Tribhuvan University
KU	Kathmandu University
BS	Bikram Sambad
NST	Nepal Standard Time
UTC	Universal Time Coordinated
UNESCO	United Nations Education Scientific and Cultural Organization
UNICEF	United Nations International Children's Emergency Fund
IFRC	International Federation of Red Cross and Red Crescent Societies
PDNA	Post Disaster Needs Assessment
BPMDC	Buddhist Philosophy and Monastery Development Committee
PADT	Pashupatinath Area Development Trust
KVERMP	Kathmandu Valley Earthquake Risk Management Project
JICA	Japan International Cooperation Agency
NGO	Non-Government Organization
INGO	International Non-Government Organization
USGS	United States Geological Society
PM	Prime Minister
JBR	Junga Bahadur Rana
NE	North East
US	United States
UK	United Kingdom
UN	United Nations
GDP	Gross Domestic Production
KTM	Kathmandu
PTSD	Post-Traumatic Stress Disorder
GPS	Global Positioning System
AI	Artificial Intelligence

Key Terms

1. Earthquake Swarms : sequence of seismic events occurring in a local area within a relatively short period

2. Modern Mercalli Intensity(MMI) : It is a scale used to measure the intensity of an earthquake at specific location bases on observed shaking and damage

3. Richter Scale : It is a scale used to measure the strength of earthquake. It measure the energy released by an earthquake in magnitude

4. Seismologists : Geologists who studies in genesis and propagation of seismic waves

5. Seismic Evaluation : evaluation to provide a general idea about the building performance during an earthquake

6. Décollement : It is a gliding plane between two rock masses, also known as a basal detachment fault.

Executive Summary

Nepal is number one in the list of top ten countries vulnerable to catastrophic earthquakes. Nepal lies in the high risk zone, above the fault lines along Main Himalayan Thrust where the force is accumulated since over 520 years as of 2025 AD. We can't stop the earthquakes in Nepal from happening as it is natural but we surely can be prepared to face it. So, is the objective of this research report, to aware people about the seismic hazard zone Nepal Iies on, aware people how vulnerable they can be if a predicted mega-quake is to strike Nepal, and aware people about the vulnerability of buildings in Nepal, reminding them of past big earthquakes.

This report can be considered a surface level awareness based research report. I have introduced the scientific concept of earthquake and context of earthquake in Nepal. We forget the disasters too easily, hence remembering the past can be a good trigger point to aware people of Nepal about the possible mega earthquake of more than 8.0 - 8.5 magnitude richter scale. This report suggests concerned authorities to invest in pre earthquake awareness and retrofitting of Western Nepal rather than focusing on past quakes and reconstruction for years. This report also defines the importance of these kind of studies. It consists of importance of seismic evaluations, coping capacity, pre disaster management and awareness in Western Nepal. The vulnerability of school buildings is also discussed along the types of Building Topology of Nepal.

This research report covers a story of a village in Gorkha to share the Importance of coping capacity. Instead of hoping, the villagers of Gorkha who were isolated and got negleted by the government during 2072 earthquake for almost a week had decided to act and be self sufficient and they succeeded in that.

The earthquake of 2072 had not only affected the land but it had launched waves into air, travelling upto ionosphere and rising F2 region of ionosphere by 30 km within a minute. This research report also presents the data of geological effects of 2072 Gorkha Earthquake.

Facing the earthquake isn't only about facing the shakes of earthquake, but to face natural disasters triggered by it. I believe the data presented in this report helps the reader to get aware and help to increase Coping Capacity in case of future earthquakes. The case of Nepal Landslide Crisis 2081 is also discussed in this report in Case Study - II.

Introduction

Nepalese people love to grief on disasters. We cry, we lose and we get devastated by another natural calamities within a year again. There is a huge history on the natural calamities in Nepal which is still not resolved and has been going on. Neither the government of Nepal nor the citizens of Nepal care about it enough in time.

There are huge problems of monsoon floods, flash floods, glacier floods, glacier outbreak, forest fire, pollution, landslides and Earthquakes in Nepal. But whilst there is time, not much of us Nepalese are concerned about it and when the disaster occurs, politicians to celebrities and general public who had the privilege to resist these disasters start cold riots of few weeks in social media platforms and get back to their respective work-life. Meanwhile, the survivors of earthquake dies of freezing temperature, landslide kills and blocks roadways affecting a lot of factors including economy and floods affects hundreds of lives which could have been minimized.

The disaster we are talking about in this particular research paper is EARTHQUAKES.

Introduction

Earthquakes are vibrant motion of grounds of the Earth's crust caused by a sudden blow which may be caused by surface, volcanic or tectonic processes. In context of Nepal, Earthquakes are the result of the Indian Tectonic Plate moving in NE direction at the rate of ~ 4.5 - 5 cm every year against the Eurasian Tectonic Plate. Table 1.1 shows some of the deadliest earthquakes occurred around this region.

YEAR	LOCATION	DEATHS(around)
1976	Tangshan, China	2,50,000
1737	Calcutta, India	3,00,000
1556	Shenshi, China	8,30,000

Table 1.1 Some of the deadliest Earthquakes in the History around our region

The most recent massive hit was recorded on January 26, 2001 at 8:46 AM in Bhuj of Gujrat, India of magnitude 8.1 killing approximately 20,000 people. Earthquakes above the magnitude 8 in the region of Indian and Eurasian Tectonic Plate Collisions are listed in the table 1.2.

DATE	LOCATION (EARTHQUAKES)	MAGNITUDE
12 June 1897	Shilong (Meghalaya)	8.7
15 January 1934	Nepal-Bihar Earthquake	8.1
15 August 1950	Arunachal Pradesh-China Border Earthquake	8.5
26 January 2001	Gujrat, Bhuj Earthquake	8.1

Table 1.2 Earthquakes above magnitude of 8 around our region

Tectonic Plates

Tectonic Plates are basically composed of various types of rocks and materials inside the Earth's surface on Crust. The different tectonic plates keeps moving under the Earth surface and keeps on passing each other which gives rise to elastic strain within the rocks on either sides of faults. The elastic strain energy is released in the form of seismic waves. The initial movement of the rocks generates the shock waves k/a fore shocks which precede the main Earthquake. For example, Bajhang district faced a 5.3 richter scale earthquake at 2:40 PM on 2080 Asoj 16. On the same date after 26 minutes, i.e. at 3:06 PM, Bajhang faced a 6.3 richter scale earthquake injuring 16 people as per the reports within a day. The earthquake of 2:40 PM was a fore shock of the 3:06 PM main earthquake and the earthquakes after 3:06 pm were after shocks.

The main movement of rock masses in faulting relieves the main stress, causing main earthquake and this develops stresses in adjacent areas, and causes minor adjustments that may give aftershocks.

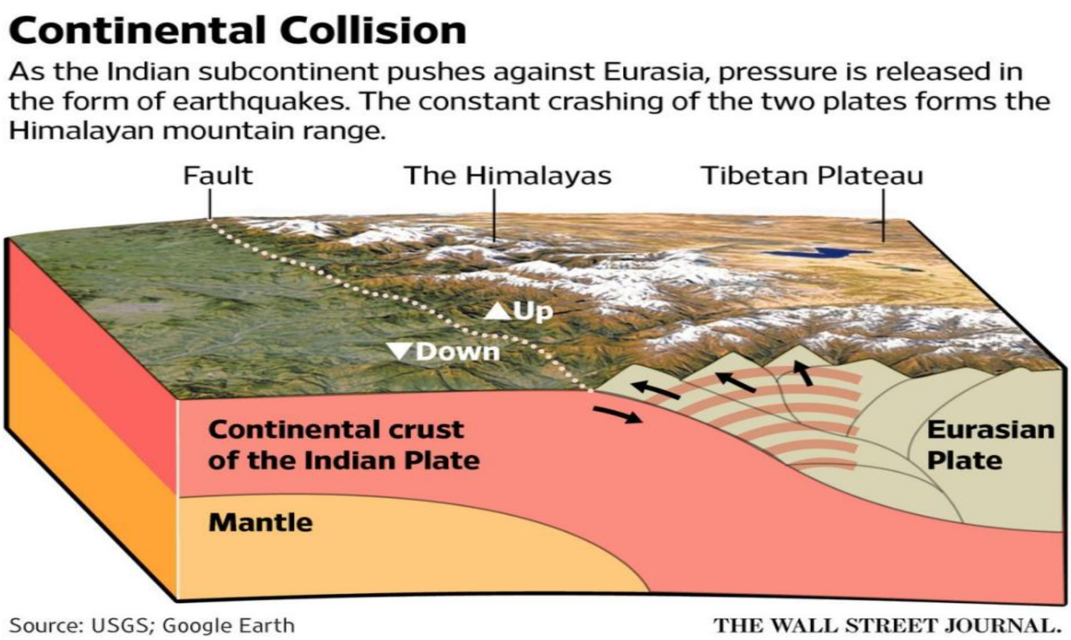

Fig 1.1 Collision of Indian and Eurasian Tectonic Plates

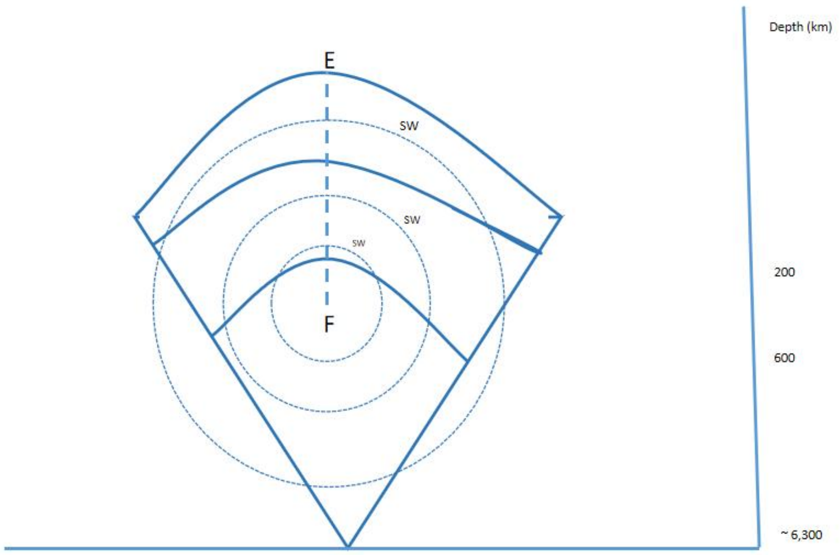

Fig 1.2 Earth's Crust and Waves Origination

As shown in the fig 1.2 above, the earthquake originates from (f) / focus / hypo-center point and the earthquake shock waves (SW) radiates from the focus in all directions. In modern seismology, focus signifies a zone rather than a point of origin. Similarly, the point or place on the surface vertically above the focus of a particular earthquake is termed as the Epicenter (E).

The locus points of earthquakes are generally sited above the depth of 700 km. Earthquakes rarely originate at the surface of Earth. Majority of the earthquakes of the past had their focii lying within 50 km.

According to the depth of origin, the types of Earthquakes are listed as follows:

1. Shallow Earthquakes : It occurs within the upper 70 km of the Earth.

2. Intermediate Earthquakes : It occurs within the range of 70 km to 300 km.

3. Deep Earthquake : It occurs within the range of 300 km to 700 km.

Nature of Seismic Waves

During each earthquake, the elastic waves are generated at the focus. These are called seismic waves and they travel in all directions with their characteristic velocities. There are three seismic waves types abbreviated as the P-Waves, the S-Waves and the L-Waves:

1. P-Waves : These are also called the primary waves, push waves, longitudinal waves and compression waves and are longitudinal in character. The velocity of P-Waves can be calculated as:

$$V = \frac{\sqrt{\lambda + 2\mu}}{\rho} ------ (I)$$

Where, V is Velocity of P-wave, λ is Lame's first parameter, μ is shear modulus (also k/a Lame's second parameter) and ρ is density. Both (λ and μ) are also known as elastic constants. P-waves travel faster in rigid rocks. The P-wave travels 3 times faster than that of the S-waves. The waves used by the earthquake alert systems to alert the people prior few seconds is P-waves.

2. S-waves : These are also called the secondary waves, the shear waves, transverse waves, the shock waves, and the distortional waves. These waves are transverse in character. The velocity of S-waves can be calculated as:

$$\mathrm{V} = \frac{\sqrt{\mu}}{\rho} ----- \text{(II)}$$

Where, V is Velocity of S-waves, μ is shear modulus. The shear modulus (μ) is also called the modulus of rigidity, is a measure of material's resistance to shear deformation. It tells us how much a material deforms when a tangential (shear) force is applied. It is calculated as,

$$\mu = \frac{\text{shear stress}}{\text{shear strain}} ----- \text{(III)}$$

The shear modulus of liquid / fluids / water is 0, hence if the formula (II) is applied to calculate the S-waves, it is sure that S-waves would not pass through fluids as:

$$\mathrm{V} = \frac{\sqrt{0}}{\rho} ----- \text{(IV)(as, } \mu = 0 \text{ in case of liquids)}$$

Both the P-waves and S-waves are collectively referrer as body waves because they travel deep into the body of the Earth.

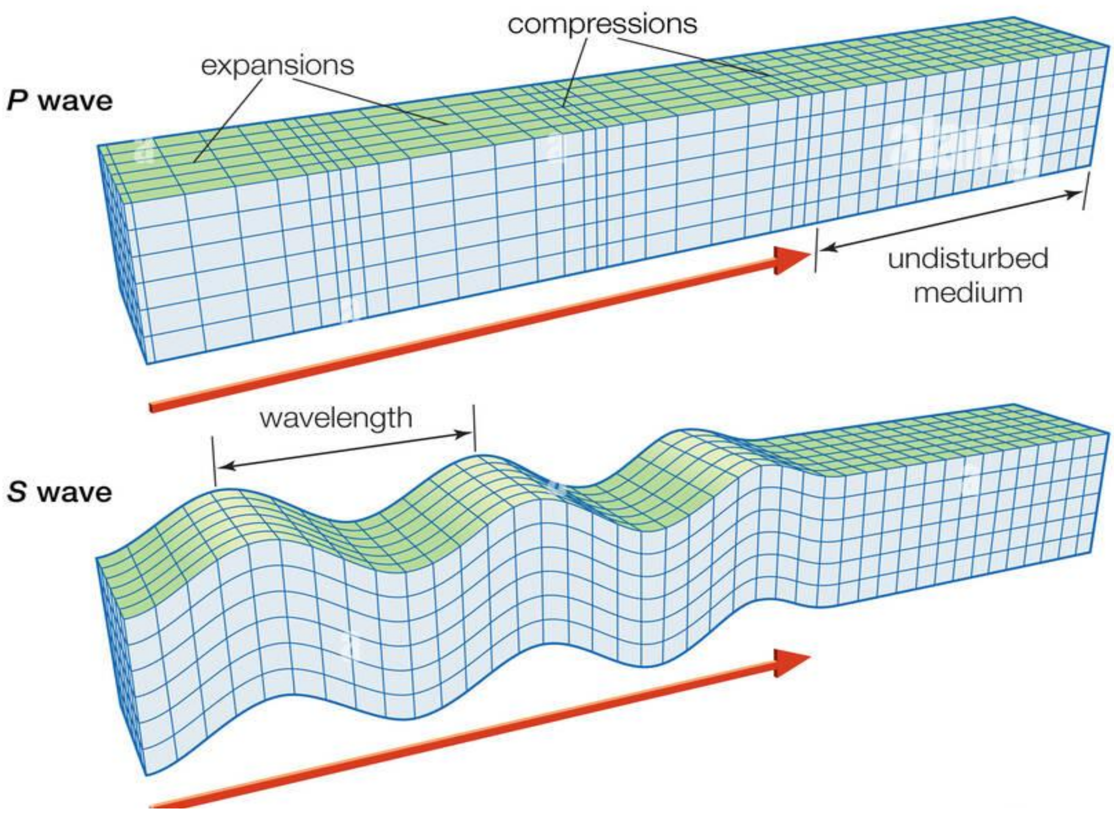

Fig 1.3

3. L-waves : These are also called Long waves or Surface waves because they are formed mainly in the surface of Earth. There are two main types of surface waves :

I. Love waves : These waves moves horizontally, causing shearing motion. The particle movement is perpendicular to the direction of wave propagation , resulting in side to side shaking.

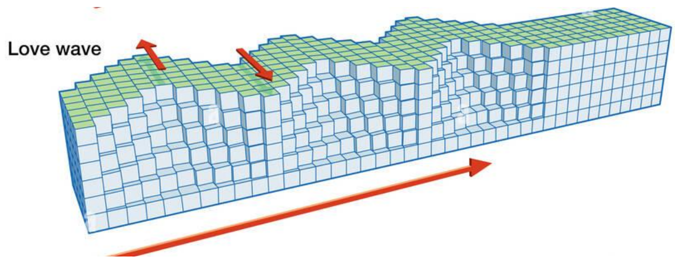

Fig 1.4

II. Rayleigh waves : These waves cause both vertical and horizontal ground movement. The particle motion is elliptical, which leads to rolling motion similar to ocean waves, producing complex shaking that intensely affects structures.

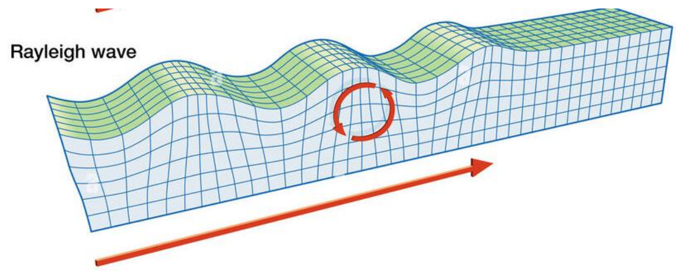

Fig 1.5

Nature of Waves

WAVE	WHERE THEY TRAVEL?	SPEED	GROUND SHAKING	DESTRUCTION LEVEL
P-waves (Body Wave)	Through Earth's Interior	Fastest	Weakest	Minimal
S-Waves (Body Wave)	Through Earth's Interior (not liquid)	Slower than P	Moderate	More than P
Love Wave (Surface Wave)	Only on the Surface	Slower than S	Strong	High
Rayleigh waves(Surface Wave)	Only on the Surface	Slowest	Rolling Motion	Very High

Table 1.3 Nature of Waves

Magnitude of Earthquake

Magnitude is the rating of an Earthquake on the basis of amplitude of seismic waves recorded in seismographs. It is the scientific measurement of energy released during the earthquake. The method of finding the magnitude was first used by Charles F. Richter in 1935 who developed a scale of magnitude for local use on the basis of study of records of earthquakes of California. That scale was improved and is now used internationally for describing the size of an earthquake.

Magnitude (Richter)	Ground Acceleration (cm/s^2)	Type Name	Description	Equivalent MMI
<3.0	<0.1	Micro EQ	Generally not felt by people, recorded by seismographs only	I (Not felt)
3.0 - 3.9	0.1 - 1	Minor EQ	Often felt, but usually causes no damage, vibrations feels like vehicles pass by	II - III (Weak-Slightly felt)
4.0 - 4.9	1 - 10	Light EQ	Felt by many, can cause slight damage to weak structures, wakes people, doors swing	IV - V (Noticeable shaking, minor damage)
5.0 - 5.9	10 - 50	Moderate EQ	Can cause damage to buildings, particularly in areas near the epicenter, cracks in wall, nushes moved	VI - VII (Strong shaking, Moderate Damage)
6.0 - 6.9	50 - 100	Strong EQ	Can cause significant structural damage to buildings, general panic, felt over a wide area, steering of vehicles in motion gets disordered	VII - IX (Severe shaking, heavy damage)
7.0 - 7.9	100 - 500	Major EQ	Can cause structural damages with widespread destruction particularly in urban areas, cracks in grounds, considerable loss of lives	IX - X (Devastating Destruction)
8.0 - 8.9	500 - 1000	Great EQ	Can cause catastrophic damage over a large area, hard to stand or run, landslides triggered in hilly regions, large loss of lives and property	X - XI (Most structures destroyed)
≥9.0	>1000	Massive EQ	Devastating worldwide effects, with extreme destruction, ground displacements, dams and embankments destruction, flash floods, blending of railway tracks, objects thrown in air	XII (Total destruction, Ground displacements)

Table 1.4 Magnitude Scale of Earthquake

Context

"We shall not wait for the disaster to figure out how to cope with it."

This above saying is universally well popular but not quite relevant in context of Nepal. We Nepalese wait for the disaster to figure out how to cope with it. Talking about the massive earthquake hit on 2072 Baishak 12 (2015 AD), seismologists were much concerned about the great possibility of big earthquake in the east of Deharadun and west of Gorkha due to release of very old seismic accumulation at major faults. This accumulation of energy strain is still not released and is a considerable risk.

Dr. Naresh Kazi Tamrakar, Associate Professor of Geology in Department of Geology, T.U, Kirtipur, Kathmandu had published a book named "Geo-Environmental Hazard" on November 29, 2011, 4 years prior the Gorkha-Earthquake 2072 where he had mentioned about the possible big hit of earthquake in Gorkha region of Nepal referring the research articles of (Rajaure and Sapkota 2007). But the government of Nepal and common citizens of this great nation are carefree and careless about such concerning topics. A proper government funded research on this possible risks and management of Gorkha-Earthquake and Pre - Earthquake Management could have saved thousands of lives.

1934 Earthquake (90 saal ko bhuichalo)

Before diving into the 2072 Gorkha Earthquake, we shall not forget that Nepal had already faced a huge earthquake of magnitude 8.0 in 1934 January 15 popularly k/a *90 saal ko bhuichalo* in Nepal and 'Nepal - Bihar Earthquake' in the world. The Nepal - Bihar Earthquake is one of the worst earthquake in the history of Nepal.

This earthquake occurred on 15th January 1934 at 2:24:22 pm NST (Brahmashamsher J.B.R). The epicenter of this earthquake was located in Eastern Nepal about 9.5 km south of the Mount Everest, having fault or hypo-center just 15 km (9.3 mi) deep. Some of the massive earthquake hits in Nepal including 1934 earthquake are listed in the table 2.1.

YEAR (BS)	MAGNITUDE	EPICENTER	DAMAGE / CASUALTIES
1990 Magh 12	8.0	Chainpur, Sankhuwashaba	Above 16,000 deaths
2045 Bhadra 5	6.8	Udaypur	Above 700 deaths
2072 Baishak 12	7.8	Barpak, Gorkha	Above 9000 deaths
2072 Baishak 29	7.3	Dolakha	

Table 2.1 Massive Earthquake hits in Nepal

Thousands of people in this earthquake were trapped in debris and died untimely, while thousands of others were badly injured. A total of around 8,500 people in Nepal and 7,200 people in India died. (S.N Sapkota and L. Bollinger) as shown in chart 2.1 including two of King Tribhuvan's daughters aged 10 and 8 years old due to the earthquake. (Pukar Joshi)

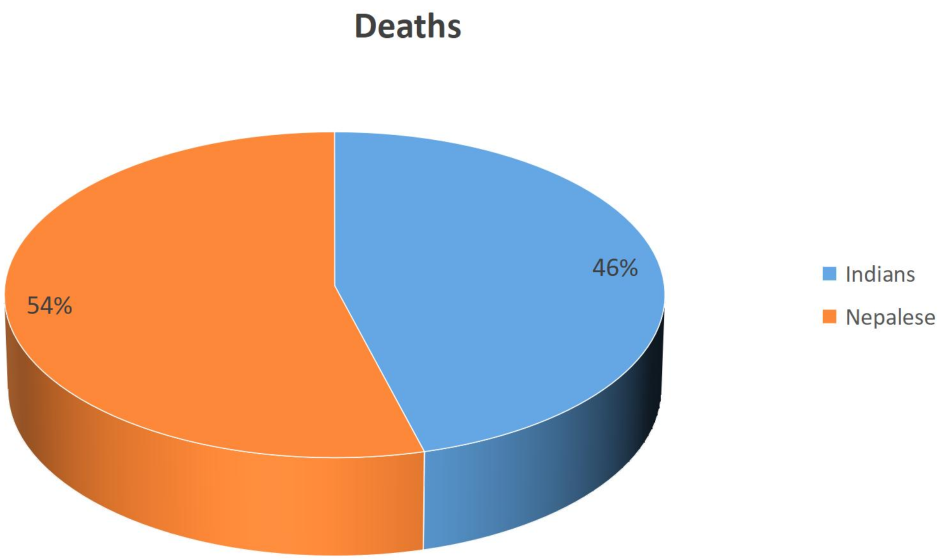

Chart 2.1 Approximate Death Toll of Nepalese and Indians in 1934 Earthquake

The 1990 BS Earthquake affected many lives. In order to help the people who had to restart their lives, PM Juddha Shumsher Rana gave every victim Rs. 100. The money didn't come from any foreign donars, instead it was from government fund itself.

Century man and culture expert Satya Mohan Joshi had said, "An interest-free loan of up to Rs. 3000 was given by the government to rebuild their homes." According to the historians, the fund came from a disaster fund created by Junga Bahadur Rana. (Online Khabar)

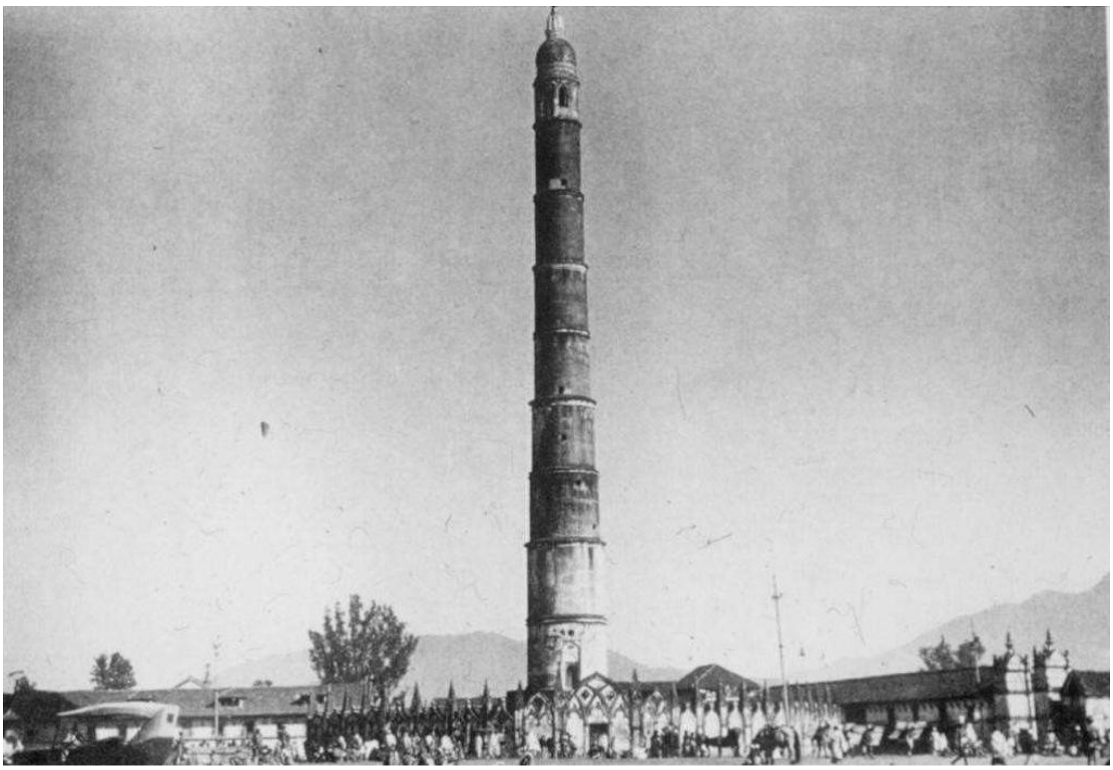

Fig 2.1

Fig 2.2

Fig 2.4

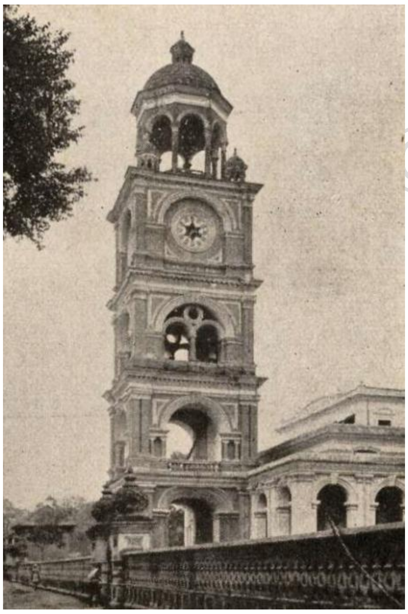

Fig 2.3

The above 4 figures Fig 2.1, Fig 2.2, Fig 2.3, Fig 2.4 demonstrates the pre and post condition of two of the major monuments of Nepal, *Dharahara* and *Ghantaghar*. Fig 2.1 is the condition of *Dharahara* before the 1934 Earthquake and fig 2.2 is the post earthquake condition of *Dharahara*. Fig 2.3 is the condition of *Ghantaghar* before the 1934 Earthquake and fig 2.4 is the post earthquake condition of *Ghantaghar*.

Gorkha Earthquake 2072

After 81 long years of no massive earthquake hits in Nepal besides 6.8 magnitude hit in 2045, the big earthquake of a magnitude 7.8 hit east of Gorkha district, Barpak making it's epicenter at 11:56 NST (06:11:25 UTC) on Saturday of 2072 Baishak 12. The epicenter Barpak was roughly 85 km NE of central Kathmandu, and it's hypo-center was at just a depth of approximately 8.2 km (5.1 mi) which is considered shallow type of earthquake and therefore more damaging than the earthquakes that originates deeper in the ground as we had discussed earlier. This earthquake had shaken the floor for around 50 long seconds. The April 2015 earthquake also k/a Gorkha Earthquake killed 8,962 people and injured 21,952 (wikipedia) across the countries of Nepal, India, China and Bangladesh.

There are several noticeable effects of this earthquake mentioned as follows:
1. Economic Effect
2. Mental Effect
3. Architectural Effect
4. Geological Movement
5. Casualties and Property damage
6. Other natural calamities

1. Econimoc Effect

The Gorkha Earthquake had striken Nepal economically. The estimated damages and losses were at US $ 7 Billion or nearly one third of Nepal's GDP. (IMF)
The GDP of Nepal in 2015 AD was US $ 24.361 Billion but because of the earthquake, it increased by only 0.4 % in 2016, making GDP of US $ 24.524 billion. There were seen price volatility and supply chain disruptions as a result of blockade from India, further complicating the economic recovery. But on the positive side, the disaster was seen as an opportunity for economic reforms and development, with potential increase in wages for construction workers during the recovery phase. In year 2017 AD, Nepal had achieved significant 9% growth in GDP making it, US $ 28.972 billion. (country economy)

This growth in GDP in 2017 shows how Nepal lacked behind a whole year economically back in 2015 because of the earthquake. The earthquake directly affected the development sectors, education sectors and almost every economic sector of Nepal. Nepal being a developing nation, located right in between two giants of world in geopolitics and economy, can't afford lacking a whole year because of natural calamities. We have already seen how India's and China's economy had collapsed in the medieval age majorly because of the natural calamities. The Yang Si river of China also k/a Sorrow of China had affected China's farmers in medieval age and the flood which affected China's farmers in medieval age and the flood which affected the farmers had a great negative impacts on the livelihood. Historically, the nature has challenged the human and forced people take a break. The disasters had created crisis all over India and China back then. We shall not let the history repeat itself. It is the job of common citizens and the concerned authorities to raise the awareness about great potential disaster like earthquake. Nepal has seen a major economic setback just a decade ago. We must be prepared for next big disaster to cope with. We can not stop it from happening but we surely can be prepared to face it.

The government should conduct awareness programs in the red zones like Western Nepal about the earthquakes. Government should teach the citizens of Western and Far Western regions of Nepal to sustain their lives on their own and to not be dependent over anyone because in crucial moments like of Earthquakes, everyone is seeking for funds, foods and help but the communities there should be awared to be independent on food security and education. The best example of this awareness program can be considered the Gorkha Village Independence discussed in the following case study-I.

Case Study - I Project Gurkha

Manish Khatri is a Social worker based in Uk. He was an elected president of Edinburgh Napier Students Association (ENSA) during 2017 AD. He had talked about his experience raising money for the Nepal earthquake and doing 12 different projects in relief of Gorkha earthquake.

One of his project was 'Project Gurkha' which was implemented in a rural village of Gorkha. That particular village in the Gorkha was negelated by the Government of Nepal. Government had not sent any support, communication and whats so over for 6 days although it was one of the most affected area. On the 6th day of the main earthquake, government decided to drop the bags of rice and noodles through helicopters because it was too risky for them to go because of the active after shocks as per the speech of Manish.

Then, the team of Manish decided to go to that village and called the school headmaster of the village. Instead of demanding foods and relief materials like others, the headmaster demanded stationary materials, desks and benches as those were the things their students needed. Team of Manish brought two trucks of stationery in village. The villagers used to work everyday and provided free food and shelter to students and affected people.

Students aged even around 7 years old were Coming to the temporary schools at 6 AM after walking for hours as it was difficult to study in daytime because of heat as per Manish Khatri. The entire village was self dependent. Instead of hoping, they decided to act. Soon, they became self sufficient.

It was recorded as a speech given by Manish Khatri at TEDx event.

2. Mental Effect

The earthquake survivors of Gorkha earthquake had experienced significant psychological trauma including anxiety, PTSD and sleep disturbances that persisted even long after the event. Even after months, people were being haunted by Earthquake every day and night. There was a survey conducted in Bhaktapur district after four months of earthquake. The survey suggested that almost 50% of people there were suffering psychiatric illness. Additionally, survey conducted in other 15 districts suggested around 34% people were suffering depression and around 11% were having Suicidal thoughts. (TNC)

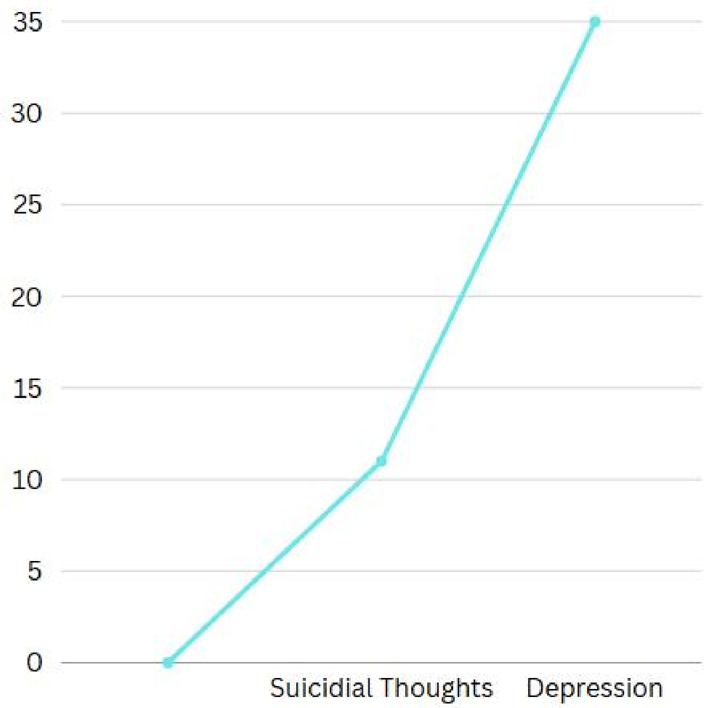

Chart 2.2 Demonstration of Mental state of Nepalese during Gorkha Earthquake

The chart 2.2 clearly shows the true nature of Nepalese. The Survey conducted had resulted in almost 50% of the people being psychiatrically ill. In a developing nation like Nepal, the natural disasters causes the citizens more than anything. It is a devastating loss of lives and properties. Only if the people were well awared about the disaster and the infrastructural damage it could do to them, they could have been mentally prepared.

Raising awareness is for being mentally prepared to do right things in the time of disaster. The awareness program helps to make people aware about the potential causes. The awareness programs can't fill the economic gap created by the disaster but it surely can set a clear mindset.

The major causes of psychological traumas and depression are:

- The grief of losing loved ones.
- The sorrow of not having a proper place to live on.
- Having trauma activated by the terrors of earthquake.
- Thoughts about the economic losses.
- Limitations on travel, health, communication, education facilities, etc.

A Common Nepali who has lost his family members and house in an earthquake, whose trauma related to earthquake is activated and has not been able to look into far future but only the losses he has been facing economically has got no option but to get mentally ill. If he was well prepared, he could have prevented this situation of him.

3. Architectural and Cultural Heritage Damage

Nepal is a rich country in terms of medieval architectures and cultural heritage sites. There are 10 UNESCO heritage sites in Nepal. In the aftermath of the Gorkha Earthquake, Nepal suffered it's worst loss of heritage since the earthquake of 1934 (Nepal - Bihar Earthquake). Major monuments in Kathmandu's seven world heritage monument zones were severely damaged and many collapsed completely. In addition to that, in more than 20 districts, thousands of private residences built on traditional lines, historic public buildings, monuments, ancient and recently built temples and monasteries were affected by the disaster, 25% of which were completely destroyed. This earthquake affected about 2,900 structures with cultural, historical and religious heritage value. The total estimated damages was NRP 16.9 billion (US $169 million).

The earthquake affected a total of 691 buildings of historic value in 16 districts. Of these buildings, 131 were fully destroyed and 560 were damaged. And close to 1,400 monasteries in remote areas had suffered damage or collapse.

Here's the list of major destruction caused by the earthquake:

a) Hanuman Dhoka (Durbar Square of Kathmandu) :
Several temples, including Kasthamandap, panchtale temple (a 5 story temple), Dasa Avatar Temple and shrines behind the Shiva Parbati Temple were demolished.
The nine story palace (Basantapur Durbar) sustained significant damage, as evidenced by images and reports. (researchgate)

b) Patan DUrbar Square:
This site is a center of Newari Architecture and saw a significant loss in Gorkha Earthquake. Char Narayan Mandir was destroyed along with the statue of Yog Narendra Malla and a *paati* inside the square.
The Taleju temple, Hari Shankar temple, Uma Maheshwor Temple, and Macchindranath Temple in Bugamati were damaged and partially collapsed.

c) Bhaktapur Durbar Square:
The Phasi Deva Temple, Chardham Temple, and the 17th century Vatsala Durga Temple were fully or partially destroyed making it a challenge to restore it's heritage value.

d) Swayambhunath:
The stupa experienced cracks in the spire and crown, with the 17th century Pratapur Temple collapsing. The main structure was relatively intact, while the damage only affecting it's aesthetics and structural integrity.

e) Pashupatinath Temple:
The main temple structure was largely undamaged due to it's earthquake resistant construction whose some parts of area including boundary walls suffered minor cracks.

f) Boudhanath Stupa:
The stupa had cracks in it's dome, torn walls at the base, and damage to it's gold-plated spire and crown, as detailed in various news articles. Restoration began in May 2015 and it was reopened in November 2016, costing US $ 2.1 Million and using over 30 kg of gold, majorly funded by private donations. (The Guardian)

g) Changu Narayan Temple:
The temple was damaged with reports indicating structural issues.

h) Lumbini:
The site is located approximately 310 km from central Kathmandu and 110 km from the epicenter. Lumbini experienced minimal or no significant damage to the Maya Devi Temple or any other key sites due to it's distance from the epicenter.

i) Other Cultural and Religious Sites:
Beyond the UNESCO sites, other significant cultural and religious sites were affected, including Manakamana Temple in Gorkha which is tilted further as it was previously damaged in earlier earthquakes. Gorkha Durbar suffered damage, Palanchowk Bhagwati Temple, Rani Mahal, Churiyamai, Dolakha Bhimsennath, Nuwakot Durbar and so on had experienced severe damage.

The Department of Archaeology's preliminary report indicated 745 monuments affected. While as per the report of the Pashupatinath Area Depelopment Trust (PADT) and the Buddhist Philosophy and Monastery Development Committee (BPMDC) had estimated damage of 691 buildings just in 16 districts and close to 1400 monasteries. The PADT and BPMDC had estimated the total damages to cultural heritage properties were at US $ 169 million and the total financial requirement for a full recovery comes to approximately US $ 205 million. A six year recovery period was proposed for the restoration and reconstruction of all damaged and collapsed historic buildings including the refurbishment of cultural institutions and museums. For the six year recovery plan, on average US $ 34 million every year was required. (Post Disaster Needs Assessment)

4. Geological Effects

There are mainly three geological effects after Gorkha Earthquake discussed below:

a) Seismic Activity : The earthquake was a result of the Indian and Eurasian tectonic plates moving, causing 7.8 magnitude earthquake with many significant aftershocks.

b) Ionospheric Impact : The earthquake disturbed the Ionosphere, affecting electron density structures, demonstrating the seismic event's far reaching effects on Earth's atmosphere.

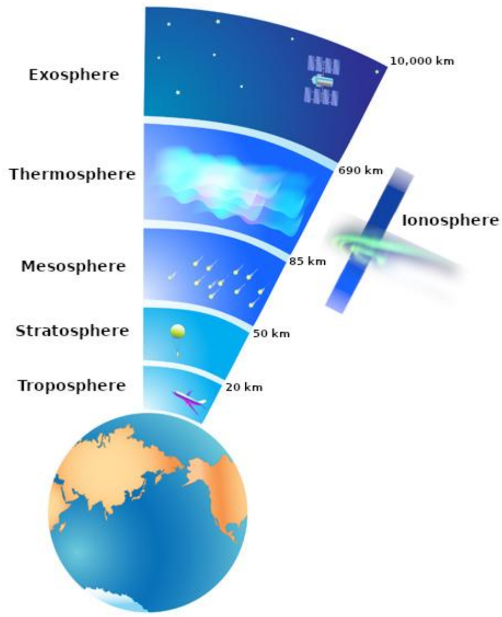

Fig 2.5Atmospheric layers of Earth with Ionosphere

There are three ionospheric impacts discussed below:

I. Impact on GPS and Communication System: The earthquake had shook the ionosphere, causing changes in Total Electron Content (TEC) (the number of free electrons in the ionosphere) Since, GPS signals travels trough the ionosphere, these sudden changes distorted GPS accuracy, making location tracking slightly off resulting hardness and problems in avalanches. Communication systems like satellite signals also faced temporary disturbances. While the infrastructural damages disrupted the signals of Nepal's major tele communication operators like Nepal Telecom (NTC) and Ncell. Ncell reported that 220 sites were initially offline, a number that rose to 600 within 24 hours.

II. Impact on the Atmosphere: The earthquake launched waves into the air, travelling upto the ionosphere. These waves caused the F2 region of ionosphere (where charged particles are densest) to rise by 30 km within a minute. This created temporary air pressure and electron density variations, affecting how the signals moved through space according to the various scientific researches around it.

III. Impact on earthquake Research and Prediction: Scientists saw that the ionospheric changes happened very quickly after the earthquake. If future studies can prove that ionospheric disturbances happen even before an earthquake, we might one day use this as an early warning system. In present context, the interrelation between earthquakes and ionospheric changes isn't strong enough to predict earthquake, but this research is a step forward.

The major ionospheric disturbances happened immediately after the quake, not before. Scientists found that the changes in the ionosphere began within 10-20 minutes after the earthquake initiated and lasted for about 30-60 minutes in total.

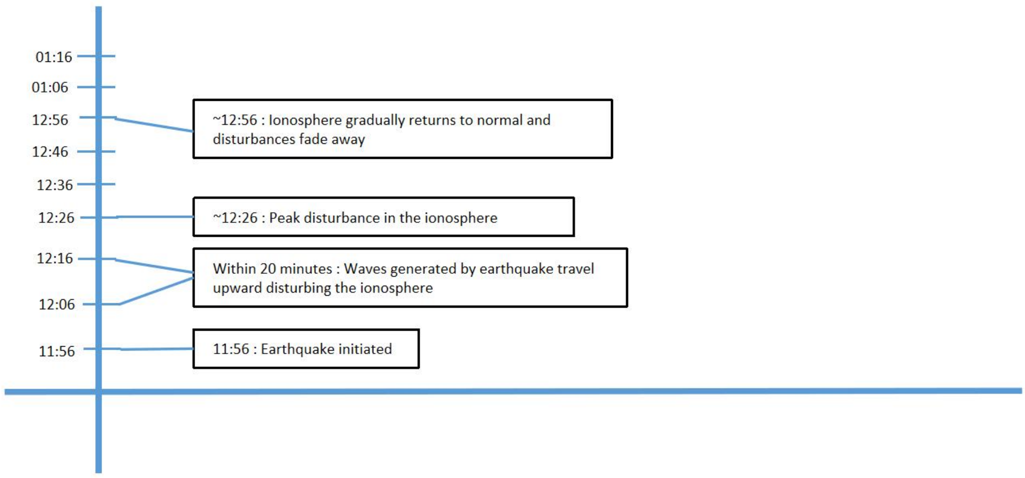

Chart 2.3 Timeline of the Ionospheric Impact during Gorkha Earthquake

Scientists study ionosphere-based measurements caused by natural hazards such as earthquakes, volcanic eruptions and tsunamis to better understand wave propagation in the upper atmosphere. The disturbances caused the earthquakes help scientists develop a new first-principle-based wave propagation models. These models may become part of future early warning systems for tsunamis and other difficult-to-detect natural hazards. (Nasa)

The above timeline of chart 2.3 shows the data related to the ionospheric disturbance. A clear ionospheric disturbance was observed 10 minutes after the earthquake, while the geomagnetic conditions solar activity and weather condition remained calm. (Research published in the Journal of Geodesy)

c) Topographical Influence: One of the geological effect of Gorkha Earthquake is the significant topographical influence due to the unique and varied terrain of Nepal, which amplified seismic effects and increased the impact of the earthquake in 2015 AD. There are three effects of the topographical influence in Nepal discussed below:

I) Amplification of Seismic Waves: The Himalayan region's uneven and irregular topography, with elevations ranging from ~100m in the southern plains to 7000m in the northern mountains, played a critical role in amplifying the seismic waves. Simulations of seismic wave propagation revealed that the wave field was enhanced in mountainous regions between two basins. The southern plains experienced stronger wave fields with higher frequency components compared to northern mountainous areas. These variations were caused due to the differences in soil composition, elevation and geological structures.

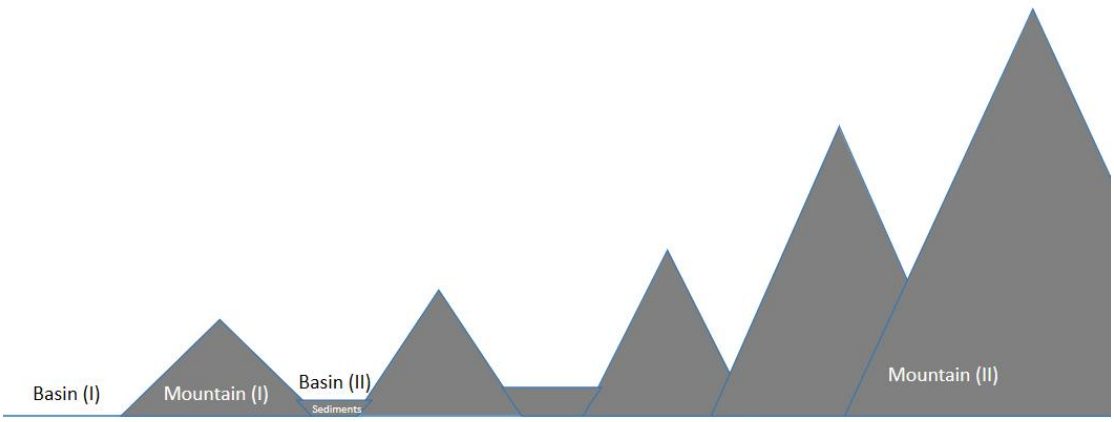

Fig 2.6 Structures of Mountains and Basins in Nepal

In In the above fig 2.6, the mountain 'I' is situated between two basins. Hence the seismic wave field will be enhanced in this mountain. But it is not quite safe to say that mountains are more dangerous then valley during earthquakes because there are numerous factors affecting the level of earthquake. The Basin 'II' in the above figure is more dangerous to earthquake than the mountain 'II' or maybe even mountain 'I'.

Why Basins / Valleys are more dangerous?

Valleys are considered more dangerous than mountains as if valley is filled with loose sediments, seismic waves slows down and increase in amplitude, leading to a stronger and long-time shaking. This is why cities built on soft grounds like Kathmandu experience more damage than those on hard bedrocks. In deep and bowl-shaped valleys, waves bounce back and forth and increases shaking intensity and duration. There is even a risk of liquefaction. If a valley has water saturated soil, the ground can liquefy during strong shaking causing buildings to sink or tilt.

Why mountains Shake more but are less dangerous?

The shaking is stronger at the peak due to the topography, but mountains are mostly made of solid rocks, which doesn't amplify waves much as loose valley soil does. Hence, the mountains suffer stronger shaking but shorter duration while the valleys especially with soft ground suffers longer shaking and higher risk of destruction.

II) The Kathmandu Valley Effect : In simple terms, the Kathmandu valley rose itself due to the earthquake. Kathmandu valley, situated on sedimentary basin had experienced severe amplification of the ground shaking due to it's soft sediment layers. This phenomenon is known as the "**basin effect"**.

The Basin (Valley) effect in earthquakes refers to the way seismic waves behave when they enter a sedimentary basin (a valley filled with loose soil and sediments). This effect can cause stronger, longer and more damaging shaking in valleys compared to surrounding hard rock area.

How it Works?

- Wave Amplification: When seismic waves enter a basin, they slow down due to the soft soil. Since energy is conserved, the waves increase in amplitude, causing stronger shaking.
- Seismic Wave Trapping: The shape of a basin can cause waves to bounce back and fourth, trapping energy and extending the shaking duration.

The basin effect is important to consider as it brings changes in land level affecting rivers, drainage systems and infrastructures. This effect's repeated upliftment of valley contributes to the formation of Himalayas and future earthquakes might reverse or continue the uplift process, affecting long term seismic hazards.

III) Landslides and Secondary Hazards : The steep slopes of the mountains made the region highly unsuitable after landslides triggered by seismic activity. Numerous landslides had blocked roads and isolated communities, which hindered rescue and relief teams. Rainfall following the earthquake and the repetitive landslides affected alot. This is briefly discussed in the section of 'Other Natural Calamities' ahead in report.

5. Casualties and Property Damage

The Gorkha Earthquake of Nepal on 25th April 2015 had a massive negative impact in Nepal. The earthquake was of 7.8 magnitude and was at the Extreme level of intensity being on MMI. It affected not only Nepal but India, China and Bangladesh as well. There were 459 aftershocks recorded above 4 Magnitude (M_w) of which two major aftershocks were 6.7 Magnitude aftershock on 26th April 2015 and 7.3 Magnitude aftershock 12th May 2015. All the major earthquakes were struck at the day time and during day offs. Still the number of casualties and property damage is insane. If it were to be a office day and school day on 25th April 2015, we could have faced the most darkest day in history of Nepal. There were 8,962 people dead and 21,952 people injured and lakhs of people got homeless. Researches suggests that over 7,55,000 houses with nearly 5,00,000 fully collapsed and other faced damages. It seems likely that schools, health facilities, and cultural heritage sites including UNESCO world heritage sites were significantly affected, with over 7,500 schools and 1,100 health facilities being damaged. There were over 2,600 government buildings and infrastructures fully damaged. The casualties count of main earthquake (7.8) and aftershock (7.3) is listed in table below.

COUNTRY	DEATHS	INJURIES
Nepal	8857	22304
India	78	200
China	25	383
Bangladesh	4	200
Total	8964	23447

Table 2.2 Casualties by shock of 25th April 2015

COUNTRIES	DEATHS	INJURIES
Nepal	152	3275
India	62	~200
China	1	3
Bangladesh	2	~150
Total	218	~3268

Table 2.3 Casualties by shock on 12th May 2015

There were total of 127 foreign casualties in Nepal including 78 Indians.

6. Other Natural Calamities

Facing the earthquake is not only about facing the shakes and strokes of earthquake but to face natural disasters triggered by it. The earthquakes bring landslides, avalanches, dammed rivers/river blockages and infrastructural damage with it. We have to deal with all of that as those can affect the process of providing relief and resilience. Here are few natural calamities caused along with earthquake discussed:

a) Landslides: In the Gorkha Earthquake, there were over 21,000 landslides across 25,000 km² (nature) with concentrations In Sindhupalchok, Gorkha, and Rasuwa districts. The main earthquake was not enough so the aftershocks were reactivating the landslide zones. Estimated 251-1,503 million m³ of materials was displaced. (nature) There were approximately 1,000 counted deaths and the landslides had caused river blockages and infrastructural blockages like highways getting blocked. Major blocked highways were Araniko and Prithivi Highway. The blockage of highways isolated 39 villages in Nepal. (ACAPS)

The largest single landslide of Gorkha Earthquake was the Langtang Valley disaster. The Langtang rock-ice avalanche of 14.38 million m³ swept away a whole village.
Kali Gandaki river blockage was a significant landslide cause too. The landslide blocked the Kali Gandaki river creating a temporary dam. This posed a severe flood risks to downstream communities forcing evacuations of numerous residents. (USGS)
There were numerous Smaller landslides occurring in Trishuli river as well, causing notable damage in areas like Mailung, Simle and Archale. (wikipedia)

This earthquake has increased the risk of landslide in future as the seismic event caused extensive fracturing of rock and soil, making slopes of mountains of Nepal more unstable and prone to landslides, especially during heavy rainfall. This increased risk is expected to be for years following the earthquake. It is well discussed in 'Case Study-II'.

b) Avalanches : The earthquake of 2015 caused two major avalanches in Nepal as following:
i. Mount Everest Avalanche: This earthquake caused a massive avalanche on Mount Everest, resulting in the deaths of at least 24 and injuring 61 and others not found. This event marked one of the deadliest days in Mountain's history. Between 700 and 1000 people were on or near the mountain when the earthquake struck including 359 in base camp. The earthquake triggered several large avalanches on and around the mountain. One avalanche, originating on the nearby peak of Pumori, swept into Base Camp and blew many tents across the Khumbu Glacier towards the lower Icefall. (wikipedia)

ii. Langtang Disaster: The village suffered an estimated 310 deaths, including 176 Langtang residents, 80 foreigners and 10 army personnel. More than 100 bodies were never recovered. Several other villages in upper Langtang Valley were also destroyed (wikipedia). Langtang region experienced severe avalanches that buried the whole villages and trekking routes, leading to significant casualties and destruction.
There was only 3.5 million m³ of initial ice/snow release but it grew to massive 14.38 million m³ with debris & rocks because of landslide and hence a huge avalanche with debris broke.

c) River Blockages and Infrastructural Damage: The earthquake had caused 23 river blockages, with a notable blockage in Marshyangdi river lasting 26 days, increasing risks to downstream villages (Samjwal Bajracharya). Landslide dam in Kali Gandaki created a 3 km³ lake forcing around 10,000 people evacuate from downstream (Internet Geography). There were multiple blockages and Emergency flood control by Nepal Army in the Trishuli river. About 1,500 km of roads were damaged with 400 km completely destroyed, and 100 bridges were affected significantly hampering relief efforts and daily life. (The World Bank)

Jajarkot Earthquake 2080

Almost After 8 years and more of the Gorkha-Earthquake (2015), a less strong but destructive earthquake hit Jajarkot and West Rukum district. It was a 6.4 magnitude earthquake struck in Barekot of Jajarkot district, Karnali Province Nepal. The western Nepal had experienced earthquakes stronger than this i.e. around 6.5 or 6.6 as well but this 6.4 quake struck hard on civilization. It is commonly believed that the eastern and central part of Nepal has been facing major earthquakes in past while the western part comes out to be lucky. But the same problem of massive hits in past has now made the central and eastern part of Nepal comparatively less dangerous while the western Nepal still relies on the same old and traditional infrastructures made out of soil, mud, stones, and bricks.

This same old and traditional infrastructure which were never upgraded showed the vulnerability during the minor 6.4 magnitude earthquake of Jajarkot. Although, the aftershocks could be also the major reasons of the destruction in kartik 17 2080. The earthquake was recorded at 23:47 NST (18:02 UTC) killing 153 people and injuring at least 375 (wikipedia). The earthquake was widely felt in western Nepal and Northern India and it is believed that this was the deadliest since the 2015 Gorkha Earthquake. It had a magnitude of 6.4 richter scale and it had a depth of 32.6 km (20.3 mi). While the Nepal's National Earthquake Monitoring and Research Centre (NEMRC), says it was a 6.4 magnitude earthquake, the USGS reported it was 5.7 magnitude.

The late night timing of the earthquake heavily contributed in the casualties. It was 11:47 pm, People were peacefully sleeping while the rocks beneath them collided and shaked the ground. Laxman Pun, an earthquake survivor said, “We were sleeping and felt like dying.”

As per Mani Dahal, a writer of Kantipur, says there was no massive earthquakes recorded in Western Nepal for last 520-500 years except for the 6.6 magnitude quake in Bajhang on 2037 Shrawan 14 killing around 100 people. But recently, the tectonic plates are showing movements under the topology of Western Nepal.

Earthquake Swarm

After the Baishak of 2078, there were 136 earthquakes recorded in Nepal that were above the magnitude of 4. And surprisingly 86 out of 136 earthquakes were recorded on the districts west to Gorkha.

Date	Magnitude	District
2080 Kartik 5	6.1	Dhading
2080 Kartik 5	4.1	Dhading
2080 Kartik 5	4.2	Dhading
2080 Kartik 5	5.0	Dhading
2080 Kartik 5	4.1	Dhading
2080 Kartik 5	4.4	Dhading
2080 Kartik 5	4.3	Dhading

Table 2.4

Date	Magnitude	District
2080 Baishak 10	4.1	Bajura
2080 Baishak 14	5.9	Bajura
2080 Baishak 14	4.9	Bajura
2080 Baishak 15	4.1	Bajura
2080 Baishak 21	4.1	Bajura
2080 Baishak 27	4.3	Bajura
2080 Jestha 8	4.1	Bajura
2080 Jestha 9	4.5	Bajura
2080 Jestha 29	4.4	Bajura

Table 2.5

Date	Magnitude	District
2080 Asoj 16	5.1	Bajhang
2080 Asoj 16	4.4	Bajhang
2080 Asoj 16	6.3	Bajhang
2080 Asoj 16	4.3	Bajhang
2080 Asoj 16	4.1	Bajhang
2080 Asoj 16	4.3	Bajhang
2080 Asoj 16	5.1	Bajhang
2080 Asoj 16	4.1	Bajhang
2080 Asoj 16	4.3	Bajhang
2080 Asoj 16	6.3	Bajhang
2080 Asoj 16	5.0	Bajhang
2080 Asoj 18	4.5	Bajhang
2080 Asoj 18	4.5	Bajhang
2080 Asoj 19	4.2	Bajhang
2080 Asoj 20	5.3	Bajhang
2080 Asoj 20	4.3	Bajhang
2080 Asoj 24	5.2	Bajhang
2080 Asoj 25	4.4	Bajhang
2080 Asoj 25	5.0	Bajhang
2080 Kartik 1	4.6	Bajhang
2080 Kartik 4	4.4	Bajhang

Table 2.6

Date	Magnitude	District
2080 Kartik 17	4.5	Jajarkot
2080 Kartik 17	4.2	Jajarkot
2080 Kartik 17	4.5	Jajarkot
2080 Kartik 17	6.4	Jajarkot
2080 Kartik 17	4.3	Jajarkot
2080 Kartik 18	4.2	Jajarkot
2080 Kartik 18	4.0	Jajarkot
2080 Kartik 19	4.1	Jajarkot
2080 Kartik 20	5.8	Jajarkot
2080 Kartik 20	4.5	Jajarkot
2080 Kartik 22	4.2	Jajarkot
2080 Kartik 28	4.0	Jajarkot

Table 2.7

Out of those 136 earthquakes, Bajhang recorded 25 earthquakes, Bajura recorded 15, Lamjung recorded 9, Jajarkot recorded 6, Darchula recorded 5, Dhading 7, Baglung recorded 4, Doti recorded 3, Acham, Baitadi, Humla and Dailekh recorded 2 and many other western districts were epicenters. In the same time period, earthquakes above 5.5 magnitude were recorded 7 times in altogether 4 districts which includes two 6.3 magnitude earthquakes in Bajhang on 2079 Asoj 16, 5.9 quake in Bajura on 2080 Baishak 14, 6.4 magnitude earthquake and 5.8 magnitude earthquake in Jajarkot on 2080 kartik 17 and 2080 Kartik 20 respectively, 6.1 magnitude earthquake in Dhading on 2080 kartik 5 and 6.6 magnitude earthquake in Doti district on 2080 kartik 22.

This Swarm of earthquakes had deadly impact in Jajarkot and not been recorded on that level since. The earthquake swarm recorded in Bajhang District on 2080 Asoj 16 has an interesting case. That day, Bajhang had faced 11 earthquakes over 4 magnitude with total of 21 earthquakes in 19 days in that particular swarm.

On Asoj 16, Bajhang faced 5.3 magnitude earthquake at 2:40 pm making epicenter in Taalkot of Bajhang. Most of the schools' classes in the district got dismissed and students returned home. Just after 26 minutes of that, at 3:06 pm, Bajhang faced a 6.3 magnitude earthquake destroying alot of houses and school buildings. A teacher of Jay Prithivi Bal Bikash Secondary School, Narendra Upadhaya Said, "We sent them home after first hit, then after a while big earthquake hit and school building got collapsed. There was to be severe loss if we had not sent the students back home." Later that night, Police Department reported 16 people injured including mostly students and the landslide blocked the Jay Prithivi Highway. (B.P. Singh 2080)

Case Study-II : Nepal Landslide Crisis 2081

Nepal's 2081 monsoon triggered the deadliest landslide in recent times.

a. Hypothesis of the study: The 2081 landslides resulted from compounding effects of extreme monsoon rainfall and persistent geological instability caused by 2072 Gorkha Earthquake and the earthquake swarms including Jajarkot earthquake.
Poor infrastructure planning, deforestation and climate change amplified disaster effects.

b. Background: A 7.8 magnitude earthquake triggered ~21,000 landslides, fracturing bedrock and destabilizing slopes across 25,000 km² in 2072 earthquake. Seasonal rainfall typically causes landslides and kill around 100 but 2081 was disastrous also because of earthquake swarms of 2079 and 2080. Also geographically, ~ 68% of Nepal's land area is classified as landslide - prone.

c. Methodology: Data Collection:
Primary Sources: Government reports, UN agencies (UNICEF, IFRC) and various disaster related articles.
Secondary Sources: Studies and research on Post-2072 seismic impacts and monsoon trends, comparative analysis provided by research based AI tool, perplexity

d. Results:
Rainfall: Kathmandu valley received 240-322 mm in 24 hours (28-29 September), breaking a 54-year record.
Impact: 300 and more deaths, more than 50 missing and more than 17 Arba economic loss by damages. More than 81,000 people affected by blocking 23 highways and isolating Kathmandu.
Earthquake Legacy: Post-2072 satellite imagery showed widespread rock fracturing in Bagmati and Gandaki provinces.
Landslide hot spots: Nepal Government declared 71 municipalities across 20 districts as disaster zones overlapped with 2072 quake affected regions.

e. Discussion: The above average rainfall in monsoon of 2081 exceeded soil saturation in earthquake-damaged slopes. Moreover, 25% of forest covered area is lost since 2000 AD which reduced slope stability in eastern Nepal.

Multivariables Risk Model:
Land slide risk = (Rainfall intensity x Seismic Vulnerability) + (Deforestation + Unplanned Urbanization)

f. Conclusion: The 2081 landslide crisis was a compound disaster caused by above average rainfall and earthquake fractured hills and slopes, amplified by the unplanned urbanization and deforestation.

Case Study Validation : This analysis aligns with the disaster reports of (reliefweb), (wikipedia) and (Swechhya Raut). Moreover, disaster reports of EU confirms "hills weakened by the 2072 Gorkha Earthquake became unstable when saturated."

Importance

This research report holds great importance for the people of Nepal. This research report holds the capability of informing and awaring the citizens of Nepal while alarming the situation. I believe that this research report can make people aware to an extent. This report is important to citizens and concerned authorities for following reasons:

1. For Preparedness and response capacity awareness on earthquakes,
2. For awareness about seismic evaluation.
3. For preparing to increase the coping capacity.
4. For recommending the concerned authorities about pre-disaster management.
5. For awaring the Nepalese and especially Western- Nepalese about the great potential of big earthquake hit.

The destruction & casualties of earthquakes depend on following factors:

1. Response Capacity
2. Awareness
3. Structures

The response capacity simply means the capacity of the individual responding during the earthquake. It can be heavily influenced if the education and awareness is provided high quality. The role of awareness is really important in any disaster and especially in case of disasters which are hard to predict like Earthquake. If the people are well-awared, the casualties, infrastructural damage and the mental effects can be decreased drastically. As mentioned above, the destruction and casualties depends on the structures as well, in case of earthquakes. Hence, the development of right and strong structures is really important. The rightful way of building infrastructures is discussed further in report.

Seismic Evaluation

The National Earthquake Monitoring and Research Center (NEMRC), under the department of Mines and Geology, operates 42 seismic stations, 50 GPS stations, and 36 accelerometer as of recent updates, enhancing real-time monitoring and hazard evaluation. These evaluation tools and ways should be enhanced more, considering the risks where Nepal lies on. The seismic evaluation of the buildings constructed should be also closely considered.

In 2001 AD, looking at the urbanization of Kathmandu valley, there was a scenario created if similar earthquake as that of 1990 BS was to occur, Japan International Cooperation Agency (JICA) and Kathmandu Valley Earthquake Risk Management Project (KVERMP) predicted the scenario would be more devastating, and the fatalities would be very high. For that earthquake scenario, JICA estimated upto 59,000 houses destroyed, 18,000 deaths and 59,000 seriously injured. Another study carried out in the frame work of the KVERMP estimated a total of 40,000 deaths, 95,000 injuries and 6,00,000 or more people homeless. Soon after around 13 years, the 2072 Gorkha earthquake struck Nepal and became a disastrous event. But the earthquake of 2072 didn't really came even close to what studies had shown.

It was so because the day earthquake hit Nepal was 2072 Baishak 12, Saturday and that too at 11:56 am. Saturday is public holiday in Nepal and the time was of noon too. If that same earthquake was to strike Nepal at mid night, the casualties would have been more and if the earthquake had delayed for a day and stricken Nepal on Sunday, the death counts would have rocketed. It would have been a black day in Nepal's history because if the earthquake had came when people were working in offices and students were in school, that earthquake could have killed tens of thousands of people. It can be also validated as the infrastructures prior Gorkha earthquake were too much traditional and not safe as discussed further and if there were mass of students and workers, those weak structures could not have been resisted.

Building Topology of Nepal

1	Adobe, Stone in mud and Brick in mud (Low Strength Masonry)	Adobe Buildings: There are buildings constructed in sun-dried bricks with mud mortar for the construction of structural walls. Stone in Mud: Stone masonry buildings constructed using stones with mud mortar Brick in Mud: Brick masonry buildings constructed using fired bricks with mud mortar.
2	Brick in cement, Stone in cement	These are the brick masonry buildings with fired bricks in cement and stone masonry buildings with stones with cement mortar.
3	Non-Engineered Reinforced Concrete (RC) Movement - Resisting Frame Buildings	It has concrete pillars (columns) and beams, but not built with proper engineering design. The prevalent practice of most urban areas of Nepal for the construction of residential and commercial complexes is generally of this type as of the studies of 2013. These buildings are not structurally designed and supervised by engineers during construction.
4	Engineered Reinforced Concrete (RC) Movement - Resisting Frame Buildings	These buildings consists of a frame of concrete beams and columns. Floor and roof framing consists of concrete slabs. These are engineered buildings with structural design and construction supervised by the engineers.

Table 3.1 Common Building Topology of Nepal

The above 4 are the types of buildings commonly build in Nepal. After the Gorkha earthquake the engineered reinforced concrete movement-resisting frame buildings are more of a trendy one but still in rural areas, the adobe, stone in mud, brick in mud, brick in cement, stone in cement and non-engineered reinforced concrete movement-resisting frame buildings are in existence. The no. 1.2.& 3 types of buildings mentioned in the above table are not safe options during an earthquake. The damage grade of different building typologies trough different intensity earthquakes from fragility functions availiable in," The Development of Alternative Building Materials and Technologies for Nepal and Appendix-C: Vulnerability Assessment, UNDP/UNHS 1994", are in table 3.2, 3.3 and 3.4.

NOTE	The original table consists of only MMI scale (Modified Mercalli Intensity) but for the reader’s convenience. I have stated the approximate magnitude level of the earthquake as well

Damage Grades of the buildings : This classification of damage grade of buildings has been taken from European Macro-seismic Scale (EMS98):

Damage Grade 1 (DG1)	No structural damage and slight non-structural damage
Damage Grade 2 (DG2)	Slight structural damage and moderate non - structural damage
Damage Grade 3 (DG3)	Moderate structural damage and heavy non - structural damage
Damage Grade 4 (DG4)	Heavy structural damage and very heavy non - structural damage
Damage Grade 5 (DG5)	Very heavy structural damage

PGA : Peak Ground Acceleration

Shaking Intensity (MMI)		VI	VII	VIII	IX
PGA (%g)		5 - 10	10 - 20	20 - 35	>35
Richter Magnitude		~ 5 - 5.9	~ 6 - 6.4	~ 6.5 - 6.9	~ 7 - 7.4
Damage Grade for different classes of buildings	WEAK	DG2	DG3	DG4	DG5
	AVERAGE	DG1	DG2	DG3	DG4
	GOOD	-	DG1	DG2	DG3

Table 3.2 Building Fragility : Brick in mud(Well Built) or Brick in cement (ordinary)

Shaking Intensity (MMI)		VI	VII	VIII	IX
PGA (%g)		5 - 10	10 - 20	20 - 35	>35
Richter Magnitude		~ 5 - 5.9	~ 6 - 6.4	~ 6.5 - 6.9	~ 7 - 7.4
Damage Grade for different classes of buildings	WEAK	DG1	DG2	DG4	DG5
	AVERAGE	-	DG1	DG3	DG4
	GOOD	-	DG1	DG2	DG3

Table 3.3 Building Fragility : Non-Engineered RC Frame Buildings (≥ 4 story)

Shaking Intensity (MMI)		VI	VII	VIII	IX
PGA (%g)		5 - 10	10 - 20	20 - 35	>35
Richter Magnitude		~ 5 - 5.9	~ 6 - 6.4	~ 6.5 - 6.9	~ 7 - 7.4
Damage Grade for different classes of buildings	WEAK	DG1	DG2	DG3	DG4
	AVERAGE	-	DG1	DG2	DG3
	GOOD	-	-	DG1	DG2

Table 3.4 Building Fragility : Non-Engineered RC Frame Buildings (≤ 3 story) or Engineered RC Frame Buildings or Reinforced Masonry Buildings

The above tables 3.2, 3.3 and 3.4 are the evaluation of what and how much damage can a different level of earthquake do. These evaluations and studies were done way before the Gorkha Earthquake but the government didn't took any actions awaring people and communities about it. The department of Urban Development and Building Construction developed the Nepal National Building Code in 1994 AD with the assistance of UNDP. Since 2003 AD, the implementation of Nepal National Building Code became mandatory.

Due to the various faults in Nepal National Building Code, the Gorkha Earthquake after 12 years of it's implementation, resulted as a disaster for buildings, as more than 7,55,000 houses were damaged including nearly 5,00,000 collapsed. Later after 5 years of the Gorkha earthquake, the Nepal National Building Code was revised on 2020 AD (2076 BS) as NBC 105:2020.

Vulnerability of School Buildings

Schools are certainly among a community's most important buildings, but many people do not think of school first when they think of starting earthquake mitigation programs. Schools in Nepal, both their buildings and the students, staff, teachers or anyone inside face extreme risk from earthquakes. School buildings in Nepal, be it government or private were generally used to be constructed without the input of trained engineers or engineers with knowledge about seismically resistant construction, before 2072 earthquakes but after 2072, the government school buildings seem to have well engineered Reinforced Concrete buildings but most of the private school buildings are not reformed.

The education sector of Nepal has became a profitable business market. The investors want to invest less and profit more in this sector building unsafe buildings and providing less qualitative education to the students. Budgets for the school construction are typically very limited, increasing the likelihood that poor materials or workmanship will be used. School children are also vulnerable to natural disasters including earthquake, especially the youngest children.

The loss suffered by a community in the collapse of a school is psychologically much greater than the loss faced by collapses of any other building types as schools house an entire generation and a community's future. The vulnerability of schools during earthquake can be illustrated by the events of the 1998 AD Udaypur Earthquake in eastern Nepal. Around 950 school buildings were destroyed in this event, luckily during non-school hours, just like 2072 Gorkha earthquake. Schools play a crucial role after an earthquake as well, helping a community to get back on it's feet. Since, schools are typically well distributed throughout neighborhoods, they are an ideal location for homeless shelters, medical clinics, and other emergency functions. Also, by raising awareness in schools, the entire community is reached because the lesson goes to parents, relatives and friends of the students.

Many of the private school buildings of Nepal may not be under the code of conduct as it is generally seen private school buildings having residential house engineered construction. The residential buildings don't have necessarily the capacity of holding itself when hundreds of student's mass is inside it.

The major factors affecting vulnerability of school buildings are:
1. Structural System of Building: It refers to how the building's load-bearing elements (walls, beams, columns and slabs) are arranged. A well-planned structure distributes load evenly, make it more resistant to earthquake forces while a weakly designed structure with missing or poorly connected structural elements can collapse easily.

2. Building Configuration: The shape of the building affects how forces are distributed. Simple shapes like rectangle or square perform better while Complex shapes (T, L, U or irregular designs) may create weak points.

3. Building Height: Taller buildings experience stronger shaking at the top and if not designed properly, the higher floor may collapse or create additional stress on the lower floors. Building is weak if the height is too tall for it's base width, making it unstable.

4. Symmetry: A symmetrical building with equal weight and strength on all sides moves uniformly during an earthquake while an unsymmetrical building has unequal weight distribution and may twist and collapse.

5. Pounding between Adjacent Buildings: It happens when two buildings are too close and hit each other during an earthquake. This can cause severe damage as buildings transfer forces to each other. Buildings too close to each other can collide hence, should have enough gap in between.

6. Building Construction Material and Construction Quality: The strength of a building depends on materials used. Buildings are stronger if reinforced concrete, steel and engineered bricks are used instead of low-quality bricks, mud or weak concrete. Even with good materials, poor construction methods can make a building unsafe as bad workmanship, missing reinforcements and poor joints lead to early failure. Construction must follow engineering standards and proper supervision.

Coping Capacity

The coping capacity simply refers to the capacity or ability of the people to face the disaster. The destruction and the level of disaster depends on the coping capacity. If the people are capable enough to face the disaster and sustain afterwards, then the coping capacity is high and hence the destruction and level of a disaster will feel like normal. It is important to increase preparedness regarding the coping capacity of general public.

In context of Nepal, I have researched on the most recent deadly earthquake of Nepal, 2080 Jajarkot Earthquake and found out that the coping capacity of Nepalese people is way too low. Nepalese are not ready to cope with any disasters, be it floods, landslides or avalanches and earthquake is something that Nepalese definitely are not ready as it is almost impossible to predict in Nepal. Though, the science of predicting earthquakes are developing in other nations like Japan, China, USA etc. but due to lack of instruments, resources and infrastructures needed, predicting earthquakes as of now is a dream in Nepal. What I found while researching on this 2080 earthquake was that the people of Western Nepal were not ready and the infrastructures and property got tremendously damaged.

It was just on 2080 kartik 17 when a 6.4 magnitude earthquake hit Barekot affecting Jajarkot and West Rukum district alongside few other districts resulting a massive destruction. After 37 days of the initial midnight shock, there were 60,000 and more temporary settlements needed for the victims. "We were sleeping. We felt like dying." said Laxman Pun, an earthquake Survivor. Even at the aftershock of Gorkha earthquake back in 2072, people were panicked as many were living in the open air. "For the first seconds, it was complete silence. By the fifth second, everybody started to scream," said an eyewitness. "It was really, really intense. Even when the shaking stopped, people were still screaming." The tremor caused fresh landslides and destroyed some buildings which survived the first quake (CNN World).

Then Prime Minister Puspha kamal Dahal (Prachanda) arrived Jajarkot on Saturday after showing grief at loss of life and property brought by the earthquake in social media platforms. The government of Nepal leaded by Puspha Kamal Dahal decided to compensate the victims with NPR 50,000, that too in two installments of 25,000 each. There were more than 60,000 temporary settlements needed for the survivors, out of which barely 20% of it were built as of 2080 mangshir 24. After a month and a week of earthquake, only 20% of total temporary settelments needed were built meaning that the other 80% of victims had to survive on the freezing temperature of Mangshir, Poush and following months. In Ramidada of Barekot, where this midnight quake had originated and had epicenter, there were no people recorded dead because of the earthquake. Everyone had survived there. But after 43 days of the shock, on 2080 Mangshir 30, there were 14 people recorded dead in Barekot alone because of the freezing temperature in the absence of shelter. In total there were 34 people recorded dead because of freezing temperature in absence of shelter and diarrhea meaning there was lack of sanitation as well.

This 2080 Jajarkot Earthquake showed us how vulnerable we are during earthquakes. We are not even ready to cope with it. We rely on faith and the faith has been saving us, be it 1998 AD Udaypur earthquake or 2072 Gorkha earthquake. It was a matter of shame for government that it's citizens were dying because of freezing temperature and diarrhea post-earthquake. Not only government but it showed the vulnerability of the citizens themselves too, who couldn't build a safe shelter and maintain sanitation during such crisis. Is it shameful in 21st Century world. I remember the Case Study-I of Project Gurkha where they had sustained by themselves during post-Gorkha Earthquake. This shows how awareness and improved education can teach the people to cope with disasters. The village we discussed about in the case study was an educated village where the headmaster along with his current and old students, managed to sustain the village and even provided education on such crisis. Whereas, most of the Western Nepalese villages are unaware and uneducated which clearly can be seen in the situation of Post - Jajarkot Earthquake. There were more than 60,000 shelters needed in Jajarkot only. While in West Rukum, the count of homeless was 32,996 as per the reports of District Administration Office.

As on 2080 Falgun 21, the reports presented by the District Administration office on the count of destroyed houses in Barekot was 5,586. And the number of temporary shelters built were 4,511. The remaining 1,075 contrasting number of families must have co-operated with other families or else they enjoyed the open air, on support of a tent. The chairperson of Barekot Rural Municipality, Bir Bahadur Giri said, "Most of the wards of Barekot Rural Municipality are covered in Snow. The snow has covered 10 inches to 1 feet." Nalgaun Municipality which had suffered most damage in this earthquake was also covered in snow up to 1 meter with heavy snowfall. A place named Jiri situated in Barekot of Jajarkot had suffered snowfall where Bal Bahadur Nepali was sustaining life of his 7 members family. Another man there, Govinda BK with 8 family members said, “There is snow all around the house, there are no warm clothes, everyone in the family has started to wake up all night around the fireplace since Saturday. Now, there is no chance or condition of working and sleeping until the snow melts.” (K.P Gautam and H.S Rathaur 2080) There were a lot of old-aged and very young-aged deaths as mentioned in table 3.5. As of 2080 Mangshir 21, 32 earthquake survivors lost their lives as government could not provide funds to build temporary shelters in time. (N. Upadhyaya 2080)

Due to the cold temperature, chronically ill, pregnant women, infants and children were sick. They were lacking on proper diet and care as well showing the vulnerability when an earthquake hits Nepal. Although the government had said that they will provide funds of 50,000 rupees in two installments, due to the lack of procedures and neglect of concerned authorities, housing construction became slow and resulted in deaths post - earthquake.

SN	Name	Age	SN	Name	Age
1	Niruta Pun	1 (month)	17	Siduge Shahi	70
2	Niraj Shahi	1	18	Birkhe Damai	64
3	Rakshya Badi	3	19	Mansari Kami	56
4	Deepak Saraki	12	20	Mani Rawat	62
5	Maina Singh	80	21	Setu Budha	61
6	Man Bahadur Shahi	55	22	Hari Bahadur Rawat	57
7	Dume Pun	70	23	Lile Buddha	65
8	Galpu Shahi	51	24	Dhuleshwar Karki	88
9	Padam Bahadur Shahi	59	25	Narendra Singh	71
10	Lal Bahadur Shahi	54	26	Challi Damai	80
11	Ramsilan Shahi	52	27	Namraj Basnet	29
12	Pampha Rawal	49	28	Khagi Jaisi	65
13	Gopal Bahadur Rawat	84	29	Tike Jaisi	64
14	Dhankali Buddha Chettri	38	30	Naule Pun Magar	75
15	Sarmila BK	25	31	Rato Khatri	60
16	Sugili Nepali	89	32	Nandakali Pun	61

Table 3.5 Post - Jajarkot Earthquake Deaths (Cold, diarrhea , illness)

Pre Disaster Management

In the current situation of Nepal, all the organizations, departments and institutes related to earthquake risk management and assessment should be focusing more on Pre - Disaster management for potential mega-quake. As Om Astha Rai said, “Preparing Western Nepal for a mega-quake is much more urgent and important. Government and concerned authorities should be focusing on preparedness of potential mega-quake instead of taking too much time on Jajarkot Earthquake.” The reconstruction must be completed in Jajarkot but the time they are taking is insane. It is getting late day by day to aware the people in rural areas. There are handful of government departments, NGOS, INGOs and research institutions for earthquake related researches and works in Nepal. The major government Departments and offices are:

1. National Earthquake Monitoring and Research Center (NEMRC): It operates under department of Mines and Geology. NEMRC represents an expanded structure of what was previously known as the National Seismological Center (NSC). Based in Kathmandu, NEMRC is the primary government agency responsible for seismic monitoring throughout Nepal. It's activities include:
    i. Maintaning seismic observations accross Nepal.
    ii. Publishing the details of earthquakes of magnitude greater or equals to 4 that occur within or around the country.
    iii. Sharing location data with international institutes including the International Seismological Center (ISC), United States Geological Survey (USGS) and European-Mediterranean Seismological Centre (EMSC).

2. National Disaster risk Reduction and Management Authority : It operates Under Ministry of Home Affairs. It helps in disaster preparedness, response and policy making.

3. Department of Mines and Geology: It operates under the ministry of Industry, Commerce and Supplies. It does geological and seismological studies and earthquake hazard mapping.

4. Nepal Geological Society: It contributes in seismology research, earthquake risk reduction and geological studies.

5. Department of Urban Development and Building Construction (DUDBC): It operates under the ministry of urban development. It works on building code development and implementation based on seismic researches.

The major NGOs and INGOs includes the following:

1. National Society for Earthquake Technology (NSET): It helps to enhance community-based earthquake education by conducting awareness programs. It helps in earthquake risk management and policy development. NSET should develop a nationwide campaign using local languages and cultural contexts to teach earthquake safety, focusing on rural areas. It should partner with schools and women group to make "earthquake ambassadors" who are capable of leading drills and passing knowledge.

2. Geo Hazards International-Nepal: It helps in earthquake risk reduction and conducting school safety programs. It is also doing it's work in India and Bangladesh and had worked in China as well.

3. Society of Nepalese Engineers in Seismology (SONES): They can contribute in development of structural engineering and seismic evaluation of the buildings and do earthquake safety researches.

Similarly, the universities and research institutions should Introduce dedicated seismology and earthquake engineering courses at undergraduate and graduate levels. They should establish interdisciplinary research hubs to study seismic hazards, collaborating with international universities for funding and expertise. Expanding academic focus can build a skilled workforce and advance research, addressing the shortage of local seismology experts while using TU's existing infrastructures. The universities and departments that contributes in Earthquake assessment and awareness are as follows:

1. TU - Department of Seismology

2. Tu - Institute of Engineering (IoE), Pulchowk Campus : It helps in development and awareness about structural engineering and disaster - resistant infrastructure research.

3. KU - Department of Civil Engineering : It helps in disaster - resistant infrastructure research and earthquake hazards analysis.

All the above mentioned departments, institutions, NGOs and INGOs play a vital role during and after earthquake including the relief and resilience program conducting organizations. But quite disappointing when it comes to Pre-Earthquake management. Most of the people of Nepal has not even heard about these organizations and government departments. It means the general awareness is lacking. For the sake of Pre-Disaster Management, they all should be working hard on awaring the people about the earthquake risks. One of the need for Nepal is:

- Promotion of Earthquake Resilient Infrastructure: The concerned authorities should make the building codes stricter based on the latest seismic researches. They should also provide subsidies for retrofitting existing structures. They should partner with engineers from universities and NSET to train builders and certify safe construction practices. Nepal's high casualty rates in past earthquakes highlight the need for resilient buildings. Combining research with practical application can reduce the future risks.

Awareness in Western Nepal

“2015 was just a warning, a mega-quake is overdue in western Nepal, and we better start preparing for it”, Sonia Awale is trying to aware Nepalese about potential mega-earthquake in West of Nepal through Nepali Times.

In recent times, western parts of Nepal, including the Far West Province is at high seismic risk. According to seismologist Bharat Prasad koirala of the National Earthquake Monitoring and Research Center, there has been no earthquake in the western region of Nepal since the last 518 years. He stated that the energy to cause earthquakes has been stored under the ground of western Nepal for such a long time, he said, “Since 1505, there has been no major earthquakes in the mountainous region from Gorkha in Nepal to Dehradun in West India. So, the large amount of energy to cause earthquake has been stored here.”

Q . Can we believe the predictions of seismologists?
→ Looking down the history, the seismologists and scientists have always been predicting big earthquakes before a decade or around, pretty much accurately. The research articles of (Rajaure and Sapkota) in 2007 had mentioned about the big possible mega-quake in Gorkha region. Geologist Dr. Naresh Kazi Tamrakar had also mentioned about it in his 2011 book “Geo-Environmental Hazard”. Even in 2001, JICA and KVERMP had published reports demonstrating how Nepal is going to get devastated in mega-quake. After all these, when the mega-quake really struck in Barpak, Gorkha in 2015, people realized how important those predictions were and how the people themselves and the government could have minimized the risks. We should and must believe the predictions given by the seismologists. Even if that turned out to be not accurately correct, it is no harm to you. You live in Nepal, a country where mega-earthquake is sure to happen. Retrofitting your house, school, and community buildings is not something that will go waste. Hence, we should believe in seismologists regarding earthquake predictions.

After 3 years of 2072 Gorkha Earthquake, Om Astha Rai published an article in Nepali Times saying “**Preparing western Nepal for a future megaquake is now even more urgent than reconstruction in areas hit by the 2015 disaster.**" Nobody seemingly took Rai seriously and negelated it for 5 years. Government was not interested in preparing western Nepal. After 5 years, the 2080 Jajarkot earthquake happened. That earthquake was just of magnitude 6.4 and damaged tremendously while the mega-quake mentioned by Om Astha Rai, Sonia Awale and Bharat Prasad Koirala is yet to strike Nepal. It is going to be almost 10 years since the seismologists had dropped the initial predictions meaning that a mega-quake in Western Nepal is closer than we think now. Om Astha Rai, in her article says, “Nepalis live in one of the most seismically active zones in the world. Nepal is number one in the list of top ten countries vulnerable to catastrophic earthquakes. But even the 2015 earthquake disaster will pale in comparison to a much bigger earthquake which scientists say threatens western Nepal.”

Beneath our mountains calm and still,

The earth holds power, silent will

When it rumbles, cities shake

A sleeping giant, we mustn’t underestimate.

The lower literacy rate, and lack of awareness in western Nepal is probably going to make a hard scenario for the people after earthquake. We had an example of what it could look like from the Jajarkot earthquake.

We have to admit the fact that the western Part of Nepal is really in danger of a mega-quake, potentially an earthquake of above **8.5 magnitude**. During the 2072 Gorkha earthquake, a massive block of Earth's crust, roughly 120 km (75 mi) and 60km (37 mi) wide, lurched ~3 meters to the south over the course of 30 seconds. Riding atop this block of the planet was the capital of Nepal-

Kathmandu and millions of Nepalese (R. Bilham). This was KTM valley effect we discussed earlier and the whole land was moved ~3 meters.

The Main Himalayan Thrust (MHT) is a décollement under the Himalayan range. It is the largest active continental mega thrust fault in the world and Nepal lies on that thrust. Studies indicate that the strain (energy) builds up over centuries along MHT. Western Nepal has been identified as a seismic gap which means Western Nepal is a region where a major earthquake hasn't occurred in a long time suggesting that the accumulated energy might be released as a large earthquake. As we know, the Himalayas of Nepal are formed by the collision of the Indian and Eurasian tectonic plates and we have already discussed in 'Introduction' section that the Indian Tectonic Plate is moving in North-East direction at the rate of ~5 cm every year against the Eurasian Tectonic Plate.

Now, according to the seismologists, no massive earthquake has hit Western Nepal since 1505 AD, meaning that the thrusts underneath the land of western part of Nepal has not released it's energy since around 520 years. The Gorkha Earthquake had helped to release some energy and moved the land ~3 meters but the 3 meters of movement is not enough. Indian tectonic plate moves 4-5 cm North-East every year. We can take average as 4.5 cm for simplicity. And the years of energy accumulated is 520.

∴ We can estimate the total displacement (TD) as:

$$\mathrm{TD} = \frac{4.5 \times 520}{100} \mathrm{meters}$$

Hence, Total displacement is 23.4 meters. In tectonic terms, this 23.4 meters represents the potential displacement or strain that has built up along the fault system (like the MHT). Although, some strain might be released through small or big earthquakes in the time period. Like the Gorkha Earthquake released around 3 meters of energy, moving Kathmandu by 3 meters. The strain of around 20 meters accumulated beneath Western Nepal may not necessarily release at once. The amount of slip depends on various factors. A magnitude 8.0+ Earthquake might produce 5-20 meters of slip in one go, depending on rupture length and depth. So, western Nepal could experience a significant shift in a major earthquake but it may not release all 20 meters of accumulated strain in a single event, there may be alot of aftershocks or swarms or maybe released gradually by future quakes.

We can imagine how big earthquake will strike Western Nepal affecting Nepal and nearby countries if the strain is accumulated now by analyzing the fact that the deadly 2072 Gorkha earthquake had released energy of only ~3 meters and Western Nepal has accumulated energy of ~20 meters, in present day.

Scientific models suggests that the stress has reached a critical level, making potential of earthquake higher than 8.0 - 8.5 magnitude. The current strain measurements suggest it is very likely to happen within few years or the next few decades or a century in max as the strain accumulation has reached extreme levels.

Research Findings

The primary goal of this research paper was to aware Nepalese people about seismic hazards in Nepal. The following are the major findings of this research report :

1. **Mega-Quake is coming soon**: The western part of Nepal, including the Far-West Province is at a high risk of earthquake which could potentially go upto 8.0 magnitude or over that for releasing the strain accumulated beneath the surface along the Main Himalayan Thrust (MHT), calculated ~ 23.4 meters in previous chapter. Such level of energy need to strike a mega-quake in order to release it's strain. According to Sonia Awale, Om Astha Rai, geologists like Dr. Naresh Kazi Tamrakar, report publishers Rajaure and Sapkota and renowned seismologists of National Earthquake Monitoring and Research Center (NEMRC), National Society for Earthquake Technology (NSET) etc. including seismologist Bharat Prasad Koirala suggests that the large amount of energy to cause big earthquake has been stored in the mountainous region from Gorkha in Nepal to Dehradun in West India.

2. **Lack of Assessment of seismic evaluation of buildings**: Despite having developed the Nepal National Building Code in 1994 AD with the assistance of UNDP and making it mandatory since 2003 AD, the Gorkha earthquake damaged over 7,55,000 houses including almost 5,00,000 houses being completely collapsed. That showed the vulnerability of Nepal National Building Code and it was revised in 2076 BS as Nepal National Building Code 105:2020, while the engineers still doubt for the flaws.
Most of the Nepal's community and private buildings are not safe during earthquakes, especially school buildings as we discussed earlier. Mostly school buildings or community buildings including hospitals or big complexes are not well structured to stand upright while carrying people in it's full potential and even if the buildings were well structured and planned, they've become old and not been retrofitted. It doesn't mean all buildings are unsafe. There were several cases I had found during this research, which were well structured and been retrofitted as well.

3. **Government need to be prepared to face huge economic crisis in case of a mega-quake:** The 7.8 magnitude earthquake had made an estimated damages and looses of around US $7 Billion during 2072 Gorkha earthquake, which was nearly one third of then Nepal's GDP. If the potential mega-quake is going to strike Nepal, the human and economic loss will be way more than that.

4. **Public should be aware:** The major effect of the Gorkha earthquake was the mental effect. The general public should be aware in order to not get mentally broken and to reduce casualties, thefts and crimes post-earthquake. If public are aware they must be following the points mentioned in the “recommendations” section and that can help to a great extent.

5. **Communities should learn to self sustain:** In 2072 Gorkha earthquake, about 1,500 km of roads were damaged, 100 bridges were affected and over 21,000 landslides blocked major highways isolating 39 villages. Many of the communities were not getting resilience and reliefs due to the isolation. We must be well prepared to face such issues next time.

6. Concerned authorities should be focusing more on preparing Western Nepalese for mega-quake instead to of still reconstructing in Jajarkot (2081/12/19). Authorities must advocate for funds and support from the government to invest in the reconstruction of all the buildings, particularly in Western Nepal which are non-resistant to earthquakes, before any mega-quake strikes Nepal, reducing the casualties. Government will have to spend money for reconstruction if earthquake strikes. Instead of that, it will be better if government along with concerned authorities starts the campaign of **Reconstructing Nepal**, eliminating all the buildings which are non-resistant to the earthquake with a strong building following the Nepal National Building Code 105:2020. That will

help to minimize the casualties rate and the downgrade of mental state of general public which will help to recover the economy more effectively in future.

Research Recommendations

Every readers of this research paper has a role in the resilience of earthquake in Nepal, from awareness to advocacy. I believe every student, teacher, critic, leader, concerned authority or whoever came across this research paper got the awareness motive and the importance of awareness initiative. There will be no one for you and your family in the time of disaster. You will have to cope with it by yourself. And for that you need to increase your coping capacity as discussed prior in 'importance' chapter of this report. As we had discussed, the village of Barpak, Gorkha was totally isolated for almost a week since Earthquake, losing all it's connectivity from outer world, in 2072 earthquake. But the community leaders and educated people sustained the village and rescued the villagers on their own for a week. It showed that either the educated personalities of village were aware of the earthquake risks or the leaders and most of the people had great coping capacity.
While, we can have both of those factors (awareness and coping capacity) as we have got enough time to get aware about seismic hazards, spread awareness and increase our coping capacity.

This report recommends general public or general reader to implement and engage in following points:

1. Stay Informed and Engaged: General public of Nepal must regularly follow updates from Nepal's National Seismological Center and organizations, like NSET to understand seismic risks and advancements. If your area is facing earthquake swarms (you can check recent earthquake updates of Nepal on "seismonepal.gov.np"), you must spread awareness and increase your coping capacity as any mid level earthquake during swarms can damage buildings or cause landslides. Swarms continuously affect the area and when a big or mid-quake strike, it tends to damage alot like in the earthquake swarm cases of Jajarkot and Bajhang in 2080.

2. Participate in or Promote Awareness Programs: As a general public, you can participate in workshops and awareness programs related to Pre-Disaster management and aware people about what you learned. You can join or even organize community earthquake drills, workshops, or awareness programs taking inspiration from NSET's community-based models. You can also share resources and news on social platforms.

3. Prepare Personally and Locally: You can create personal or community earthquake preparedness plans by keeping limited amount of emergency stocks, Emergency kits, learning first-aid and finding/identifying safe zones inside and outside of your house or workplace. You can encourage others to do same by suggesting them to keep an emergency kit with basic needy stuff like, packed snacks, first-aid kit, communication device, certain amount of cash, flashlights, whistle and other important stuff for Post Earthquake survival.

4. Spread Nepal's Seismic stories: You can use blogs, social media, or local forums to highlight Nepal's earthquake challenges and efforts. You can share the stories of resilience of past-quakes, to increase the awareness among people indirectly.

Similarly, there are few things a student can do too. As we have discussed earlier in this research report that the school buildings are the most vulnerable community building, which if in case got collapsed, it will finish off a whole generation and the backbone of a community along with a group of skilled teachers. As the most vulnerable group during earthquake. it a big responsibility of the students to do as follows:

1. Explore and Share Research Opportunities: If a student or researcher pursue studies on Nepal's seismology, they should collaborate with TU or any other Universities and the professors there in order to explore more on this topic. Also, if there are any findings of student's research or reports, they should openly share it to inspire further work. It matters if student pursue on studies on Nepal's seismology as Nepal needs more local expertise. Japan is not so developed in seismology and can take big earthquakes with less damage by importing human resource from developed countries to study their geology but because they had their local expertise.

2. Encourage more than one (Interdisciplinary) Collaboration: You can push for partnerships between seismologists, engineers, educators and policy makers in your circles. You can attend or host discussions liking these fields to Nepal’s need.

This research report recommends the policymakers/authorities to:

1. Advocate for Funding and Support: You can urge local governments or international governments, universities, and donors to fund Nepal’s earthquake research and preparedness initiatives. You can write to policymakers or support crowd funding campaigns for seismic projects. You should pressurize the different levels of governments to start preparing the Pre - Disaster Preparedness Campaigns.

2. Encourage Interdisciplinary Collaboration

3. Support Resilient Building Practices: If you are involved in the sector of construction, structural engineering or policy making, you should advocate for earthquake-resilient buildings and adopt it yourself too. You should encourage friends or families in Nepal to retrofit their homes with expert guidance.

CONCLUSION

Experiencing the tremors of 2072 Gorkha Earthquake, fear of 2080 Jajarkot Earthquake followed by major Earthquake Swarms, and experiencing Earthquakes every now and then forced me to go deep into the topic of **Earthquakes in Nepal**, and write this. I got to know how Nepal has been shivering and will continue to shiver in Future as well. This research report is concluded after covering many aspects of Earthquakes in Nepal with ways and importance of awareness about it.

I found out that the seismologists are trying to aware the people about the possible mega earthquake in Nepal in recent future but seems like no one is much concerned about it. If the predictions come true, Nepal will face it's worst Earthquake in history, probably of more than 8.0 - 8.5 magnitude. This is a massive prediction and should not be negligated. There were predictions dropped before 2072 Gorkha Earthquake as well. Either authorities didn't take the studies seriously or didn't get support from government for awareness and pre earthquake management like seismic evaluations of buildings. Even today, it looks like a similar pattern of seismologists predicting earthquakes prior 5-10 years and noone caring about it. Small efforts like preparing Emergency Kits, First-Aid Kits, spreading Awareness, providing contextual Emergency based Education to students, Retrofitting Schools, community buildings and houses, and urging government regarding the preparations for loss of lives, economy, mental state, heritages, etc could help to survive the Earthquake.

In conclusion, Nepal lies in the high risk of Earthquakes and more importantly, there is a huge chance of a mega-quake in Nepal soon. For the sake of preparedness regarding this possible disaster, we need to get active and work on awareness. I wish every reader of this report will play a great role in the awareness campaign for mega-quake possible in Western Nepal.

REFERENCES

1. Brahma Shamsher JBR (The Great Earthquake in Nepal 1934 A.D.)
2. S.N Sapkota and L.Bollinger (Soma Nath Sapkota and Laurent Bollinger : Primary surface ruptures of the great Himalayan earthquakes in 1934 and 1255)
3. Pukar Joshi (Ph.D. student in Geotechnical Engineering at Montana State University)
4. Online khabar (online articles)
5. Wikipedia (disaster related articles)
6. Country economy.com
7. IMS (International Monetary Fund Country Report No. 15/317)
8. TEDx Event
9. TNC (The Nepali Comment/youtube)
10. Research gate (various researches related to disaster)
11. The Guardian
12. Nature (Nature scientific report article number : 3434 (2021) by A. Valagussa, P. Frattini, E. Valbuzzi and G.B Costa)
13. ACAPS (Briefing note Update 1-26 April 2015)
14. USGS (open-file report 2015-1142 version 1.1)
15. Internet Geography (Nepal Earthquake 2015)
16. Samjwal Bajracharya (landslides dams and their hazard after the 25 April 2015 Gorkha Earthquake in Central Nepal)
17. The World Bank (Nepal Earthquake 2015: Post Disaster Needs Assessment)
18. Post Disaster Need Assessment (PDNA: Government of Nepal National Planning Commission)
19. reliefweb (glide: FL-2024-000177-NPL)
20. Swechhya Raut (In Focus: Nepal: How monsoons bring rain, landslides and tragedy)
21. CNN World (eyewitness Marc Sarrado, 41 y/o doccumentrician from Spain)
22. N. Upadhyaya 2080 (Nagendra Upadhyaya in República on 2023 Dec 10)
23. KP Gautam & HS Rathaur 2080 (Krishna Prasad Gautam and Harihar Singh Rathaur 2080/11/21 Kantipur article)
24. B.P Singh (Basanta Pratap Singh, article in Kantipur on 2080/6/17)
25. R. Bilham (Roger Bilham, a world renowned expert on Himalayan earthquakes and geologist in University of Colorado)