International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979, Impact Factor: RJIF 5.72
www.allsubjectjournal.com
Volume 3; Issue 3; March 2016; Page No. 190-193

Increasing vulnerability of building stocks of Gangtok Town, Sikkim (India): An Issue and challenges for local people after Earthquake of 18th September 2011

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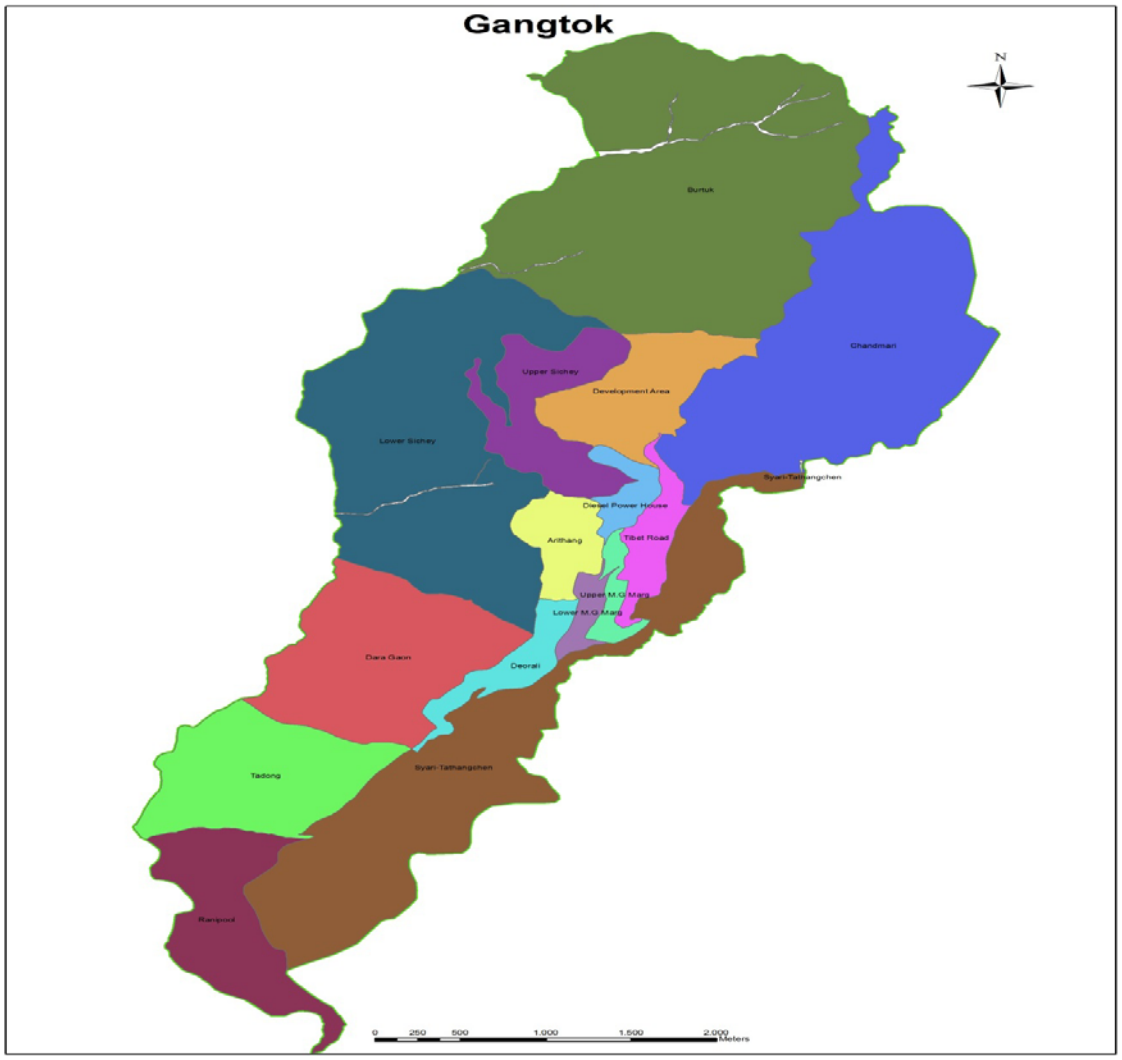
Abstract
Earthquake is a disastrous/hazardous event, cause after the trembling of earth, which may claims lives, property and destruction of the environment. Earthquake may cause due to movement of plate apart or collision of plates or subduction / override of two or more plates. Gangtok, a capital town of Sikkim is located in high intensity zone-IV in hazard zonation map of India. The Main Central Trust (MCT) fault line, as the earthquake or volcanic active zone passes through the area is considered for high seismic zone of India. Sikkim (Gangtok) lies in young-fold Himalayan belt, which is still rising due to collision of two giant plates i.e. Eurasian and Indo-Australian plates. Geologically, area is not much stable composition of Phyllites, Gneiss and Schist which are sensitive to bear the strong shaking of ground surface. The alarming growth rate of population and rapid construction of multi-stores buildings in past last decades may pose serious threat of risk in Gangtok Town.
The rapid growth of population and haphazardly construction of houses, buildings and increasing numbers of urban population particularly developing countries including India needs primary concern to assessment of buildings before occurrence of any major disastrous events like earthquake. The alarming growth rate of population and rapid construction of multi-stores buildings in past last decades in small and big towns of India may pose serious threat of vulnerability for further earthquake.

Keywords: Earthquake, Gangtok Town, Plates, Fault line, Seismic zone, Population, buildings, Risk, Vulnerability Assessment

1. Introduction
Earthquake is the trembling of Earth initiated by sudden shock. An earthquake (also known as a quake, tremor or temblor) is the result of a sudden release of energy in the Earth's crust that creates seismic waves *(Wikipedia).* Earthquake is a disastrous/hazardous event, cause after the trembling of earth, which may claims lives, property and destruction of the environment.
Among the disasters, an earthquake is one of most dreadful disaster in India. Indian subcontinent is among the world's most earthquake prone areas. Geology predisposes sixty percent (60%) of the country's area vulnerable to earthquake disaster. Twelve percent (12%) of its land is liable to severe earthquakes of intensity IX or more on the MMI scale (NIDM, 2004) [1].
Buildings in urban areas are highly vulnerable structures in seismic events especially in developing countries. There is a direct relationship between the damage of civil structures to the number of casualties. Most causalities, damage and economic losses caused by earthquake result from ground motion acting upon buildings incapable of withstanding such motion. Damage to buildings also causes a variety of secondary effects that can be greatly destructive. Lack of capacity buildings leads to increase in risk of property loss in developing countries. Damage to essential buildings substantially increases the rate of casualties. In the absence of risk analysis tools and databases required for earthquake risk assessment, it will be very difficult to assess the loss in Post-Earthquake event.
The risk assessment process helps in the preparing of a proper disaster management plan and plays a major role in the process of preparedness, mitigation, response and recovery. The proper implementation of building permits and controls, building codes, and awareness-raising can effectively reduce the earthquake vulnerability to large extent. The process of risk estimation began in the late 19th century, with the systematic recording of weather, stream heights and then earthquakes (Charles, 2005). Gangtok Town has recognized the need for enhancing the activities in earthquake risk reduction. The Gangtok Municipal Corporation does not have the required spatial information to investigate the existing trend of urbanization, population growth rate, and the resulting level of buildings vulnerability.

2. Study Area
Gangtok, a capital Town of Sikkim is situated in the lower Himalayas at an altitude of 5,800 ft (1,676m). It is located at 27°20'N to 27°33'N and 88°37'E to 88°52'E of latitude and longitude respectively. The total geographical area of the Gangtok town is 35sq.kms. The town lays on one side of a hill with "the ridge" a promenade housing the Governor's residence at one end and the palace at the other. The city is flanked on east and west by two streams, namely Roro Chu and Rani Khola, respectively. The hills are nestled within higher peaks and the snow-clad Himalayan ranges tower over the town from the distance. Mount Kanchenjunga (8,598 m or 28,208 ft)—the world's third-highest peak—is visible to the west of the city. (SFCPoA, 2012) [2].



Source: (Source: UD&HD, Gangtok, Govt. of Sikkim, 2013)

Fig 1: Map of Gangtok Town

3. Objective of the Study

The main objective of the study is to bring forth awareness among the residents of Gangtok Town. The others general objectives of my research focus in the following heads:

- To study the socio-economic impact of the earthquakes on the communities inhabiting the areas prone to earthquakes
- To raise the awareness of seismic risk among decision makers, and the public as well as local institutional to sustain the earthquake risk mitigation plan.
- To prepare a risk management plan and propose as well as the action plan for earthquake disaster mitigation.

4. Significance of the Problem

The study area is located in hilly terrain mountainous region; it was characterized by high seismic zones. According to the Bureau of Indian Standards, the Gangtok town falls under seismic zone-IV (on a scale of I to V, in order of increasing seismic activity), near the convergent boundary of the Indian and the Eurasian tectonic plates and is subject to frequent earthquakes. The population and infrastructure growth of Gangtok is increasing at an alarming rate.

The earthquake hit over the Gangtok town and adjoining areas on 14th February 2006 is one of the remarkable events in the earthquake history of State. Where there is several residential, public and administrative buildings of Gangtok town have been cracked down during earthquake.

The city has been expanding in a very improper manner having huge encroachment, haphazardly constructions of multi-stories public buildings, incapable land-man-material ratio, lack of proper infrastructure facilities, unplanned urban development etc. Moreover, the earthquake risk in the area makes the problem much more acute for the urban governing body. According to previous studies the probability of human casualties, death and damage of buildings and urban infrastructures during the large earthquakes seems to be very high (JICA, 2002).

Therefore, a planned seismic vulnerability assessment of building structures of Gangtok Town is necessary to cope on such disaster in near future.

5. Literature Review

In the recent year's rapid growth of population and haphazardly construction of public buildings in sensitive zone led to more susceptibility for earthquakes. Hazard is the probability of occurrences of a potentially damaging

phenomenon within a specified period of time and within a given area (Smith, 2001) [3].

Buildings in urban areas, especially in developing countries are highly vulnerable during any time seismic events. There is a direct relationship between the damage of physical structures to the number of casualties. Most causalities, damage and economic losses caused by earthquake result from ground motion acceleration acting upon buildings not capable of withstanding in such motion. Damage of buildings also causes varieties of secondary effects that could be greatly destructive. Lack of incapable buildings leads to increase in risk of property loss in developing countries. Damage to residential buildings substantially increases the rate of casualties. If construction of buildings will go on such unplanned manner and improper record, it will be very difficult to assess the loss in post-earthquake event.

6. Methodology and Source of Data

- To assess seismic vulnerability of the existing building stock in the wards of Gangtok town, Purposive Sampling method is implemented (5% of total existing buildings from each 15 wards).
- To collection of primary sources of data, researcher directly engage in the field survey through observation, questionnaires, opinionaires, personal interviews and group interviews.
- To collection of secondary sources of data, researcher did extensive review of books, volumes, journals, magazines, articles, newspapers and electronic sources.
- Supportive photographs have been taken from all 15 wards of Gangtok Municipal Corporation.

7. Ward-wise Population and Numbers of Buildings

The ward-wise total population is 105196 and numbers of buildings is 26641 estimated as of Gangtok town by UD & HD, Govt. of Sikkim in 2011.

Table 1: Ward-wise Population and Numbers of Buildings

Ward No.	Ward's Name	Total no. of Buildings	Total Population
01	Burtuk	2474	10282
02	Lower Sichey	1555	6198
03	Upper Sichey	2189	8304
04	Chanmari	1640	6502
05	Development Area	1879	7048
06	Diesel Power House	1182	4312
07	Arithang	2200	8537
08	Lower M.G.Marg	1001	4357
09	Upper M.G.Marg	739	2989
10	Tibet Road	957	3591
11	Deorali	1945	7263
12	Daragoan	2636	9930
13	Tadong	2482	9650
14	Ranipool	1238	4845
15	Syari Tathangchen	2534	11353
Total=15		Total=26641	Total=105196

Source: (UD & HD Dept., Gangtok 2011)

8. Buildings sample analysis

Two multi-stroyed buildings has been collapse during Earthquake of 18th September, 2011 in Burtuk Ward, two buildings from Development Area and one building from Lumsey Tadong ward. Some samples of Puccha and Kuccha house have taken for different wards of the study area. Almost 60% of buildings have been damage during earthquake from this ward. Most of the building is not constructed on the bases of building code systems; repairing work is not properly done.

Existing vulnerable buildings of Upper Sichey Ward

Fig 2: Severe damage building under repair

In this building case, this building is severely damage, find structural and non-structural damage, all columns form crack. Instead of demolish, they are repairing in all effort. This building is much vulnerable, if any earthquake happen in future.

Existing vulnerable buildings of Arithang ward

Fig 3: Several structural cracks identified 6 multi stored building

In Fig. 3, Arithang ward sample building, several cracks have been identified in the all floors of building; road level floor's crack is vivid from far distance. The vibrations caused by daily running vehicles may make much vulnerable to collapse the buildings. The second one fig. 1.16 building have combined wall and form several cracks during earthquake shows much vulnerable.

Existing vulnerable buildings of Daragoan Ward

Some of the building under Daragoan ward is overloaded by multiple parallel floors and ground floor is severely damage during earthquake, some of the building are constructed in

sinking zone with multiple parallel floors add above may pose serious threatening in future.

Fig 4: Possible of buildings vulnerability at Daragoan

There is a possibility of land failure due to below construction of college hostel in Daragoan. The above lying buildings base is becoming unstable and more prone for landslide.

Fig 5: Kuccha house with severe damage

The sample of taken Buildings under Syari-Tathangchen ward fig. No. 5 considered Kuccha house, during earthquake it was severely damage and still people occupy this house. This house has low seismic resistance capacity, if same intensity of earthquake strike, there will be chances of more life to claim in near future.

9. Recommendation and Conclusions

There is no doubt development of any city is requires potential of infrastructure including buildings, but haphazardly constructions without using human resources will pay heavy penalty in future. It is recommended that, to follow building code system is ultimate solution to cope any future damage and huge amount of loss. People should aware about the capacity of land before construction of any buildings. It is further recommended that, there is need to mind the gap of at least 5 meters away from one another buildings during construction.

It has to be concluded that, buildings of all the 15 wards is below the potential to cope of any seismic events in near future, it is necessary to demolish and construct new one the buildings and houses which is severely damage during earthquake. Repairing of these severely damage building will be considered equally to incurable disease patient to keep in hospital. Early prevention is best solution.

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