When the Big One Strikes Catbalogan City, Philippines: An Earthquake Damage Assessment using REDAS

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Abstract: Buildings constructed which were designed (or not) under current realities are the most at risk during disasters. High magnitude earthquakes are feared to cause huge damage and casualties. The risk is potentially high in zones of concentration, like metropolitan areas, capital towns and cities with tall buildings or vintage structures. This paper explored the possible damage due to an earthquake of high magnitude in selected areas of Catbalogan City, Philippines. Using the Rapid Earthquake Damage Assessment System (REDAS), it was found out that up to 24%, 41%, 65% and 98% of the buildings considered in the study are expected to be damage when magnitude 6, 7, 8 and 9 earthquakes occur respectively. The most vulnerable zones are found in Barangay 3, 4 and 5 found in downtown Catbalogan. Newer buildings with strict compliance to Building Codes and the National Structural Code of the Philippines are expected to be more resilient to such hazard.

Keywords: hazard, casualties, risk estimation, retrofitting, structural integrity

1. Introduction

Throughout history, many natural disasters have occurred, and countless of lives have been lost, and cost of damages to properties was too expensive. Risk of people and properties are determined by the type of hazard, degree of exposure and vulnerability, the latter is the human dimension of disasters which matters the most. The vulnerability of countries or communities to disaster risk is complex, and factors such as physical, economic, social, environmental are associated with it (Prevention Web, 2017). The Philippines is among the most natural hazard prone countries in the world (World Bank, 2005). In the latest report from the World Bank, the Philippines ranked third at risk to disaster country in the world because of its high exposure, but it's not included in the top countries that are susceptible, vulnerable, poor coping and adaptive capacity (Garschagen et al., 2016). Natural disasters in the Philippines include floods, flash floods, sediment (including debris flow, mud flow, and lahar), landslide, storm surge, big waves, tornado, whirlwind/wind flow, earthquake, volcanic eruption, drought, and red tide (World Bank, 2005). Floods, flashfloods, and sediment have the worst share of casualties (60%) followed by earthquakes (27%) while based on property damage, worst is due to drought (33%) and earthquake follows at 25% (ibid). About 90% of the world earthquake occurs along the Ring of Fire (USGS 1, nd.) where the Philippines is found. Documented earthquakes for the Philippines dates back to 1599 when an intensity VI earthquake damaged many private buildings (Pr). To date, the most damaging earthquake that ever happened to the Philippines was in 1976 and in 1990 where Magnitude 7.6 (Moro Gulf) and 7.6 (Luzon) specifically near Baguio City resulted into 7,100 and 2,400 casualties respectively (Smoczyk et al., 2013). The 1990 earthquake has a death toll of about 1,283 with property damages reaching about PhP 31.2 billion (World Bank, 2005). In 2013, a magnitude 7.2 earthquake affected the whole Central Visayas specifically Bohol and Cebu. It killed around 222 with more than 73,000 structures damaged and 14,500 were destroyed (NDRRMC, 2013).

Eastern Visayas is one of the most disaster-prone regions of the Philippines. Ms Dolina of the Philippine Volcanology and Seismology (PHIVOCS) said in the PIA report in 2012 that the Central Leyte Fault forming pat of the 1,200 kilometers Philippine Fault Zone stretches in some areas of Leyte. Samar Island towns are also subject to jolts by the movements of Southern Samar Lineament. Eastern Visayas experienced a damaging earthquake ranging from Intensity VII in Ormoc-Kananga area to Intensity IV in Catbalogan City, Samar. Cebu, Bohol to Bago City, felt Intensity 1 earthquakes. The Magnitude 6.5 earthquake damaged 3,639 houses (40.8% totally damaged) and had affected 16,052 persons, three were dead (NDRRMC, 2017).

Earthquakes do not kill, a building collapsing due to earthquake can. This means that earthquake is only a triggering factor to disasters. A shallow earthquake with an epicenter near the ocean floor may cause tsunami; earthquakes especially high magnitude can damage buildings, it may also trigger landslide and liquefaction.

Catbalogan City, like many towns and cities in Eastern Visayas, are exposed to various forms of natural hazards to include earthquake. In the study of Orale (2006) reported that Catbalogan is likely to experience mass wasting activities due to heavy rainfall and strong earthquakes.

Governments' throughout the world has developed plans to minimize the impact of disasters like earthquakes. Impact reduction can be attained through policy and planning, physical/technical, emergency preparedness, natural protection and knowledge management strategies (Palliyagruru, 2014). The Philippines formulated the National Disaster Risk Reduction Plan (NDRRMP) from 2011 to 2028 which includes four (4) distinct and mutually reinforcing priority areas, namely (a) disaster prevention and mitigation; (b) disaster preparedness; (c) disaster response; (d) disaster recovery and rehabilitation (PreventionWeb, 2011).

This paper estimated the impact to buildings and people living in it in the event of an earthquake.

2. Objectives

This study estimated the possible impact to building structures in the City of Catbalogan when a high-intensity earthquake occurs, specifically;

2.1 Present the strongest and the latest earthquake occurrences nearby Samar

2.2 To determine the building profile and information in terms of:

a. spatial location of the structure,
b. building use,
c. number of occupants,
d. number of storey

e. structural information of buildings (building type, year of construction, etc.)
f. building value

2.3 Determine the possible impact of different earthquake scenario in the selected area in terms of:
a. structural damage
b. monetary loss
c. casualty loss

3. Methodology

The study used computer simulation to estimate the potential damage when a high-intensity earthquake occurs nearby the City of Catbalogan.

3.1 Research Design

An experimental research design was used in the study with earthquake intensity as the variable, and the structural and non-structural impact was estimated.

Figure 1. Barangay and Zones Considered in the Assessment

3.2 Research Environment

Seven (7) zones shown in Figure 1 were considered in the study, these zones are areas of concentration and tall buildings considered to be critical because of potential casualty and economic impact.

3.3 Research Instrumentation

The study used Rapid Earthquake Damage Assessment System (REDAS) to simulate the impact of earthquake scenario in the City of Catbalogan. Data used in the simulation were collected using a survey checklist and interviews. A GPS, measuring tapes and camera were used to collect spatial information and physical features of the buildings. Pictures gathered were used to validate contents of the checklist. Satellite images available in Google Map were very useful in the assessment.

3.4 Research Procedures

3.4.1 Building Profile and Information Datasets

The general profile of buildings to be included in the investigation was established. The buildings considered are at least two-storey building where people tend to congregate. These are commercial establishments, schools, clinics, offices and the likes. Using a survey checklist, camera and GPS instrument, building information was gathered. Secondary data from the Philippine Statistics Authority (PSA) and the Assessor's Office of Catbalogan to determine information about the dominant era of construction in each barangay, building typology, classification of structure and the unit value of each building class per building use.

The number of buildings surveyed in each zones qualifying the criteria.

Table 1. Number of Building Considered in the Assessment

Zone	Total Number of Building in the zone	Surveyed Buildings
1	23	13
2	42	26
3	92	31
4	103	27
5	40	14
6	25	7
7	21	9
Total	127	346

3.4.3 Simulation

United States Geological Survey (USGS) says that at around magnitude 5-5.9 or about intensity VI-VII in the modified Mercalli Intensity says thatan slight damage maybe observed at this earthquake level. Slight to moderate damage is expected at the next level especially for those structures badly designed. For this study, four magnitudes were considered starting 6 to 9. The earthquake is to occur on a thrust fault approximately 125 km from Catbalogan City with an epicenter of 124.89^{o} E and 11.78^{o} N at a depth of 1 km.

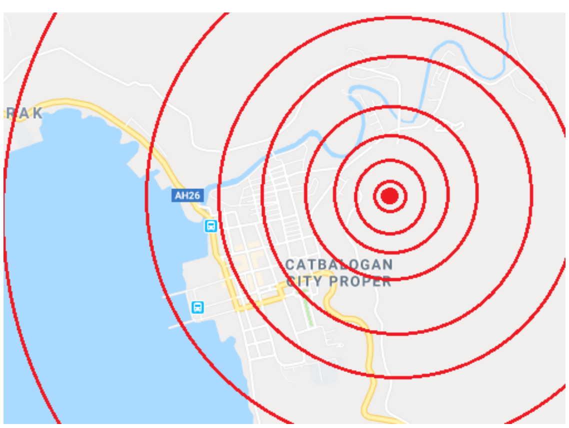

Figure 2. Location of Earthquake

Profile of buildings was inputted into the software such as its geographic location, building typology such as the number of storey, type of material used, year constructed, etc. After inputting all required data, a simulation run was performed, and reports were produced.

Reports generated include buildings damaged, casualty count and monetary loss. Physical damage was categorized into five (5) states; slight, moderate, extensive, complete and collapse. The casualties are grouped into four (4); slightly injured, non-life threatening injuries, life-threatening injuries and fatalities.

4. Results and Discussion

4.1 Active Faults and Earthquake Profile of Samar and Nearby Places

Samar Island is very adjacent to the Philippine Trench. The trench is about 60 km in width and 1,400 km long (Alpha and Galloway, 1996). This zone is an area where tectonic plates meet. According to Dr. Solidum of PHIVOCS, if the Philippine Trench causes 7.9 magnitude earthquake, a possible tsunami may hit Eastern Samar of up to 9 meter high. In 2012, a Magnitude 7.6 earthquake occurred and in 1897 somewhere in Northern Samar area a 7.3 earthquake was recorded from the area (Ye et al., 2012). On the left side of Samar Island lie the Philippine Fault and a Central Samar Lineament passes through Catbalogan City (PHIVOCS, 2015). Earthquakes occur when two blocks of the earth suddenly slip past one another and the surface where they slip is the fault or fault plane.

Samar frequently experiences earthquakes because of its proximity to this major fault system. Samar Island has experienced several stronger earthquakes in the past from as high as 7.2 happening mostly in the Eastern and Northern Samar. The more recent earthquakes above magnitude 6.5 occurred on July 6, 2017, somewhere in Leyte, the closest was in Can-Avid Eastern Samar some 15 years ago. Shown in Figure 4 and 5 is a screen grab illustration from Earthquake Track.

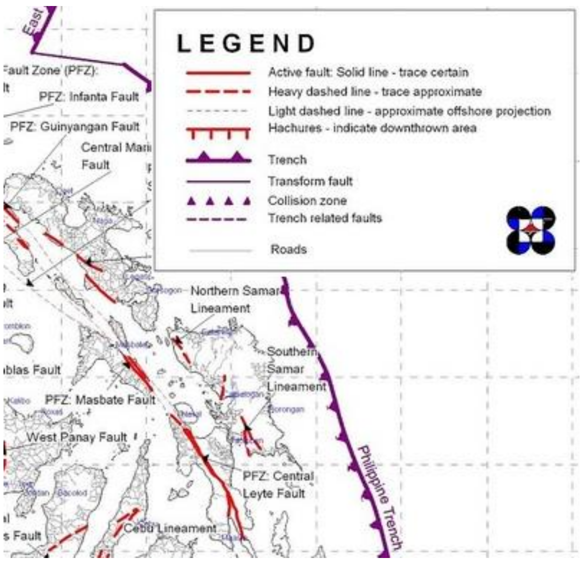

Figure 3. Distribution of Active Faults

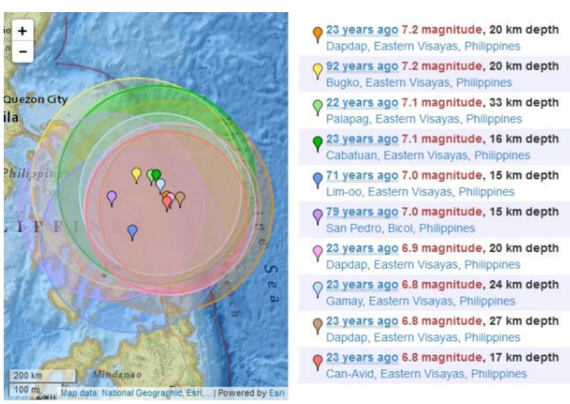

Figure 4. Biggest Earthquakes Near Samar, Philippines. (Source: Earthquake Track)

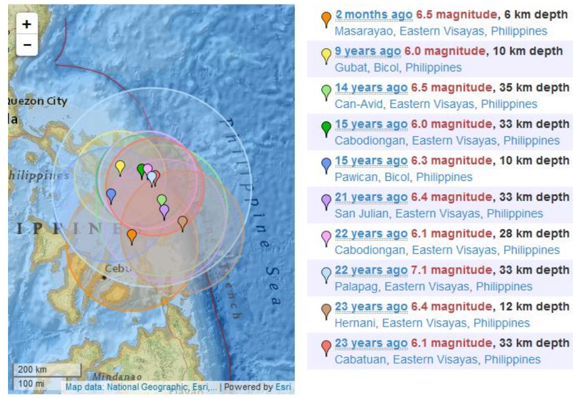

Figure 4. Recent Magnitude 6+ Earthquakes Near Samar, Philippines (Source: Earthquake Track)

4.2 Building Profile

4.1.1 Location and Building Use

A total of 127 buildings in seven (7) zones were considered in the study. Of these buildings, 40.2% are residential, 37.8% commercial, 12.6% office buildings, the rest are school (4.7%), hospital/clinics (2.4%), and storage facility (2.4%). Figure 3 shows the location of each type of building. School buildings and office included in the assessment are found in SSU Main campus.

Figure 3. Building Type and location

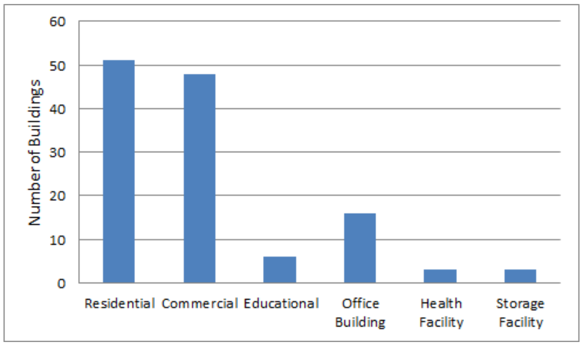

Figure 4. Number of Building Considered in the Assessment

4.1.2 Building Occupants

Population in each building type is dependent on its use. During office hours or school hours (up to 8:00 PM), school and office buildings are fully occupied. These buildings often have more than 100 people, especially during school days and hours. About 31% of the population considered in the analysis come from residential buildings, and these are mostly found in zones 1 to 4. Those with 11-20 occupants are found in zones 3 to 5.

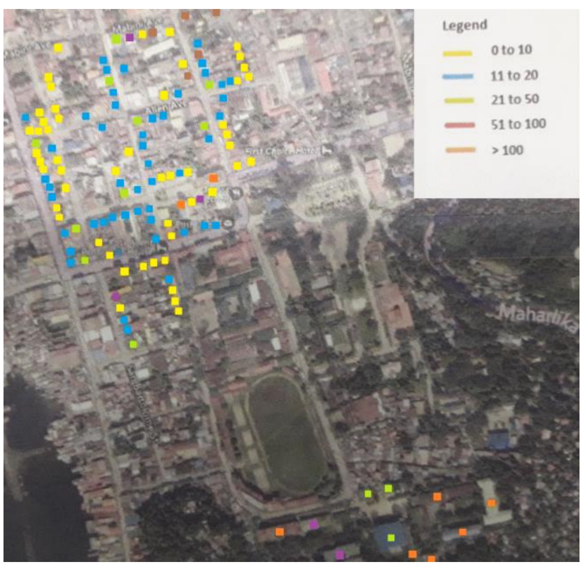

Figure 5. Occupants per Building Surveyed

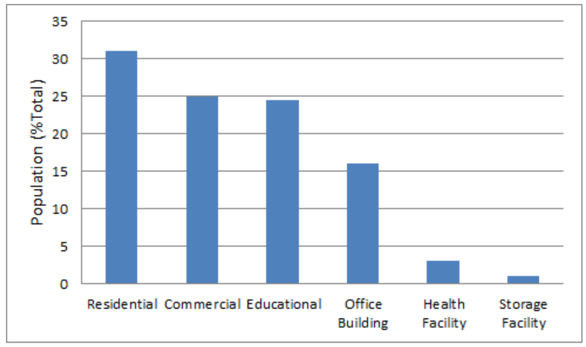

Figure 5. Population Distribution in Each Building Type

Residential, commercial and educational buildings have the most number of people. If these buildings get damage during earthquakes, larger casualties are expected.

4.1.3 Height of Buildings

Most of the buildings in the study area are of a low-rise type or buildings having 1 to 2 storeys. About 52 or 40.9% are low rise and 75 or 59.1% are midrise (3-7 storey), most of which are 3 to 4-storey buildings.

4.1.4 Building Type and Era of Construction

The specific characteristics of the study area include the vintage of the building and the predominant structure type for different years (pre-1972, 1972-1992, post-1992).

Table 2. Vintage Distribution of UPD-ICE Building Classification

Material	Type	Pre 1972	1972 1992	Post 1992	Total
Wood	W1	5	3	1	9
Masonry	CWS	4	9	14	27
	CHB	1	5	13	19
Concrete	CIL	1	6	14	21
	CIM	2	12	37	51
Total		13	35	79	127

Table 2 shows the vintage distribution of UPD-ICE building classifications from field survey data. Wood structures were built before 1972. Concrete and masonry type of buildings were common after 1972. About 72 (56.7%), 46 or (36.2%) buildings are concrete and 9 (7.1%) are wood.

4.1.5 Building Values

Building value refers to the assessed value according to the City Assessors Office. As shown in figure 6, a majority (59%) of the total buildings are valued at 1 to 5 million pesos. Most of these buildings are made of masonry walls and are 2 to 3 storeys tall with a floor area of less than 225 square meters. Few buildings (about 2%) of the buildings considered have worth of 15 million pesos or more. These are buildings with a floor area greater than 500 square meters like school buildings and hotels.

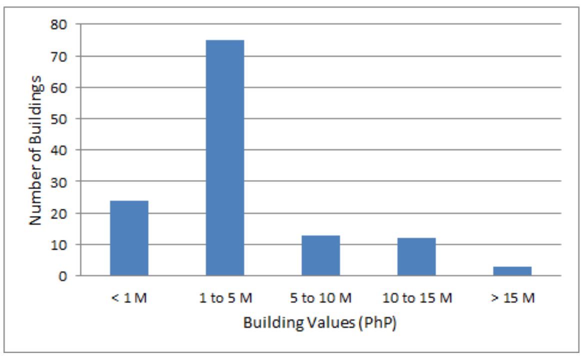

Figure 6. Building Values

4.3 Earthquake Impact Assessment

The forgoing estimates have not taken into consideration the kind of soil where the building is situated. Many of the zones considered in the study are standing on tidal flats which were reclaimed to give way to growing Catbalogan in the past. Soils Investigation Reports from the Soils and Materials Testing Laboratory of Samar State University reveals that silt to sandy soils is found in thick layers. Loose sand and silt that are saturated with water can behave like a liquid when shaken by an earthquake (USGS 2, nd.) When taken into account, geological conditions will contribute to the impact of an earthquake.

4.2.1 Structural Damage

Table 3. Number of Buildings Damaged in Each Zone Following Magnitude 6 Earthquakes

Magnitude 6								
Extent of Damage	Zone							
	1	2	3	4	5	6	7	T
Slight	1	2	3	3	1	1	1	12
Moderate	1	1	2	3	1	1	1	10
Extensive	0	1	2	2	0	0	0	5
Complete	0	0	1	1	0	0	0	2
Collapse	0	0	0	1	0	0	0	1
Total	2	4	8	10	2	2	2	30
Magnitude 7								
Slight	2	2	5	2	2	2	1	16
Moderate	2	1	3	4	2	1	1	14
Extensive	1	1	2	1	1	1	0	7
Complete	1	2	3	4	0	1	0	11
Collapse	0	1	1	2	0	0	0	4
Total	6	7	14	13	5	5	2	52
Magnitude 8								
Slight	4	2	3	4	4	2	4	23
Moderate	2	5	3	5	3	1	1	20
Extensive	1	3	3	3	1	1	1	13
Complete	3	3	5	3	2	2	1	19
Collapse	1	1	2	2	1	1	0	8
Total	11	14	16	19	11	7	7	83
Magnitude 9								
Slight	2	7	5	9	2	0	2	27
Moderate	4	9	11	8	5	3	3	43
Extensive	2	4	5	4	3	0	1	19
Complete	4	4	7	4	2	2	1	24
Collapse	1	2	2	2	1	2	1	11
Total	13	26	30	27	13	17	8	124

The impact of the earthquake was measured based on the report made by the

REDAS software after the simulation. It estimated building damaged, cost of damage and casualties.

As earthquake intensity increases, the number of building damage also increases. From less than 1% collapsing building after magnitude 6 earthquake, it rose to about 9% after magnitude 9 earthquake. At intensity 6, most of the damages expected are slight to moderate totaling to about 17% of the total building surveyed.

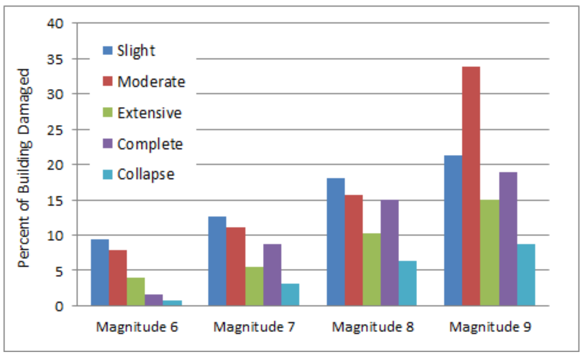

Figure 7. Building Damages at Different Magnitude

Figure 7 shows that at magnitude 6, around 24% of the buildings surveyed will have damage of varying magnitude, most of which are slight to moderate. At magnitude 7, the number of buildings damaged will rose to about 41%. The proportion of buildings with damage will rise to 65 and 98% for earthquake magnitude of 8 and 9 respectively.

Zone 6 will have more collapsing building than other zones. Zone 2, 3 and 4 will have a collapsing building even at magnitude 7 while in Zone 4, one (1) building is going to collapse at intensity 6. On the other hand, a little more than 10% of buildings at zone 7 will only collapse after Magnitude 9 earthquake.

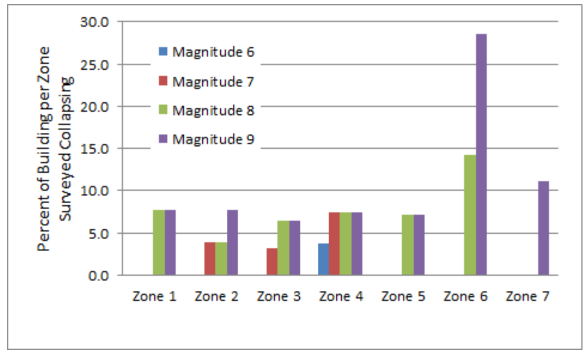

Figure 8. Percent of Building Collapsing

4.2.2 Monetary Loss

The losses herein referred are the direct losses with respect to the building value only. Estimated loss is about PhP 69 million, will rose to PhP 280 million at magnitude 7 and will reach PhP 504 million at magnitude 9 earthquake.

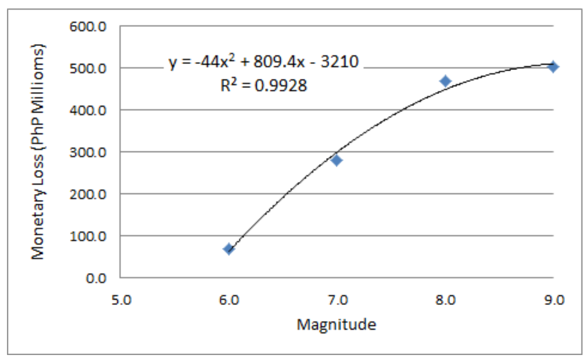

Figure 9. Monetary Loss Trend

4.2.3 Casualty Loss

Casualty loss is one of the most feared after effect of disasters. Most at risk are infrastructures where people congregate like gymnasium, classrooms, hospitals and the likes. These types of infrastructures receives higher factor of safety during designs to ensure its resilience to risks like earthquakes. Casualties were categorized as slight injuries (A), non-life threatening (B), life-threatening (C) and fatalities (D).

Table 3. Number of Buildings Damaged in Each Zone Following Magnitude 6 Earthquakes

Casualty type	Zone							
	1	2	3	4	5	6	7	T
Magnitude 6								
A	2	3	7	10	1	0	0	23
B	1	1	3	5	1	0	0	11
C	2	4	5	5	1	0	0	17
D	1	2	2	4	0	0	0	9
Total	6	10	17	24	3	0	0	60
Magnitude 7								
A	5	8	11	11	2	4	2	43
B	1	5	4	7	0	3	1	21
C	5	7	8	7	2	5	0	34
D	2	5	11	13	3	5	0	39
Total	13	25	34	38	7	17	3	137
Magnitude 8								
A	8	9	12	11	15	5	7	67
B	3	6	5	10	6	5	4	39
C	7	12	19	30	9	6	1	84
D	7	10	16	10	11	6	5	65
Total	25	37	52	61	41	22	17	225
Magnitude 9								
A	9	11	15	14	9	7	10	75
B	15	21	16	34	15	13	20	134
C	10	11	19	25	13	13	7	98
D	16	17	25	31	11	13	9	122
Total	50	60	75	104	48	46	46	429
%								

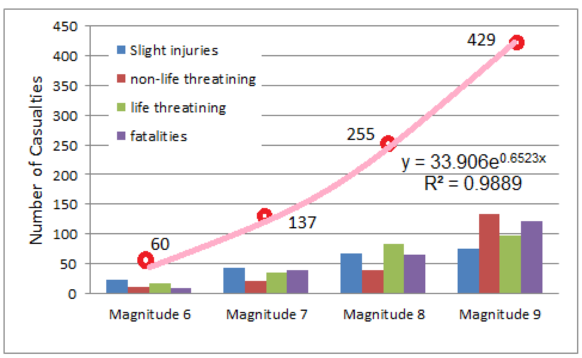

Figure 8. Number of Casualties

The number of casualties will be about 60 people out of the 3000 probable inhabitants of the buildings during magnitude 6 earthquake. Of the 60, nine fatalities are estimated found on Zone 4. The number of casualties will increase by about 128%, 197% and 290% for succeeding earthquake magnitudes respectively. Zone 4 (Barangay 3) is the most vulnerable among the seven(7) Zones evaluated. In a magnitude 9 earthquake, for example, this zone will expect 104 casualties or about 24.2% of the entire number of casualties. This section has several old structures.

5. Conclusion and Recommendation

The buildings in the area surveyed make up residential and commercial made of concrete and masonry and are midrise. About 59% of the building is worth PhP 1 to 5 million with a floor area of less than 225 sq.m.

At magnitude 6, 24% of the buildings are expected to be damaged; this will increase to 41, 65 and 98% for the Magnitude 7, 8 and 9 respectively.

Most vulnerable are buildings in zone 2, 3 and 4 with damage reaching 504 million and 122 fatalities.

The estimated data are not conclusive as it is based only on data inputted into the system. The expertise of the assessors (field surveyors) will have a huge influence on the accuracy level of the estimates. Furthermore, the software uses generalized data. The information shared here is just to provide the Building Official take-off point to do an actual assessment of buildings considered critical based on the simulation.

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