A GIS BASED APPROACH OF SEISMIC MICROZONATION OF CHITTAGONG CITY CORPORATION AREA, BANGLADESH

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ABSTRACT

The seismic microzonation map of Chittagong is prepared by using five thematic layers viz., Peak Ground Acceleration (PGA), soil type, geology, groundwater elevation and bedrock depth, integrated on GIS platform. The integration is performed following a pair-wise comparison of Analytical Hierarchy Process (AHP) where in each thematic map is assigned weight depending on expert opinion. After completing the AHP, the weightage assigned to each theme are: PGA (0.30), soil (0.24), geology (0.19), ground water (0.15) and bedrock depth (0.12). The thematic layers are overlaid and integrated using GIS. From the microzonation analysis it has been found that 12.64% and 28.39% area of it fall in very high and high seismic hazard zone respectively. It has been also found that North Halishahar, South Pahartali, Pathantooly, Rampur, Gosail Danga, South Halishahar, South Agrabad are found in high seismic hazard zone.

Introduction

Recent earthquake occurred in Nepal named Gorkha earthquake, 2015 and Japan named Kumamoto earthquake, 2016 with magnitude of 7.5 and 7.0 respectively causes lots of damages of life and property (USGS, 2016). Bangladesh is also not free from any possibilities of severe earthquake because of its geotectonic set-up (Sultana et. al, 2013). Based on the study of Seismic Hazard Assessment (SHA) report prepared by OYO International Corporation (OIC), there are five major fault zones in Bangladesh (CDMP, 2009). Chittagong city with its surroundings is situated in seismic zone II of three seismic zones (BNBC, 1993). On the other hand, 80-90% buildings and physical infrastructures in Chittagong are vulnerable to future massive earthquakes, as most of these were not designed to withstand this (Bhuiyan, Alam, Roy & Barua, 2006). So, it has become necessary to identify the seismic vulnerable areas of Chittagong city and also make earthquake vulnerability assessment of that area.

Study Area

Chittagong is the second largest city and main sea port of Bangladesh situated on the banks of the Karnafuli River. The city lies 22° 14′ North to 22° 24′30′′ north latitude and 91° 46′ east to 92° 14′east longitude and extend north bank of the Karnafuli River to west bank of the Halda River. The city, under the jurisdiction of City Corporation, has a population of about 2.5 million and is constantly growing (CDA, 2014). Chittagong city has a unique landscape. The river Karnafuli garlands it in the east and the south. The Bay of Bengal embraces it from the west. Beautiful and lush green hills adorn the city in the north (Ashraf, 2011).

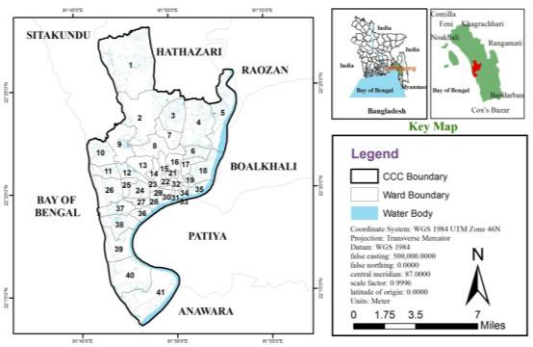

Figure 1. Location Map of CCC Area.

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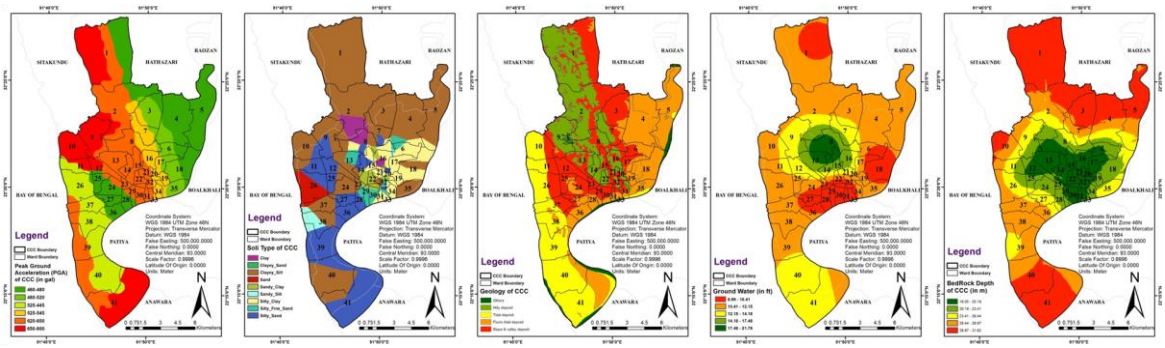
Methodology and Data

To prepare micro-zonation map, primary data has been collected through expert opinion survey. Different types of secondary data have been collected such as PGA data has been collected from CDMP by Ministry of Food and Disaster Management, Bangladesh; Geological data from Geological Survey of Bangladesh (GSB); Bedrock Depth, Ground Water and Soil Type collected from Thesis Paper, Journals, Different constriction company, Dept. of Civil Engineering, CUET and Southern University, Chittagong. GIS Data like different types of shape file has been collected from Chittagong Development Authority (CDA).

Mapping Attribute

Peak Ground Acceleration (PGA) map has been collected and manual digitized in the Arc-GIS environment. This PGA map contain six layer which are 460-480, 480-525, 525-545, 545-620, 620-650 and 650-800. Figure 2(a) represents the Peak Ground Acceleration (PGA) map. Bore hole data has been collected processed using Microsoft Excel and ArcGIS software. To prepare the soil type map mainly soil type character in 5 (five) meter depth is considered. Mainly nine types of soil is found which are Clay, Clayey Sand, Clayey Silt, Sandy Clay, Silty Clay, Sandy Silt, Silty Sand, Silty Fine sand and Sand. Figure 2(b) represents the soil type map of CCC. Geological Survey of Bangladesh (GSB) classified the geology of CCC into five classes. Classes are Fluvio tidal deposit, Hilly deposit, Slope & valley deposit, Tidal deposit and others. Figure 2(c) represents the Geological Map of CCC area. Ground water elevation data has been collected processed using Microsoft Excel and ArcGIS software data has been processed. The Ground water Depth is classified into five classes which are 17.49-21.76 (m), 14.19-17.48 (m), 12.16-14.18 (m), 10.42-12.15 (m) and 5.99-10.45 (m). Figure 2(d) represent the Ground water map of CCC. Bedrock depth data has been collected and processed in Microsoft Excel and ArcGIS software. The Bed rock Depth is classified into five classes which are 16.05-20.19, 20.20-23.41, 23.42-26.44, 26.45-28.97 and 28.98-31.82. Figure 2(e) represents the Bed rock Depth map of CCC.



(a) **(b)** **(c)** **(d)** **(e)**

Figure 2. Thematic map of the study area of CCC showing the (a) PGA map ranging from 460 to 800 gal; (b) Different types of soil at 5 m depth; (c) Different geological features; (d)ground water elevation map; (e) Bedrock depth at different levels at the subsurface.

Normalization

PGA, soil, ground water, bedrock depth and geology data contains several layers which are different in its types and unit. So, the numeric layers need to be normalized. Before normalization the numeric layers all data has been organized their preference according to their influence in seismic response (Anbazhagan & Sitharam, 2008; Mohanty et. al, 2004; Nath, & Pal, 2006). This thematic layer have been normalized between 0 and 1 to ensure that no layer exerts an influence beyond its determined weight (Anbazhagan & Sitharam, 2008; Kumar Nath, 2004; Mohanty et. al, 2006; Nath et al., 2014 and Nath, Thingbaijam, & Raj, 2008). Normalization is carried out using the following equation (1) (Nath, 2004).

$$\text{Normalized Rating, } x_i = \frac{R_j - R_{\min}}{R_{\max} - R_{\min}} \quad \text{..... (1)}$$

Where, R_j is the raw rating, After finishing normalization all thematic layers are named as their different factors name or attribute map. R_{max} and R_{min} are the maximum and minimum ratings of a particular layer.

Preparation of Weightage of Attribute Maps

After preparing attribute maps, all are weightage with Analytical Hierarchy Process (AHP). But the AHP process requires a pre-defined score or weight to input. The weighted value of each factor was derived through an expert opinion survey using AHP method. Opinion of 10 (ten) experts has been collected from the country to get better result. From the expert opinion survey and AHP operation PGA gets 0.30 weightage, Soil gets 0.24 weightage, Geology gets 0.19 weightage, Ground water gets 0.15 weightage and Bedrock depth gets 0.30 weightage. After then all layers are overlaid together using the following equation:

Microzonation Map = PGA × 0.31+ Soil × 0.23+ Geology × 0.18+ Ground water × 0.15 + Bedrock depth × 0.12 …… (2)

The weightage maps are classified into Five (5) classes using Natural breaks (Jenks) classification method. Natural Breaks classes are based on natural groupings inherent in the data. Class breaks are identified that best group similar values and that maximize the differences between classes. The features are divided into classes whose boundaries are set where there are relatively big differences in the data values (Rubel & Ahmed, 2013). The classified five classes are characterized by very high, high, Moderate, Low and Very Low hazard map is prepared.

Seismic Microzonation Analysis

Final seismic microzonation map is prepared with the help of mapping attribute and weightage develop from expert opinion survey using equation (2). The weightage maps are classified into five (5) classes using Natural breaks (Jenks) classification method. The classified five classes are characterized by Very high, high, Moderate, Low and Very Low hazard map is prepared. Figure 3 represents the Seismic Micro zonation map.

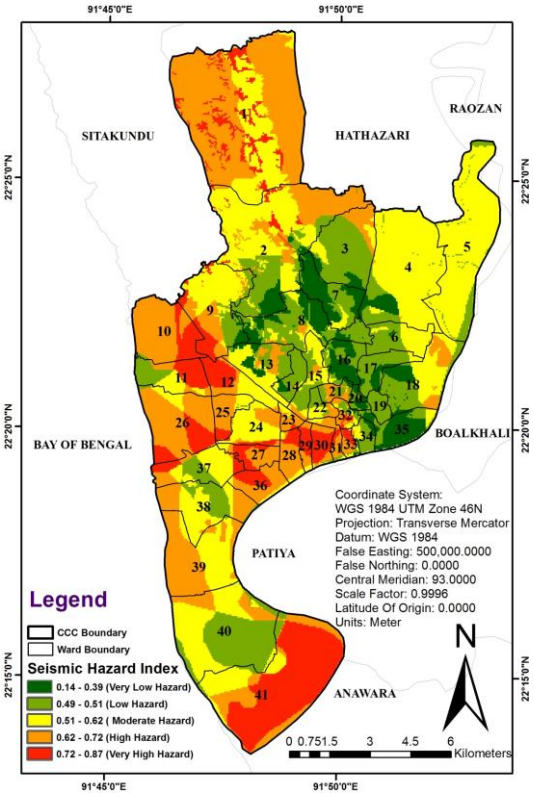


Figure 3. Seismic Microzonation Map of CCC Area (Source: Prepared by Author).

Area Wise Microzonation Analysis

From the Microzonation map hazard index value of very high, high, Moderate, Low and Very Low hazard is found 0.14 - 0.39, 0.49 – 0.51, 0.51 – 0.62, 0.62 – 0.72 and 0.72 – 0.87 respectively. Table 1 represents the area wise seismic microzonation assessment of CCC. From the seismic Microzonation map of CCC it has been found that around most of the area of it fall in moderate and high seismic hazard prone zone which is around 33 and 28 percent respectively. Very few percent of the area fall in low and very high seismic hazard prone which is around 19 and 13 percent respectively and only around 7 percent of the area fall in very low seismic prone zone. According to the above discussions of the results it is understood that most of the area of the CCC are moderate and high seismic prone area.

Ward Wise Microzonation Analysis

From the microzonation analysis it has been found that the wards named South Patenga, East Madarbari, West Madarbari, Saraipara, South Agrabad, South Kattali and Gosail Danga are found as very high seismic hazard prone areas. North Kattali, North Pathantooly, Alkaran, Gosail Danga, South Halishahar, South Agrabad, Jamal Khan and firingee bazar etc. are found as high seismic hazard prone areas. Mohra,

Chandgaon, North-Agrabad, Bagmoniram, Jalalabad, North Pahartali, South-Middle Halishahar and Pahartali etc. are found as moderate seismic hazard prone areas.

Table 1. Area Wise Seismic Microzonation Assessment of CCC

Hazard classes	**Hazard Index Value**	**Area in Sq. km**	**Percentage**
Very low Hazard	0.14 - 0.39	11.46778	6.67 %
Low Hazard	0.49 – 0.51	32.42195	18.86 %
Moderate Hazard	0.51 – 0.62	57.55365	33.47 %
High Hazard	0.62 – 0.72	48.82048	28.39 %
Very Hazard	0.72 – 0.87	21.7316	12.64 %

(Source: Prepared by Author)

Direction Wise Microzonation Analysis

From figure 3 it is understood that most of the areas of northern part of CCC fall in high and moderate zone, in southern part most of the areas fall in very high and high hazard zone and few of the areas fall in moderate and low hazard zone, in middle part most of the areas fall in low and very low hazard zone, the areas of eastern part mostly fall in moderate zone and the areas of western part mostly fall in high and moderate zone.

Conclusions

From the above analysis we can conclude that most the CCC region is exposed high to medium seismic hazard, while a small part lies within the safe zone. The seismic microzonation map can be used to prioritize risk mitigation investments, measures to strengthen the emergency preparedness and response mechanisms for reducing the losses and damages due to future earthquake events. It will also be of use for assessment of seismic risk to the existing construction, heavy industry, defense installation, and important structures like nuclear power stations, dams and other public utility services like gas pipe, water supply pipe etc.

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