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Earthquake Vulnerability Assessment of Existing Buildings in Cox's-Bazar using Field Survey & GIS

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***Abstract*—Urban earthquake vulnerability assessment of existing buildings is essential to local authorities. An efficient tool to assess the seismic vulnerability of existing buildings is also an important factor for planning urban/regional-scale emergency response and earthquake protection/retrofitting schemes to protect human lives, economy .This paper presents a methodology to predict the seismic vulnerability of buildings by key statistical analysis using GIS (Geographic Information System) based on a number of structural parameters that determined on the basis of engineering knowledge and observations. Building inventory survey chosen as a method for rapid visual screening during field survey to collect data for statistical analysis. In this case study, seismic vulnerability assessment of buildings is carried out for the city Cox's Bazar, situated on the bank of the Bay of Bengal, the main tourist's city of Bangladesh. The assessment showed seismic vulnerability factors recognized with heavy overhanging (26%), absent of basement (25%), pounding possibility (14%), plan irregularities (12%) and soft storey (7%).It is also observed that if one of the soft storey buildings under liquefaction fail which will affect the others very easily because all the building structure are very close to each other.**

Keywords—Vulnerability Factor; GIS; BuildingInventory

I. INTRODUCTION

Very few countries in the world are seismic risk like Bangladesh, as historical data reveals that several large earthquakes happened within or close to the country [24].Luckily, most of the major earthquakes were away from major cities and relatively sparsely populated areas and limited the human causalityas well as the economic losses [5].In recent years, occurrence of more frequent earthquake in and around indicates the probability of large earthquake which may affect this country any moment than any time before [13]. Thus earthquake vulnerability for Bangladesh increases due to its geology and topography, population density, building density and quality and finally the coping strategy of its people and its clear spatial variations [24, 8].Considering this reality, some awareness is raised among the limited groups but practically citizens of the cities and policy makers are far behind minimum awareness about the seismic vulnerability. However, the extent of seismic vulnerability can be reduced if necessary steps can be taken against the weakest earthquake resistant buildings as earthquakes do not kill people but unsafe buildings do.Therefore, there is a demand for the assessment of large number of existing buildings to earthquake.

Like other urban centers of Bangladesh,Cox's Bazar,most popular tourist city grown tremendously under unplanned urbanization, deny following building code, dropping down the quality control during construction and without considerationof the seismic effect in design made the existing buildings weak for future strong earthquake. Moreover due to tremendous development of the tourist spot in cox'sbazar, the town has planned without consideration of the soil parameter which is the hidden threat for that area as total sea beach and its nearby area of the town is liquefiable area [9, 2].Considering this realty, there is no significance database on structural condition of the existing buildings in cox'sbazar town and sea beach area. To address present situation of Cox's Bazar, this paper presents a seismic evaluation of existing buildings incox'sbazar to determine the nature and extent of deficiencies which can cause poor performance during future earthquake. Thus this would help to provide necessary information on the implication of planning in disaster mitigation and management measures before an earthquake strikes.

II. STUDY AREA

For this research purpose Cox'sBazar, the main tourist spot and long sea beach ofBangladesh, has been considered as a study area (Fig1).It is located at (22º-35´-0´´ N, 92º-01´-0´´E), bounded by the Chittagong district to the north,the Bandarban district to the east and the Bay of Bengal to the west.This area falls under seismic zone II as per BNBC1993 [4] and have experienced earthquake magnitude between 6 and 7 as per historical data [5]. As a result, Cox'sBazar and its nearby area is high risk zone to earthquake.

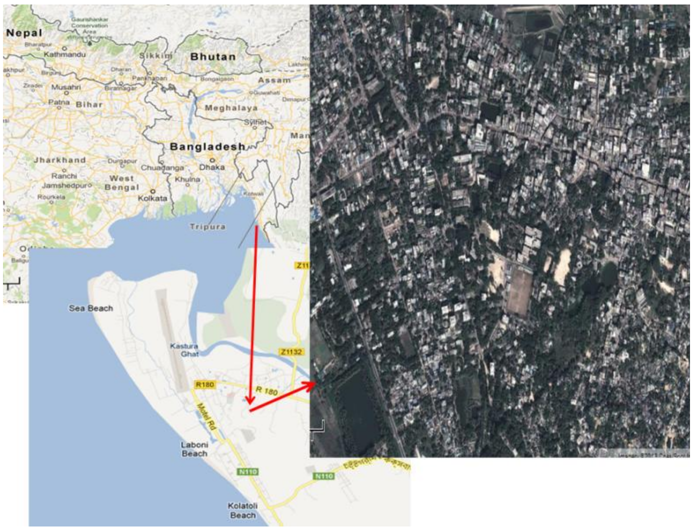

Fig1:Map showing Cox'sBazar town (Image Courtesy Google Maps)

This is one of the most densely populated areas of Bangladesh and Table 1 presents the demographic composition of the town.

TABLE 1: Demographic Composition of Cox's Bazar Municipality [6]

Item	Number
Male	81435
Female	70597
Total Population	152032
Households	31309
Population Growth Rate (%)	3.2
Density of Population	7588

Tourist resort made Cox'sBazar strategically an important area that acted as catalyst to build various establishments, construction of significant number of building structure in the past few decades. Most of these building structures are reinforced concrete frames with masonry infill with inappropriate construction practice` like soft storey. This appears that there is a need to understand the vulnerability of existing buildings so that proper measure can be taken to reduce the vulnerability.

III. BUILDING TYPE CLASSIFICATION

The absolute minimum facts required for a successful vulnerability study are number of buildings and structural types, because damage is predicted on building structure types. On this aspect it is seen that the existing building stock of Bangladesh especially in Cox's Bazar town is a rich mix of several different buildings types & construction technologies. The most commonly used buildings are (1) reinforced concrete frame building with infill brick wall;(2) brick masonry buildings with reinforced concrete roof and using cement mortar in most of the case and mud or lime mortar in few of buildings;(3)buildings made of Galvanized Iron (GI) sheets, thatch and other light weight and cheaper materials. Building classification system is utilized to group buildings with similar characteristics into a set of building classes to commensurate with the BNBC 2006[7] classes proposed as modified HAZUS building occupancy classes for Bangladesh showed in Table 3-16 by Comprehensive Disaster Management Programme[8]. For all building structural types three classes of height (Low-Rise, Mid-Rise and High-Rise) have been considered with respect to the occupancy type. Finally, the main buildings structural framing type has been categorized into thirteen types. This building classifications used in this study area for the development of inventories and vulnerability information which reflected region-specific building architecture and construction practices.

IV. SEISMIC VULNERABILITY FACTORS

All stages of earthquake vulnerability assessment, ranging from seismic hazard analysis to determination of a structure's response, include uncertainty. Structural vulnerability refers to the susceptibility of those parts of a building that are required for physical support when subjected to an intense earthquake or other hazard. This includes foundations, columns, supporting walls, beams, and floor slabs. The devastating effects of earthquakes during the last decades demonstrated in Fig 2 that the seismic vulnerability is one of the main causes of building collapse during an earthquake. Several structural features are considered as the seismic vulnerability factors for buildings including soft story, heavy overhang, short column, pounding possibility between adjacent buildings, visible ground settlement, and topographic effect etc.

Fig2.a:Soft storey effect in Düzce1999[2]

Fig 2.b: Effects of earthquake in Chile and Haiti 2010 [2]

Moreover, the existing building codes, regulations and the building types also play a vital role in seismic vulnerability of an area. Due to the existing building types and codes, the Haiti earthquake of January 2010 (Mw7 with an epicenter 25 km west of Haiti‘s capital) caused more casualties compared to the Chile earthquake in February 2010 (Mw8.8, 100 km away from the capital), (see in Fig 2.b).

V. SEISMIC VULNERABILITY ASSESSMENT METHOD

There are several well established seismic vulnerability assessment methods available around the world and it reflects own strengths and the purpose of application. However, previous application of available seismic vulnerability assessment methods to Bangladesh [5, 10] concludes that no one method around the world is suitable for Bangladesh context to evaluate seismic vulnerability of existing buildings.

In order to select appropriate tool for the seismic vulnerability assessment, it is required to review the existing methodology of seismic vulnerability assessment such as FEMA 154, FEMA 310, EURO CODE 8, NewZeland Guideline, Modified Turkish Method, NRC guideline, IITK-GSDM method, Japan method and Greek method[10,14-23],. All the methodologies have common objective to determine or quantify the future damage of building due to earthquake and identified some general steps such as –classification of building typologies, identification of a region, definition of the hazard in the region, collection of the damage evidence from past earthquake which have affected the region, choice of the methodology suitable for the region, collection of data relative to each building of the region, forecast of future damage scenarios in the region etc. Relative to review of the seismic vulnerability assessment methods it is possible recognize the main characterizes that an “Optimal Methodology” should have, in order to be able to identify seismic vulnerability [2]. However, it is difficult to find a methodology which can contain entire features mentioned. In this regard, a scoring system is proposed to select the suitable procedure as a vulnerability assessment technique that to be utilized for Cox'sBazar, Bangladesh. The ranking considers general description of vulnerability, building response factors, variance in output, applicability and ease of use, which are identified as the key characteristics required for vulnerability scales used in seismic vulnerability evaluation.

A performance scoring system is developed following Hill and Rossetto [11] to rank the vulnerability assessment methodologies according to three different criteria (general description, physical vulnerable parameters and description of output).Based on the scoring system it was observed that the“Optimal” (which includes the local site specific issues) method adequately satisfies all the criteria necessary for their use in seismic vulnerability assessment than other methods available around the world [2]. As a seismic risk analysis is an integrated approach, the choice of a suitable method for the vulnerability assessment strictly depends and strongly influences all the steps defined in the analysis as well as how in detail the built system characterized. In this regard, depending on the objective of the assessment, availability of data and technology, Lang [12] outlined an approach for increasing computational effort starting from observed vulnerability and expert options to simple analytical models and scores assignments to detail analysis procedures. However, in the Optimal method score assignment have omitted due to no data of damage for existing buildings in Cox's Bazar and based on Lang [12] approach the surveys were classified into 3 levels: Level-1, level-2, and level-3 surveys. However,this paper only focuses at Level-1 which is known as Building inventory survey.

VI. BUILDING INVENTORY SURVEY

Building inventory survey chosen as a method for rapid visual screening without performing any structural calculation. Information of each and every building structure can be collected by walking past the structure by visually inspecting. In this method a surveyor examines building from the street without entering into a building and requires maximum 30 minutes to identify features that affect the seismic performance of the building. This survey is carried out based on the checklist provided in forms.

Later this survey procedure can be integrated with GIS-based city planning database and can also be used with advanced risk analysis. Finally, combination of spatial and attribute data as input in GIS shows the vulnerability of each building element and overall vulnerability of selected areas against earthquake through maps.

A.Parameters of Building Inventory Survey

The building inventory is a simple tool used to assess the seismic vulnerability that consists of data such as building structural type, the building occupancy class, and the number of building occupants during the day and the night, the total floor area, the number of stories and the seismic vulnerability characteristics of building etc. These parameters consider on the basis of the previous expert judgment and such information is obtained through field survey.

B.Process of Building Inventory Survey

In order to perform the building inventory survey to collect different information about building structure, the building inventory survey procedure has divided namely three steps. They are: Pre-field survey, Field survey & Post field survey. Each of the step describe below:

1) Pre-field survey

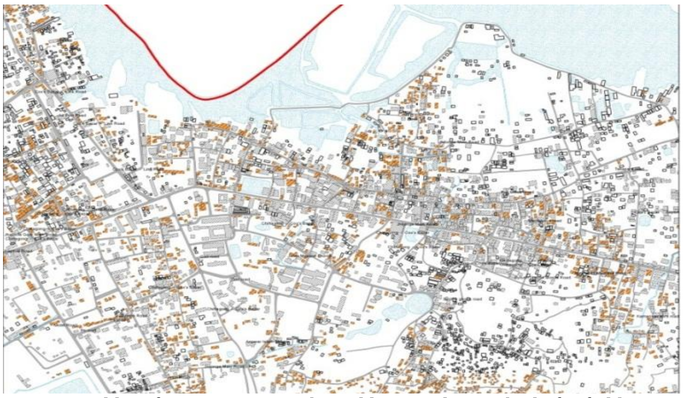

Fig3: Building footprint maps with road layer and water body for field survey [2]

Before going to field, relevant data available from different source, especially the secondary data collected from Cox's Bazar municipality. To twitch the field data collection, building footprint maps were created using JPEG image in the background of the existing road layer and water body. Having such data, the study area was divided into 9 blocks and Fig 3 shows one of the blocks in which the yellow color indicates the position of the sample building structures. Then each of the blocks printed in larger form and used for the field survey.

2) Field survey

A format of data form was developed to collect the field data. Then the positioning of the individual building in the building footprint was carried out in the field through visual observation & GPS.No internal observations of buildings and no interviews with house owners were taken in this process as well as no detailed measurements were made .Parameters like size and ages, other features were also recorded from external observation of the physical characteristics of each building. The attributes of all the buildings were recorded using this process.

3) Post-field survey

The main task in data processing after field survey consists of scanning the field maps, digitizing the field maps and linking the building foot print with the attributes collected from the field and stored in spread sheet.

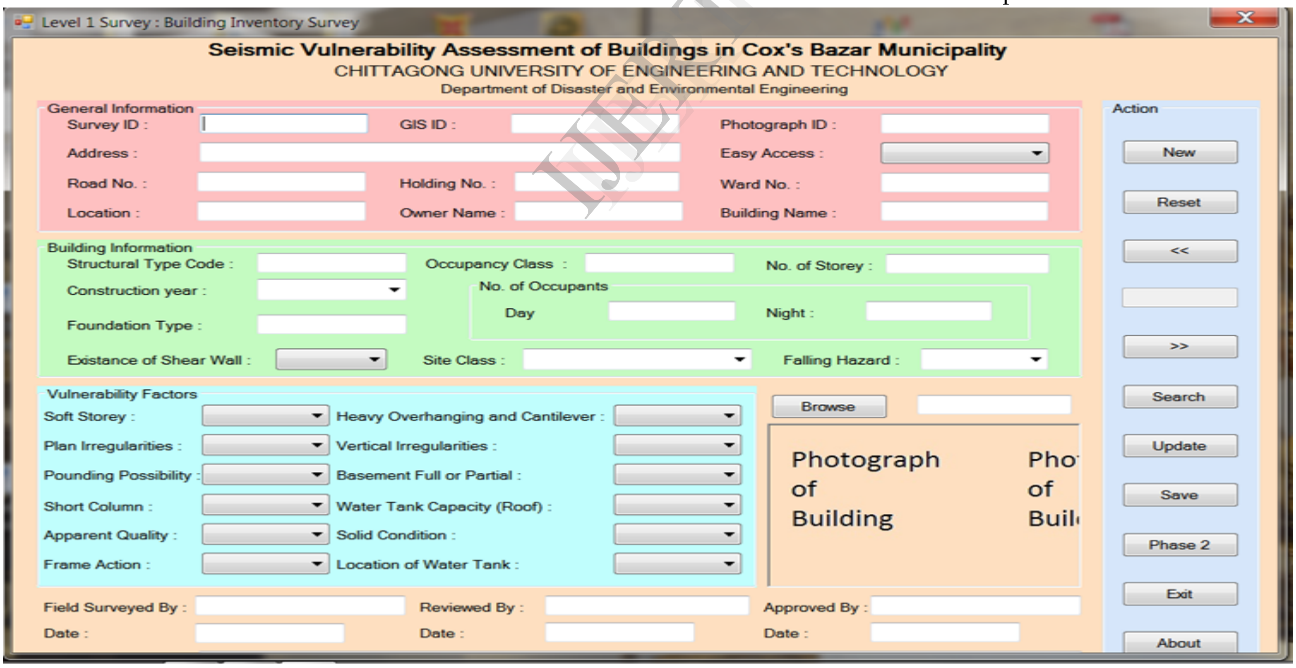

Fig 4: Input Module database format for Level-1 survey [2]

All the information gathered from the field survey was tabulated in Input Module (developed by Seasharp software) side by side with the data of field survey. Fig 4 demonstrated the window of the Input Module where data was tabulated. A corrected and adjusted Input Module database and Excel worksheet of the building inventory of Cox'sBazar Municipality and adjoining sea beach area was organized. All these data was imported in GIS [3] for further analysis. The overall procedure for generation of vulnerability factors scenarios in the GIS environment for seismic vulnerability assessment shows in Fig 5. Total 945 sample buildings in the tourist city Coxs' Bazar has been conducted to find the conveniences of the proposed vulnerability assessment method. Hence, pre-earthquake vulnerability assessment methods by visual screening using Building Inventory Survey have been considered to cope up the real picture at present. Once the required data collected; the database goes under the quality inspection phase. With the approval from the quality inspection, the whole database is subjected under a GIS query analysis to formulate the input. After completion the quality inspection the existing dataset was enriched for analysis of the vulnerability factors of sampled reinforced concrete buildings in the whole town. Result of vulnerability analysis is shown in GIS maps, to show the spatial distributions of the seismic vulnerability states of sample building structure.

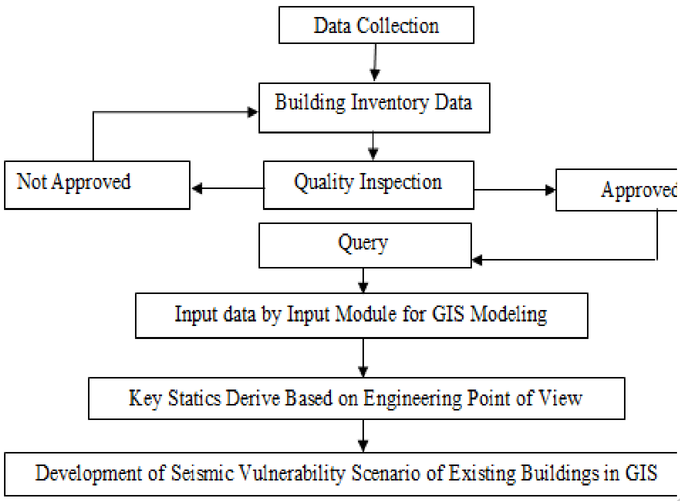

Fig5: Development of seismic vulnerability factors scenarios in GIS [2]

VII. RESULT AND ANALYSIS OFASSESSMENT OF EXISTING BUILDINGS

General observations from the collected data of Cox's Bazar municipality and adjoining sea beach area gives a view what may happen with an occurrence of future earthquake. To cope up the assessment a relationship scenario was build up with different parameters and vulnerability factors.

A Comparison among Vulnerability Factors Scenario

Fig 6 shows that there are existing different vulnerability factors which might be affecting the seismic vulnerability to sample reinforced concrete buildings in Cox's Bazar .Among considered seismic vulnerability factors in survey, heavy overhanging, & absence of basement were found 26% & 25 % respectively which are largely governed in the whole study area. It also observed form the data analysis that half of sample buildings were found seismically vulnerable for pounding possibility by 14% as compared to considered all seismic vulnerability factors. Besides, plan irregularity is 10% higher than vertical irregularities for sample buildings. Thus, plan irregularity plays major role in the geometrical irregularities as a vulnerability factor for the study area. It also seen from the analysis that soft soil condition and asymmetric location of water tank are 7% and 8 % respectively. On the other hand, there are 238 soft storey building structure among the sampled buildings.Out of all considered vulnerability factors, short column and frame action are found lowest number of buildings in thestudy area.

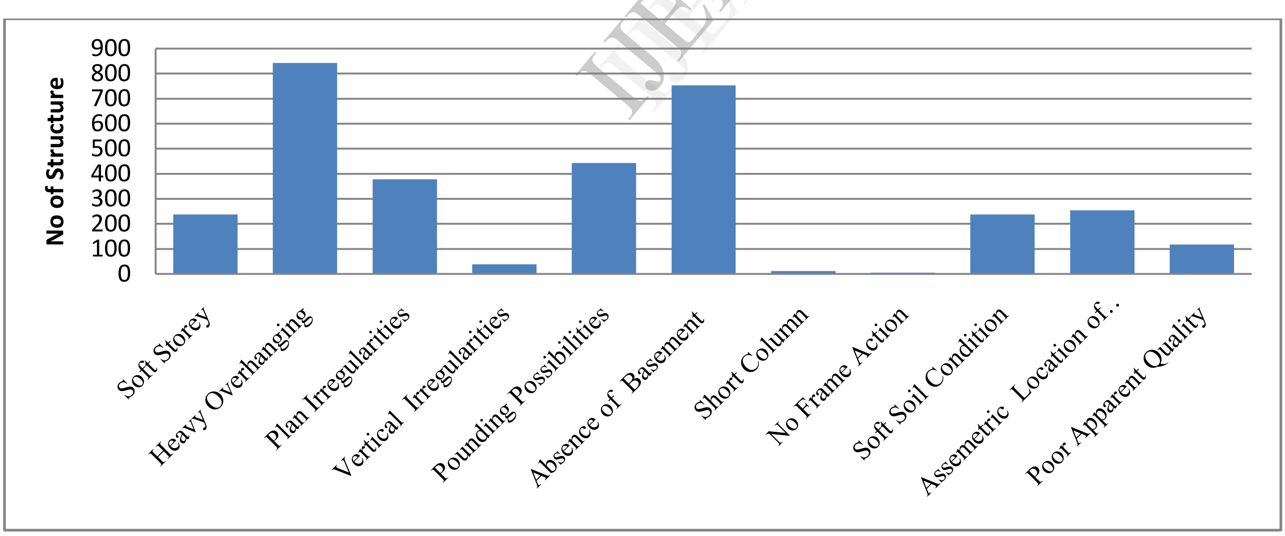

Fig 6: Vulnerability Factors of the Sample Buildings Scenario

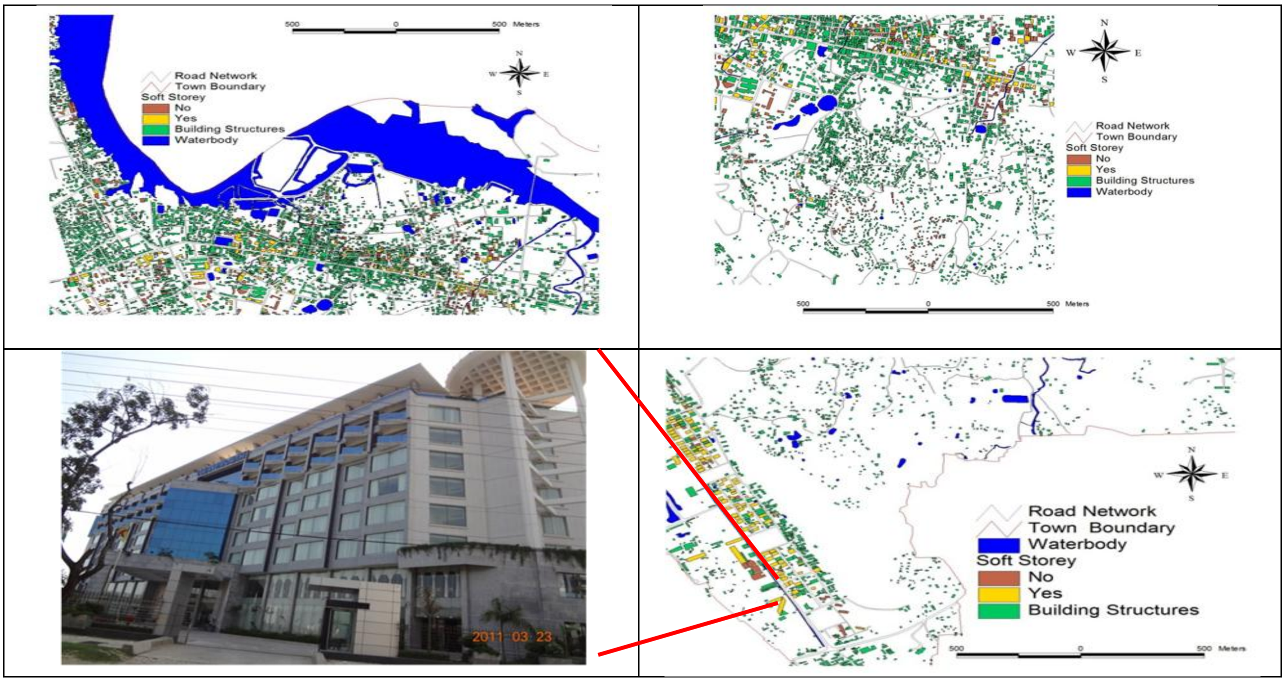

Fig7: North, Middle & South Cox’s Bazar Town with soft storey phenomena

Fig 7 describes the soft stoey scenario at CoxsBazar by building footprint in which the soft storey building structures are marked by yeollow colure . It also indicates maximum soft storey buildings are locate at Kolatoli Road near the sea beach and along the main road of the town .As a tourist spotof Bangladesh,Barmiz market is famous for traditional & sea products and all the building structures of this market exist with soft storey phenomena.

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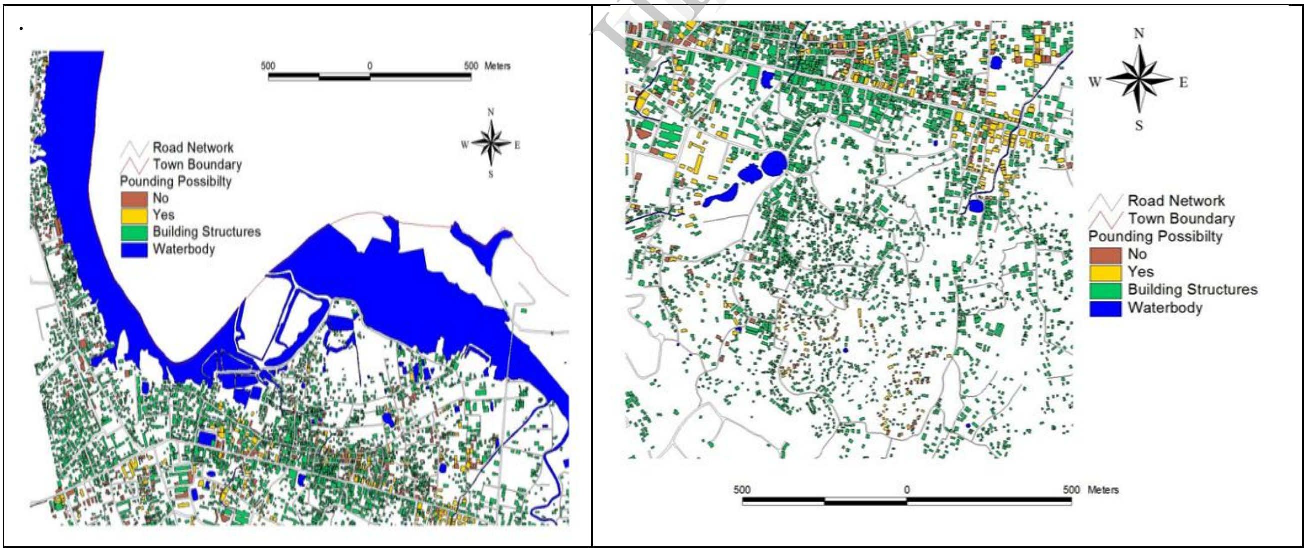

Fig8: North, Middle, and SouthCox'sBazar Town with Pounding Possibility

In the Fig 8, it is seen that lacking of sufficient distance among sample buildings. Therefore, the town is highly vulnerable due to pounding effect. Most significance feature at the Kolatoli road near sea beach hotels, motel inn and club are very close to each other which are highly possible to affect each other during the earthquake.

B Relationship between Vulnerability Factors and Structural Type

Based on the material used, frame configuration and the number of floors, during the field survey reinforced concrete buildings were focused. Fig 9 shows the survey result on three types RCC buildings for the seismic vulnerability factors contributing to damage for the sample building structure in future earthquake.However, majority portion of the sample building structure in the study area is C1 type building than C2 and C3 type building. As a result, it is indicated that C1 type sample buildings are very high vulnerability in the whole study area.

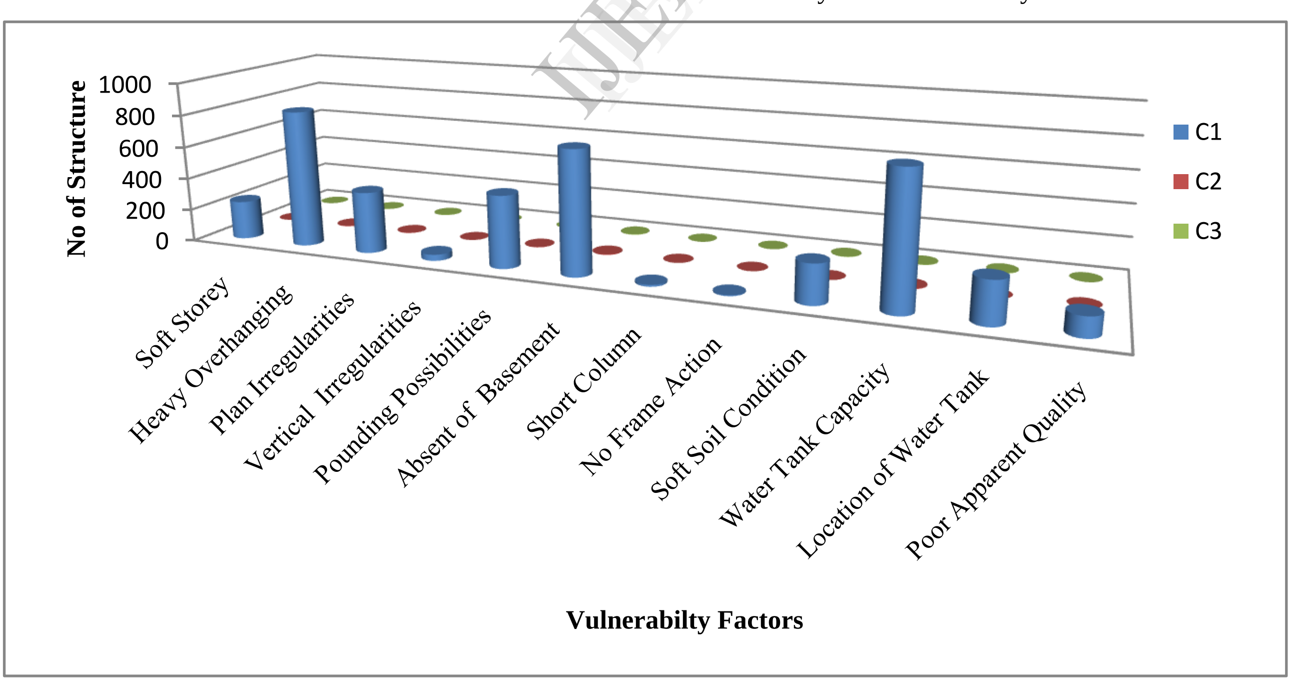

Fig9: Relationship between vulnerability factors and structural type

C Relationship between Vulnerability Factors and Occupancy Class

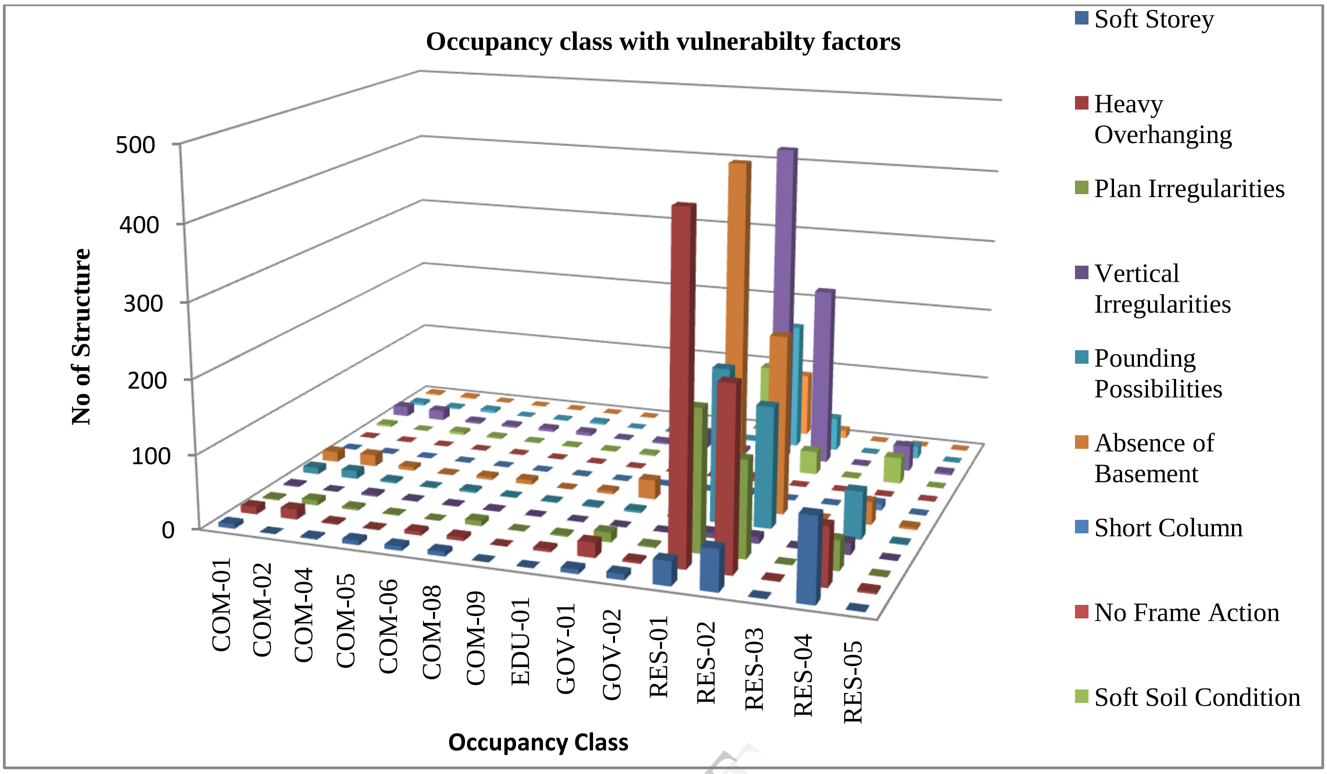

Fig10: Relationship between occupancy class and vulnerability factors

According to the Fig10, it is seen that RES-01, RES-02, and RES-04 type occupancy are more vulnerable than other occupancy class during the forthcoming earthquake. The graph also indicates motel, hotel, rest house, inns, and clubs are categories as residential type 4 belongs to highest soft storey phenomena among the occupancy class. On the other hand heavy overhanging and pounding possibility is observed maximum over (RES-01) single family residential buildings than the RES-2 type's residential apartment buildings. Therefore, it can be stated that residential sample buildings are more vulnerable in the whole study area.

D Relationship among Population Distribution with Occupancy Class and Day Time

From the collected population data during field survey it was found that the number of people varies in different times of the day for their activity. In Fig11 it is demonstrated that always some residential buildings has high population density both day and night time. However, commercial use building defined COM-05 (e.g. banks, office) has high population than other occupancy class except residential type at day time. The situation is opposite at night to day time because population started to leave after the office hour, therefore population density becomes low. On the other hand, after completion of daily activity, population started to come to the home as a result the population in the residential type building RES-02 is increased maximum at night than any other occupancy class. As it is a tourist city the population distribution for RES-04 is very high at night (34%) and day (23%), whereas for RES-02 it is 36% at night and 25% at morning (see Fig11).More specifically, in day and night time majority of the people inside of this category buildings are more vulnerable to earthquake because the possibility of trap percentage is very high.

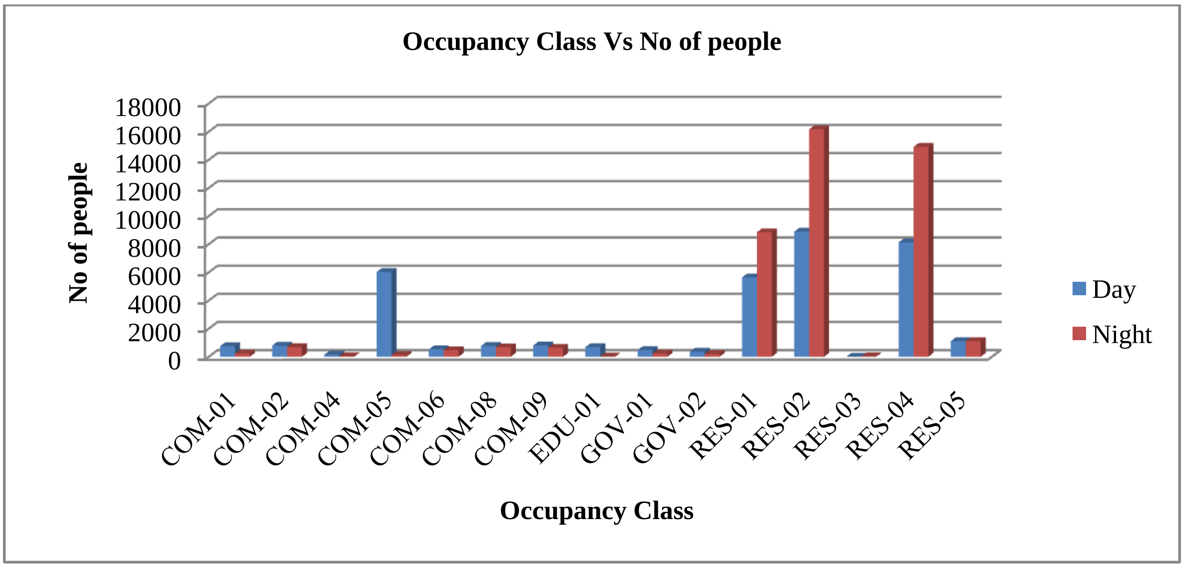

Fig11: Relationship between occupancy class and time

E Scenario of Structural Type with Apparent Quality and Age

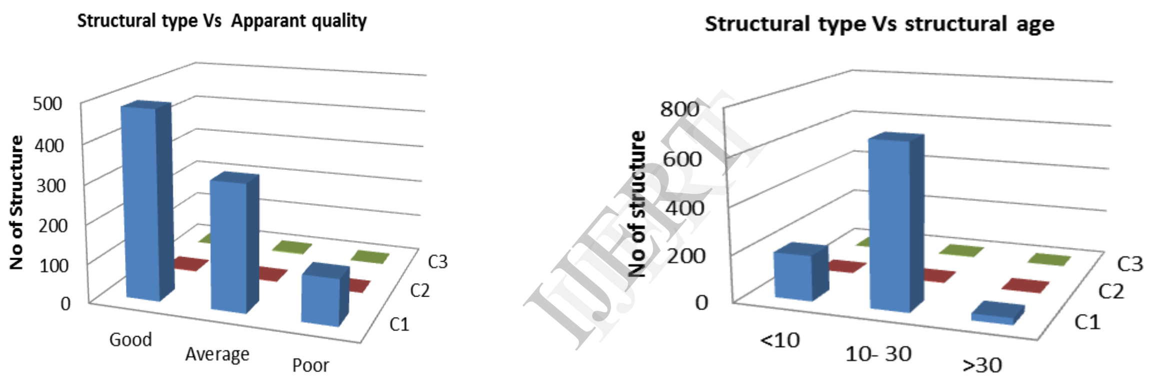

Fig12: Relationship of structural type with Apparent Quality and Age

The Fig 12 demonstrations the finding of the field survey of sample building structure based on structural age and apparent quality of reinforced concrete buildings structure types. The most striking feature is dramatic increase in the number of good apparent quality of C1 typestructure than C2 & C3 type structure. Therefore, this evidence reveals that C1 type buildings come more popular than other types during last ten years. Thus it can be supposed that construction boom have occurred in Cox'sBazar for development and tourist spot in recent time.

From the developed database and vulnerability maps, the major findings regarding to the seismic vulnerability of building, can be summarized as the followings:

a) The assessment showed that seismic vulnerability factors in Cox's Bazar town is recognized with heavy overhanging (26%), absent of basement (25%), pounding possibility (14%), plan irregularities (12%) and soft storey (7%).It is also observed that 25.18% of the sample buildings are soft storey can lead catastrophic disaster if one of the soft storey buildings under liquefaction fail that will affect the others due to very close adjacent buildings.

b) Among occupancy classes in the study area, residential class is major proportion. Their proportions are 10%, 28%, and 51% in hotel type, residential apartment, and single family house respectively.

c) Among structural type of engineered buildings, C1 (concrete moment resistant frame) is the most common class.

d) From the survey results, age of buildings has been related to structural types. For example, it was found that most buildings with concrete moment resistant frame (C1) are constructed less than 10 years as well as more than 10 years ago. On the other hand, most concrete with masonry infill (C3) are found to be older than reinforced concrete buildings (RC).

e) As expected, all residential types has an average number of occupants in the daytime less than the nighttime; nevertheless, the other occupancy classes such as commercial, industrial, government, and education have the number of occupants in the daytime more than the nighttime.

VIII. CONCLUSION

This study mainly targets to attract the interest on the present situation of Cox'sBazar for future earthquake by seismic vulnerability assessment based on rapid visual screening. It is seen that concrete moment resisting frame (most popular in residential category) is under threat for forthcoming earthquake by several vulnerability factors. If one of the soft storeybuildings under liquefaction fails [1] it will affect the others very easily because all thebuilding structureis very close to each other. Moreover, it will be catastrophic disaster if the earthquake occurs at night. It also demonstrated that most of the buildings which looks good and build within 10 years have increasing the vulnerability factors day by day. Based on this study the recommendation are marks below:

1) All the engineers, planers, architecture, local dwelling should be aware and work together for mitigation of this problem.

2) The structure which is vulnerable for future earthquake should proceed under strengthen and retrofitting program.

3) Development a score based vulnerability function for pre earthquake so that actual damage situation would provide an excellent basis for the theoretical study and conclude about methodology reliability.

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