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RAPID VISUAL SCREENING OF SEISMIC VULNERABILITY OF BANDAR ABBAS IN SOUTHERN IRAN

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ABSTRACT

Bandar Abbas, center of Hormozgan province, is one of the most important port cities in southern Iran. Importance of the Bandar Abbas, from political, economical and social aspects, in addition to the high risk of earthquake occurrence of this city, makes the study on the probable seismic hazard, risks and microzonation and seismic vulnerability assessment of buildings a necessity. This study aims at representing an overall vulnerability of existing or under construction structures based on a rapid assessment using available documents and field observations, to do so first the city area was divided into different zones, and then in each zone, required observations were performed and necessary data with respect to recent common codes were collected. Finally, the area of the Bandar Abbas city was divided into different regions; approximate value of vulnerability in each area was calculated and shown on vulnerability maps of Bandar Abbas. This map can be useful in risk management and decision-making.

Introduction

Iran, situated over the Alpine-Himalayan seismic belt, is one of the seismic active countries in the World. The existence of the active Makran fault deposits of Bandar Abbas plane and the occurrence of severe past earthquakes [1], all show the high seismicity of this region. Considering special features of this city, including highly dense population in line with political and economical importance makes evaluation of seismic vulnerability of this city of great importance. There are many methods to gain vulnerability map in combination with hazard map in order to obtain risk map [2,3]. This study is a part of an ongoing research to develop risk map of the Bandar Abbas

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region. The risk that building experience damage more severe than that it was initially designed for is a function of two principal factors: structure's vulnerability and site hazard [4]. Seismic vulnerability in wide areas is usually assessed based on inventories of structural parameters of the building stock, especially in high hazard countries like Iran. Ambient vibrations analyses seem to be an alternative way to determine the vulnerability of buildings. The modal parameters extracted from these recordings would give the researchers very useful information about the building's class that may be found in the study area. The distribution of the classes in the city will lead to a vulnerability map [5]. Different techniques are often employed to assess the vulnerability of existing buildings that are usually considered as the most vulnerable. These methods were developed for area-wide data collection. Many of them are based on the inventory of structural parameters of the design collected by visual inspections and related to observational data of damage during past earthquakes (EMS98[6], HAZUS [7], GNDT [8]). Nevertheless, these methods are well adapted in regions with high seismicity where recent significant damage due to earthquakes has been observed (like bam earthquake in Iran). Indeed, they are generally used for the calibration of the vulnerability curves, accounting for the specifications of the structural design in each region. Ambient vibration analysis is proposed as an alternative way to inspect buildings before or after an earthquake [9]. This fast and low-cost method is well adapted to large-scale studies for which a large amount of buildings has to be instrumented.

Site introduction and Study method

Hormozgan, a mountainous province, is one of the southern provinces of Iran, located between $25^{\circ}24'$, $28^{\circ}57'$ northern latitudes and, $53^{\circ}41'$, $59^{\circ}15'$ eastern longitudes. Bandar Abbas, center of Hormozgan province is located coast wise of sea and has hot and humid weather. This area has long hot summers and short mild winters.

To evaluate vulnerability of this city, Bandar Abbas was divided into three urban zones and was numbered using the existing urban maps (fig.1). Some information collected from Bandar Abbas local engineers and organizations, for instance, kinds and vulnerability of the structures, vacant houses, population distribution and some other data. To gather needed information, special forms were designed in accordance with suggested forms in FEMA 154(ATC21) [10] and other available references. Also local needs such as inclusion of: potential of landslide, or narrow streets and their potential to be blocked due to falling of buildings, lifeline such as pipeline, gas line, type of construction and their quality were included in the prepared forms. It is also essential to study vulnerability of lifelines, fire stations, hospitals, populated places (like school, Hotels) and their ability to serve people after major earthquake occurrence. However, due to determined study target, only dominant buildings in each section were studied. Outcome of the forms will be presented in other sections.

Studied building and facilities

Bandar Abbas is categorized as a high-risk region according to national seismic code of practice (2800 standard) [1]. The buildings studied are all of common types of construction in the area, such as reinforced concrete (RC) and steel structures, adobe and masonry buildings. The latter is mostly located in the centre and sometimes scattered around Bandar Abbas. Old texture of city is located in the center and near the shoreline. This kind of scattering texture makes it difficult to evaluate the exact vulnerability as a whole. Enormous variations are noticeable in types and quality of construction according to ancient and new areas of this city. Furthermore, different types of soil or different levels of underground water due to gradient of water resources cause different level of vulnerability. To study the vulnerability, the city was divided into some areas. Fig. 1 shows these areas and their local centers, the main feature of these divisions is the likelihood of vulnerability regarding to the type and quality of constructions, soil condition such as soil type according to geoseismograph records, potential of landslide, and underground water level.

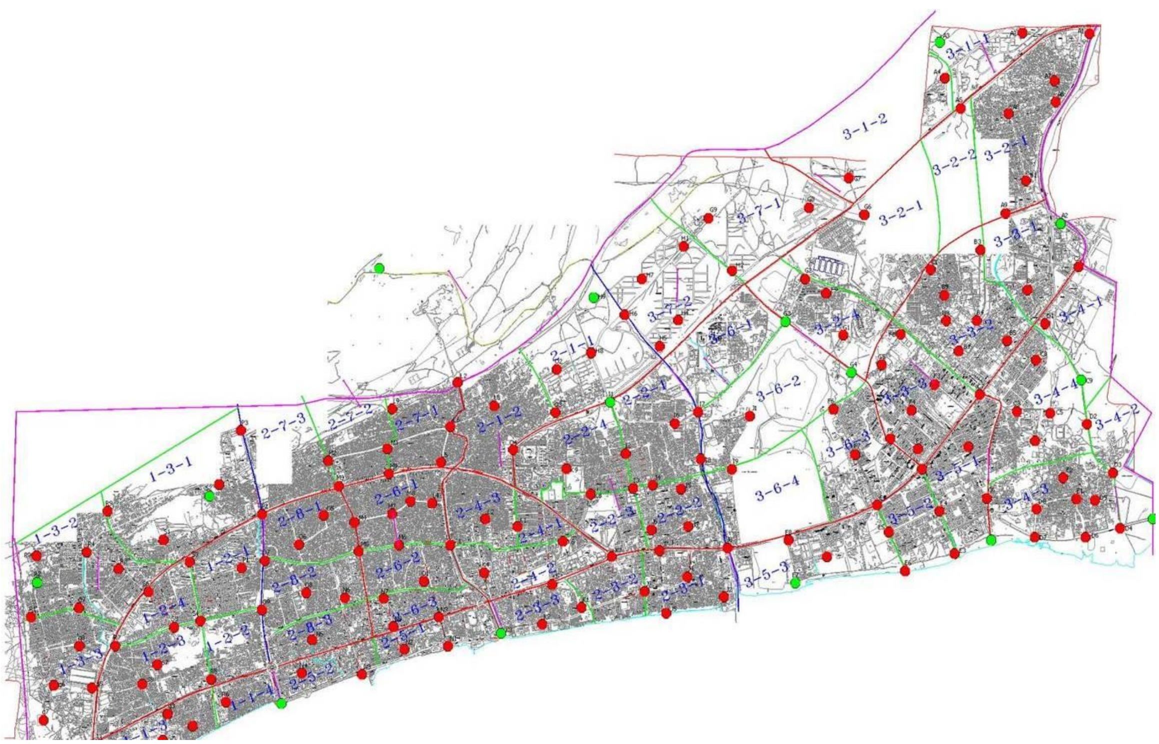

Figure 1. Primary map of Bandar Abbas zones

Categorization of problems and constructional defect in the area

According to field survey in this study some major problems were identified and classified; these classifications were performed according to foundation, site effect, constructional defects and topographic features. Hereby, some vulnerable conditions, which make the site hazardous, will be described.

Site effect

Because of Bandar Abbas proximity to Persian Gulf, the underground water level is high which would make some problem in soil bearing capacity; the soil strength in some areas reach values as low as 0.7 kg/cm^2 or even less; another issue that should be studied is the possibility of liquefaction and landslide due to high water level. This situation is critical along shoreline and in North West of Bandar Abbas that the conditions are devastating. There is evidence of landslide in some valley in north of Bandar Abbas. Fig. 2 shows risk of landslide in north of the city and fig. 3 shows high underground water level which is about 2 meters from the surface.

Figure 2. Risk of landslide in North of the city

Figure 3. High level of underground water

Constructional defect

There were many ongoing construction projects when the research was running; therefore, there were many sources to collect some information about quality of construction. Unfortunately, the quality of construction because of workmanship error and lack of expertise and devastating condition of material maintenance is poor also because of lack of proper supervision according to building codes, the quality of construction in non-governmental and governmental sections are not acceptable. Also because of improper condition of maintenance in ports near the shore and humidity and sulfate and chloride attack, corrosion effect happen in most of structures and facilities. This phenomenon is completely destructive near the port and lifelines. In addition, adobe structures because of their brittle nature and heavy ceiling without proper lateral load resisting system combined with low quality construction of ties to maintain the integrity are considered as vulnerable structures [11]; Moreover, the masonry buildings because of not employing the building regulations are commonly vulnerable. Totally, the old texture of the city consists of structures with massive element and poor foundation and lack of lateral load bearing elements and integrity. Therefore, old textures of the city are considered as very vulnerable regions. It is worth mentioning that such old textures were seen in the bam earthquake that was the location of many lost lives. Figs. 4 and 5 show improper material or improper usage of material (lack of continuous welding line) [12, 13], also fig. 6 shows bad maintenance condition. Fig. 7 shows bad condition of protection and corrosion and destruction of material of a deck and pile of the seaport.

Figure 4. Using material debris to build bearing wall

Figure 5. Discontinuity in welding line in cast column

Figure 6. Improper maintenance of material (bars)

Figure 7. Devastating condition of seaport

Figure 8. Lack of restrictions of infill and improper portioning of frame elements

Figure 9. Lack of integrity in concrete ties connection

Fig. 8 shows improper portioning of frame elements and also improper infill restriction for out of plane forces, fig. 9 shows lack of control and supervision of constructional project which lead to vulnerable situation in constructions. Constructional-defect cases in governmental projects are lower than rest of the projects because of better supervision. Masonry buildings are distributed in the city, but their concentration are near the shoreline, because of not using proper tie elements to connected the walls and ceiling together and maintain the integrity of the masonry buildings [11], it is classified as hazardous type in this area based on building codes of practice. Figs. 10 and 11 show unreinforced masonry and adobe buildings, figs. 12 to 15 show landslide danger or improper location of construction.

Figure 10. Unreinforced masonry buildings and adobe buildings

Figure 11. Improper foundation in adobe buildings

Figure 12. Improper location for construction

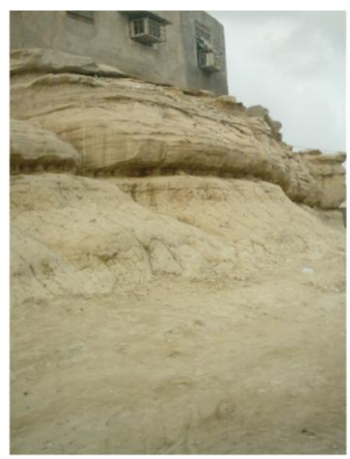

Figure13. The foundation exposed to landslide hazard

Figure 14. Buildings exposed to landslide

Figure 15. Buildings exposed to landslide

Data processing and vulnerability assessment

Conducting field survey, structures were categorized based on their overall vulnerability in the studied areas. Table 1 shows the most important factors considered in assigning vulnerability in terms of colors. Every item of this table indicates some specifications of vulnerability map and each item was included in the forms with some more details related to that subject. For example, the item of supervision and controlling of considering building regulations has more details about the presence of irregularity in stiffness or mass distribution in the height or plan of the structure.

Proposed vulnerability map of this region is shown in Fig.16. This map (along with hazard consideration) suggests that rehabilitation of the old general plan with regard to existing urban area is necessary. North and northwestern parts of this city have risk of landslide. There is no protection for foundation against the underground water level [14].

Table 1 Different vulnerability levels categorization in this study

Very high vulnerability

- Structures without frames or ties
- Structures built on improper soil, in high underground water level regions (With liquefaction and landslide potential)
- Structures without engineered foundations
- Structures constructed with no engineering supervision
- Highly corroded structures
- Structures on sides of narrow passages with no or very little vehicle passing capacity (passage width ≤ 1.5 m) that may be blocked during earthquake)
- Structures placed far from medical or emergency facilities (distance more than 20 km)

- Structures partially tied or framed
- Under construction structures partially affected by corrosion
- Structures constructed with little supervision by practical constructors
- Structures on sides of passages with limited vehicle capacity (1.5 < passage width ≤ 4 m)
- Structures placed rather far from medical or emergency facilities(distance more than 15 km)

- Structures with ties but not fully complying with building regulations
- Structures with little corrosion
- Structures accessible through nearby passages (4 < passage width ≤ 12 m)
- Structures placed within middle range distances from medical and emergency centers (distance more than 10 km)

- Structures with frames or ties, complying with regulations but with some workmanship errors
- Structures rather easily accessible through nearby passages (12 < passage width ≤ 18 m)
- Structures placed rather close to medical and emergency centers (distance more than 5 km)

Very low vulnerability

- Structures with frames or ties and comply with up to date regulations
- Structures built on proper soil, in low underground water level regions (No liquefaction or landslide potential)
- Structures without corrosion and high quality of constructions
- Structures easily accessible through nearby passages (passage width >18 m)
- Structures placed close to medical and emergency centers (distance less than 1.5 km)

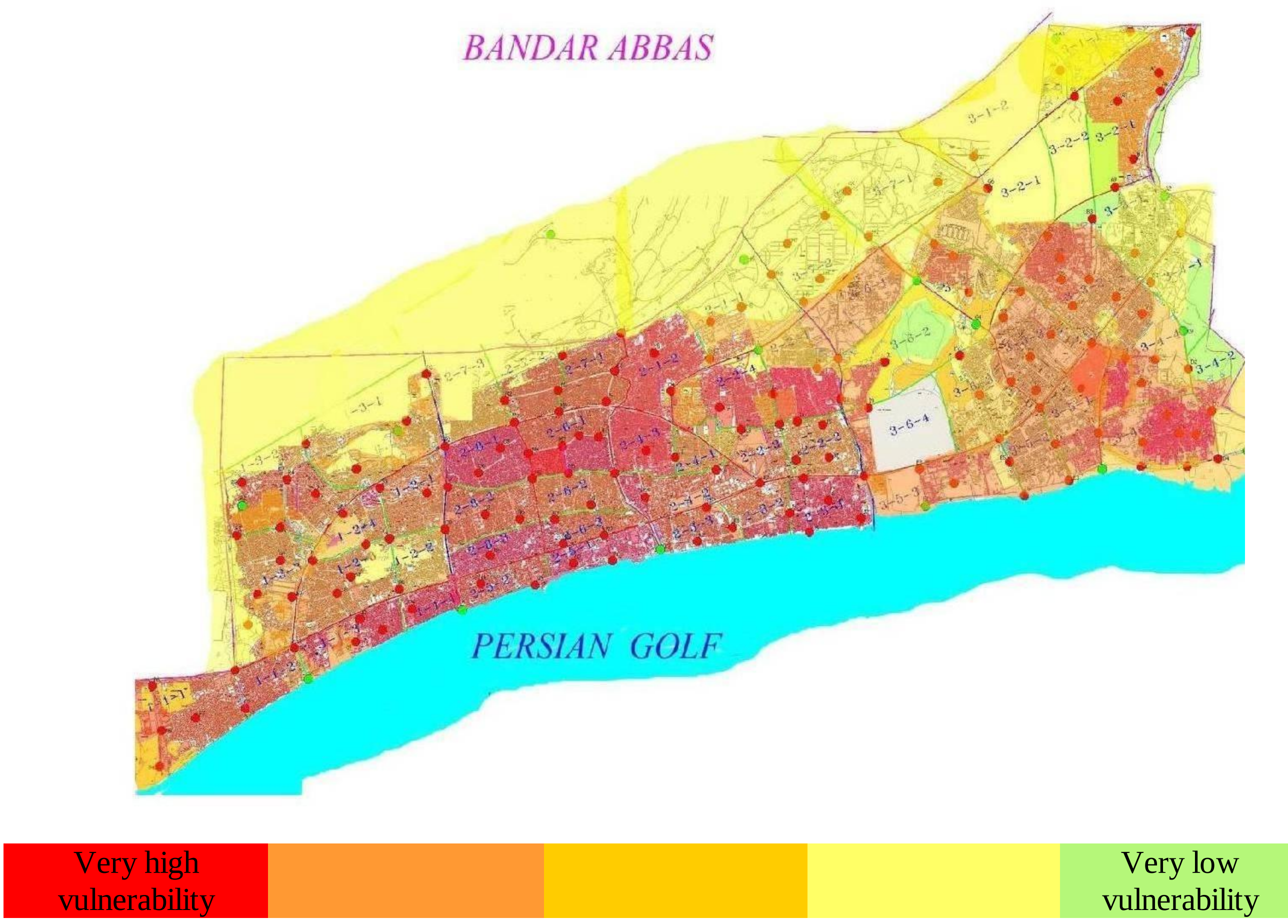

Figure 16. Recommended seismic vulnerability of Bandar Abbas region

Conclusion

Totally, Bandar Abbas possesses varieties in its topography. Differences in mean height from sea level for different locations of the city may even reach 30 to 50 meters. Therefore, the soil strength and underground water level are extremely variable and this is not limited to a definite region; as a result, the choice of foundation type and foundation construction must be variable according to soil categorization, underground water level, structural system and height of structures. In addition, soil test for determining its bearing properties should be made mandatory. However, in practice, this matter is often ignored or it is not done properly.

Regarding to high level of underground water and dominant soil type of each area, the term of “draining “ is important, but in reality, there was no draining facilities in construction of structures, or was not performed appropriately. In addition, type of foundation is very important, and in many cases, the shallow foundation has no adequate performances and deep foundations have to be used. In this Pre-Disaster Assessment study, we tried to find the general vulnerability of areas in this city and it might change with considering of some other parameters.

As a whole Bandar Abbas demonstrates very high vulnerability in most of its area. In order to reduce life damage and social effects of earthquakes, it is reasonable to build earthquake resistant structure and correct the urban arrangement. Nevertheless, in the current condition it is necessary to retrofit some existing structures and improve the texture of hazardous regions.

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