A Review on Challenges in Mitigation the Impacts of Geological Hazards Associated with Earthquake in Iran

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SUMMARY:
In this paper, some of the impacts of geo-hazards in recent earthquakes of Iran will be introduced and the shortages of existing laws and regulations as well as institutional arrangements of the country for prevention of their impacts will be discussed. Then, the recent activities in preparing necessary guidelines and plans in this context will be introduced and compared with some other countries having similar challenges. In addition, some strategies and plans for reducing of geo-hazards impacts and understanding the level of preparedness against geological hazards associated with earthquakes will be presented and discussed. Based on the results of these evaluations, the main activities needed for geo-hazard risk mitigation and management will be presented to be used in Iran and other countries facing such hazards.

Keywords: Earthquake, landslide, rock-fall, liquefaction, subsidence, mitigation plans

1. INTRODUCTION

Iran is located in a seismic prone zone along Alpine-Himalayan Orogenic belt with many active seismic faults (Amberaseys and Melville, 1982). The country has experienced many destructive earthquakes in the past, some shown in Fig. 1.

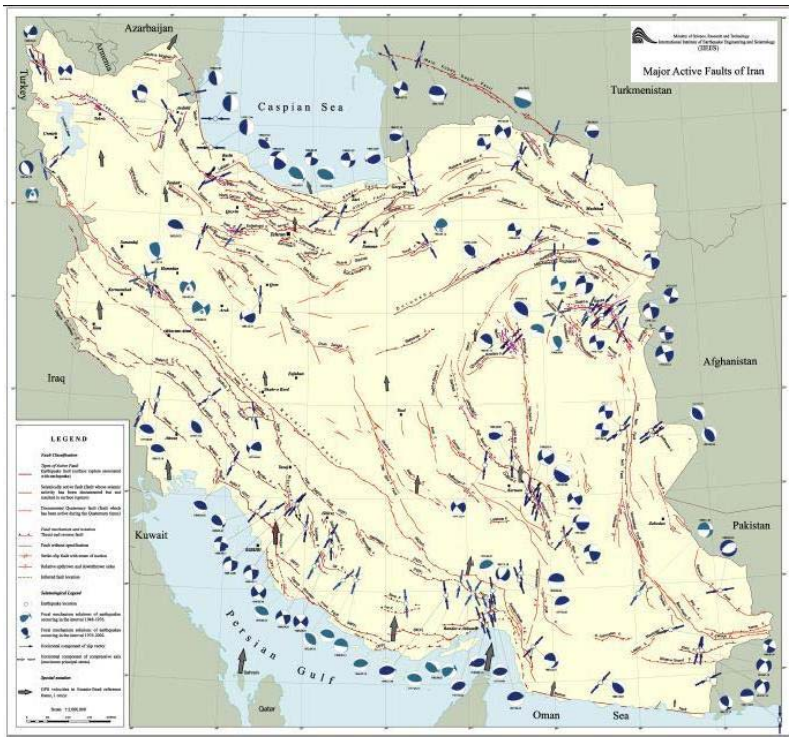


Figure 1: Main active faults and focal mechanism of some strong earthquakes in Iran (Hessami et al, 2003)

Besides of the high risk of earthquakes in Iran, many urban and rural areas were grown in or around geological hazard prone zones during the history. This may increase damage and casualties of

potential earthquakes, same as what observed in the past events. Although some measures have been implemented so far to control the impact of geo-hazards associated with earthquakes, but they have not yet resulted in tangible results in risk reduction. Same problems can be also addressed in other developing countries facing geological hazards.

Therefore, preparing practical and integrated methods for reducing the potential impacts of geo-hazards is one of the most important priorities for urban and regional managers. In this paper some of the main policies and plans for geo-hazard risk reduction will be explained based on experiences gained in recent Iran's Earthquakes.

2. THE IMPACTS OF GEO-HAZARDS IN RECENT IRAN'S EARTHQUAKES

Geo-hazards associated with earthquakes have been reported in many seismic events in Iran. The most important cases in the recent two decades are listed in Table 1 (Amini Hosseini and Ghayamghamian, 2012).

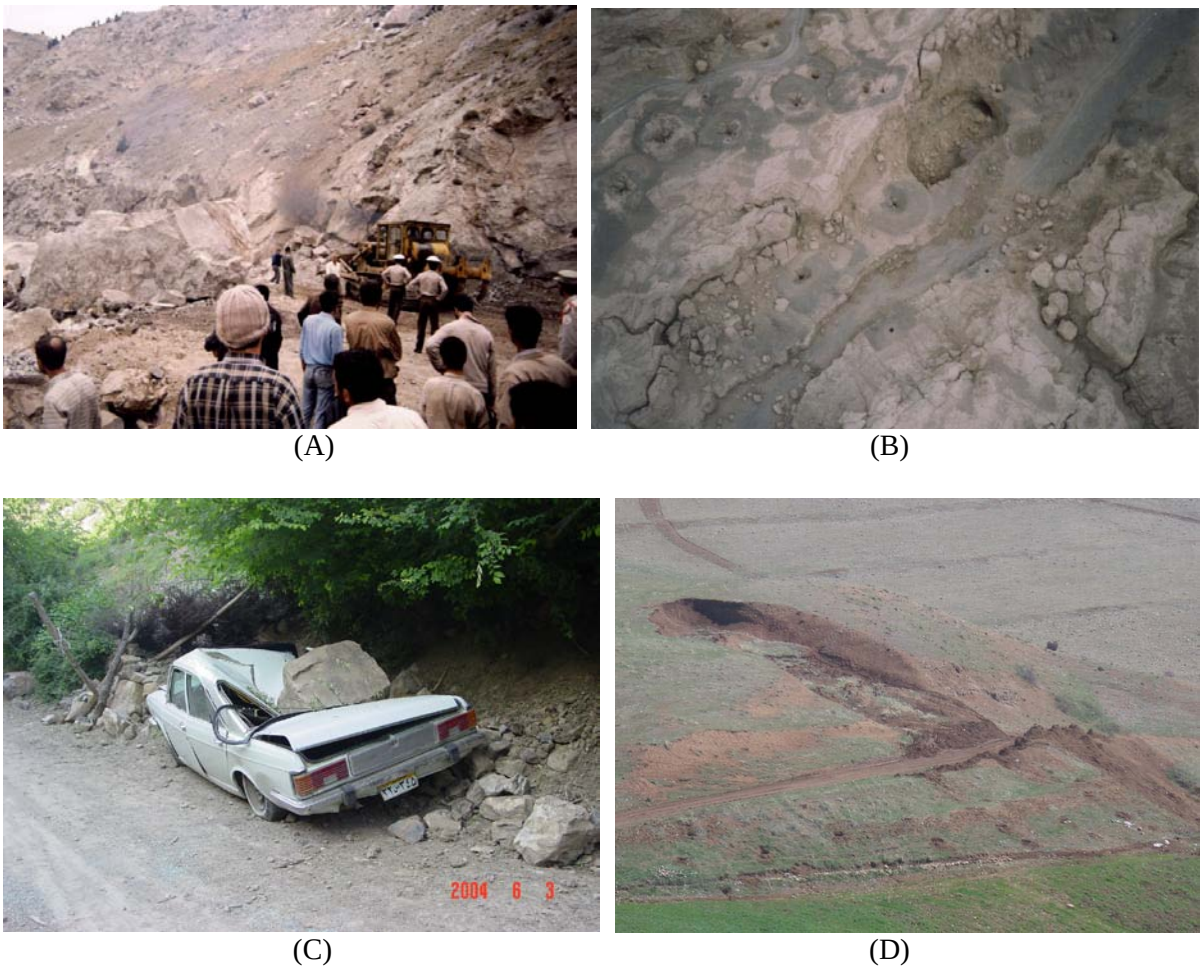
Table 1: The Impacts of Geo-Hazards in Recent Earthquakes of Iran

Earthquake	Manjil (1990)	Avaj (2002)	Bam (2003)	Koujour (2004)	Silakhor (2005)
Geo-Hazards History	Not documented	Recorded Near Epicenter	Not documented	Recorded Near Epicenter	Recorded at Epicenter
Causative Fault	Unknown	Unknown	Unknown	Known	Known
Ground Motion Amplification	Yes	Yes	Yes	Yes	Yes
Landslide and Mass Movement	Frequent	Medium	Few	Frequent	Medium
Rock Fall	Frequent	Medium	Few	Frequent	Medium
Liquefaction	Along River Side & Coastal Region	Along River Side	Along River Side	Along River Side & Coastal Region	Limited
Land Subsidence	Not Reported	Not Reported	Frequent	Not Reported	Reported in Two Cases
Impacts of Geo-Hazards	Destructive	Considerable	Considerable	Destructive	Considerable
Microzonation Map	Not Prepared	Not Prepared	Not Prepared	Not Prepared	Not Prepared

As shown in the above table almost in all of the recent earthquakes in Iran, some types of Geo-hazards associated with earthquakes have been observed, in which in some cases resulted in considerable damages and casualties (especially in cases of Manjil, 1990 and Koujour Earthquakes). In addition, the ground motion amplification has been caused further destruction in all events, while the microzonation maps were not prepared before those events in the affected areas. Even in some cases the causative faults were not investigated before the main event. Regarding the land subsidence due to collapse of existing Qanats (traditional underground irrigation channels), the impacts were more severe especially when the earthquake was occurred in arid region, where such channels have a wide extension; as observed in case of Bam Earthquake of 2003. Some of the impacts of those hazards are shown in Fig. 2.

This shows the importance of re-evaluation the plans and programs for land-use and developing activities in the areas subjected to such potential hazards. However, a review on the existing

conditions on plans and policies depicts that sufficient activities were not carried out in these lines by relevant authorities up to now. Among the approved laws and regulations the law of foundation National Committee for Mitigation of Natural Disaster Effects that was approved by the Iran's Parliament in 1990, established Earthquake and Landslide Committee to make necessary researches and activities to prevent these incidents or to mitigate their impacts. The next regulations were also discussed those issues in some extent, however they were not sufficiently considered the integrity of those subjects with urban and rural developing plans. In addition, the approved plans were also not implemented appropriately due to lack of sufficient enforcement.



(A) (B)

(C) (D)

Figure 2: Some of the impacts of geo-hazards in recent Iran's earthquakes; A: Rock fall due to Manjil Earthquake (1990) on main Tehran-Rasht Road; B: Aerial photo of land-subsidence due to Collapse of Qanats in Bam Earthquake of 2003; C: Rock fall on passing vehicles in Koujour Earthquake of 2004; D: Landslide in Silakhor Earthquake of 2005

3. GLOBAL EXPERIENCES ON GEO-HAZARDS RISK REDUCTION

Geo-hazards associated with earthquakes were also the root of considerable damage and casualties in many earthquakes occurred all around the world. However, most of the developed countries prepared and implemented some practical plans and programs for reducing such risk. A summary of some of the implemented activities in those fields in other countries in comparison with Iran is presented in Table 2.

As shown in this table, most of developed countries prepared and implemented multidisciplinary plans and programs for geo hazard risk assessment and reduction. However, most of the activities carried out in Iran and most of the developing countries are individually formulated based on the specific cases that may not have appropriate effectiveness.

Table 2: Some of the Activities of Different Countries in Landslide Risk Reduction (Amini Hosseini and Ghayamghamian, 2012).

Country	Main programs and activities for risk assessment and mitigation
Iran	Establishment of professional working groups, preparing inventories and databases, preparing zonation and microzonation maps for some regions, developing guidelines
China	Developing hazard mitigation plans, assignment of the duties for different agencies, preparing hazard zonation maps (regional to local)
Russia	Preparing databases, developing hazard zonation and microzonation maps, stabilizing unstable ground
Unites States	Research on risk reduction measures, developing guidelines and relevant codes for safe construction in or around hazard zones, preparing hazard zonation maps and risk reduction plans, development of laws and policies (restriction of construction, taxation, insurance, etc.), monitoring and early warning at critical sites, promoting public awareness, planning for ground stabilization
Italy	Preparing comprehensive plans, preparing microzonation maps, determining high risk areas, monitoring important sites (especially freeways), developing laws and regulations, investigation unstable zones in urban areas, determining at risk elements
Japan	Evaluation of risk by developing advanced evaluation methods, preparing hazard zonation maps, conducting stabilization measures, determining roles and duties, disseminating information, monitoring important hazard zones, preparing guidelines for risk assessment and stabilization

4. MAIN STRATEGIES AND PLANS FOR GEO-HAZARDS RISK REDUCTION

According to above explanation, strategies that can be used to mitigate risks in the above mentioned subjects can be listed as follows (Amini Hosseini et al., 2009):

- Identifying places prone to site effects, landslide and other geological hazards at local to national levels, particularly in places that buildings and construction are at risk;
- Preparing seismic microzonation maps at local to national levels considering site effects and geological hazards and updating them in a proper period of the time;
- Revising risk mitigation and management master and comprehensive plans, considering geological hazards in urban and rural areas;
- Developing criteria and regulations for construction and development in areas prone to ground movement, site effects and geological hazards and reflect the results into master, comprehensive and conductive plans of urban and rural areas;
- Preparing mitigation methods (technically and practically) based on local conditions, social and economic situation;
- Promoting public knowledge of earthquake related risks and hazards and planning for making relief activities, if such accidents occur in the future;
- Preventing of construction of important facilities at hazardous area (geological hazards prone areas), except in special cases by considering the necessary engineering provisions;
- Reducing the population density in dangerous areas;
- Developing the monitoring, earlier warning and automatic shut down systems (for lifelines such as gas and water) in the areas where such facilities are subject to geological hazards.

Based on the above strategies the most important programs in improvement the disaster risk management system in these areas can be classified as follows.

4.1. Formulation of the Comprehensive Plans to Mitigate Geological Hazards' Impacts

This plan that should consider different components (site effects, landslide, rock fall, liquefaction, subsidence, surface faulting, etc.) should be prepared and implemented by the relevant professional

and executive experts and authorities in order to reduce the risk of geological hazards and effects of geotechnical phenomena associated to earthquakes. Main elements of such plan must be separately studied and then integrated in a GIS environment, using standard procedure (El-Masri and Tipple, 2002). The results should be used to make geo-hazards and risks maps and information. The results of such studies can be reflected into master, comprehensive and conductive plans for developing urban and rural areas (Johnson et al., 2005). Obviously, implementation plan should be organized at provincial and local levels, and experts, governors and mayors are responsible for supervising such studies and implementing the results.

4.2. Establishment of Geo-Hazards Risk Management Center

In order to manage, tune and control all relevant activities to geo-hazard risk reduction, a specific center is needed to be established. This center would be more powerful if affiliated to the disaster management organizations and authorities. The most important objectives of this center are:

- Determining priority activities based on local conditions, the term of necessary services and cost estimation for risk reduction;
- Preparing prerequisites for developing comprehensive plans for geo-hazards risk reduction and supervision their implementation;
- Coordinating the activities of all relevant organizations and institutions for using the available capacities more effectively.

4.3. Preparing Laws and Codes

After establishment of center for managing the risk of earthquake-related geo-hazards and preparing the necessary comprehensive plans, it is required to approve and implement the regulations and instructions needed for making relevant activities. Preparing such laws can be considered as one of the activities of the above center. However, they should be approved by legal institutions. Of course, many of those regulations should be developed at local levels to be applicable based on local ground conditions and topography.

In some cases, approval and implementation of risk reduction plans may cause some dissatisfaction of the residents in the region because many of the buildings already constructed in dangerous areas and their owners are naturally very reluctant to obey those regulations. Thus, it is remarkable to consider social and economic along with technical issues for preparing such laws and regulations. Furthermore, such plans should be prepared and approved by provinces and cities based on the national policies and using the experiences of different countries and organizations in disaster management. Local offices of disaster management organization can be considered as responsible entity for supervision of the implementation of those regulations.

4.4. Developing Databases on Geo-Hazards and Preparing Microzoning Maps

One of the most important subjects in reducing risks of geological hazards is development the relevant databases and maps. Databases of geological conditions and hazards should be prepared in digital format to be used in GIS environment at different levels. Such databases can be developed by private companies as seen in many developed countries using standard methods. The time required for the preparation and completion of databases are related to the necessary accuracy of information and the need to make field reconnaissance.

This can therefore be carried out in a multi-phase project where during the initial phase can be implemented in a short time in which all available information should be collected from the provinces and the centers related to risks of geological hazards. The second phase can be implemented at all provinces using the capacity of private companies with the necessary field studies in a longer period of the time in order to collect data and process. For more precise studies (in the scale of 1/2000) it is required that studies carried out at the local level or by municipal governments that naturally the time required will be a function of different parameters (Topping, 2003).

4.5. Preparing guidelines for ground improvement and monitoring

Various policies related to remediation, stabilization and monitoring of the areas prone to geological hazards are available. Of course, the applications of some of them usually are expensive, so these measures normally considered as the last solution to reduce risk of ground movement and displacement and can be implemented only for important buildings that are subjected to those risks. Planning to deal with the effects of the geological hazards can be done by evaluation the existing methods in pilot areas. Different methods for ground improvements and monitoring can be applied in pilot areas to find the optimal methods economically and technically (Nelson and French, 2002).

However, establishment of an early warning system in hazardous areas can be also considered as a solution for saving the residents lives that are at risk, when the ground improvement is not feasible (such as when villages or cities are at risk of landslide). For this purpose, it is necessary to install monitoring and early warning systems to alert the residents when the ground starts moving. Considering the high cost of these projects, funding for related projects must be provided by using the resources of the various authorities in local, regional and even national levels.

4.6. Training and public education

Prohibition of construction at geological hazards prone areas is the most important challenge to control the effects of related disasters. Therefore, residents have an important role in understanding the risks and effects of such disasters (Burby, 2001). Public information and professional education are some of the most important ways to prevent development in dangerous areas. For this purpose, special programs should be prepared and presented for different target groups (public, experts and policy makers) to reduce the expansion of cities and villages in dangerous areas.

Information dissemination is a function of knowledge level of the hazard situation at the local to regional levels. National and regional authorities can provide applications to make such studies and encourage people being familiar with earthquakes geological hazards and how to control their effects. The growth of public awareness is essential to avoid construction in dangerous areas. It should be considered that these programs should be prepared considered socio-economic and cultural situation of different parts of the country to have more efficiency (Kapucu and Van Wert, 2006).

Preparing incentive programs for those who avoid construction in domain of geological hazards and punitive measures for those that insist to make activities in these zones (including tax exemption, difference in insurance rate, low profit loans for displacement of residents to safe areas, etc.) can be also considered as a solution in promoting public participation in those fields.

Besides of the public awareness, the development of academic researches in topics related with earthquake geological hazards is important as well. These researches will provide the necessary frames for reducing the risk of geo-hazards and helping administrative section to solve the existing problems, if defined and implemented properly.

5. CONCLUSION AND RESULTS

Recent earthquakes in Iran were associated with some geological hazards such as landslide, rock fall, liquefaction and ground subsidence; in which in some cases intensified the damages and casualties of the seismic event. It was also shown in this paper that by now there is no sufficient attention towards earthquake’s associated geological hazards in Iran. Those issues have been studied rarely and this may cause serious risks to urban and regional development plans and activities. Therefore, it is necessary to investigate those hazards at regional to local levels and provide the possibility of revising urban and rural development plans based on earthquake risk and geologic hazard. For this purpose, the impacts of geo-hazards in recent earthquakes in Iran were reviewed in this paper briefly and the activities carried out by now have been explained. In addition some measures for improving the existing conditions were evaluated and discussed. Those measures should be implemented by

different organizations and authorities. Therefore, coordinating activities of all organizations and institutions in the field of studying and applying earthquake risks, geologic hazards and geotechnical effects in urban to regional development plans is essential.

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