



علوم محیطی ۱۲، تابستان ۱۳۸۵
ENVIRONMENTAL SCIENCES 12, Summer 2006

59-66

Natural Disasters and Diagnosis of Man-made Factors, the Cases of Manjil and Bam

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Abstract

A review of earthquakes occurring in Iran during the last three decades (since 1983 up to the present) indicates the outbreak of many earthquakes, eight cases of which having a magnitude of above 7. Review of major natural disasters of the 20th century shows that earthquake is one of the most dreadful disasters of the world, four cases of which have occurred during the past century in Iran. According to the above evidence and the tectonic maps, Iran is located in an earthquake prone zone; therefore, reducing the risks of earthquakes should always be considered in all fields of human activity, especially in architecture and construction. Taking pre-emptive measures to tackle natural disasters especially earthquakes through observing the principles of architecture and urban construction, and observing the system of urban and rural construction management is a priority and an important strategy for sustaining the development of the country which can decrease the damage caused by earthquakes. From this point of view, the consideration of the way buildings are prone to earthquake and choosing the methods suitable for the structural socio-economic conditions and natural environment are among the most important measures to be taken. If vulnerable spots of buildings are not taken seriously, damage to buildings may continue.² Given that among the natural disasters of the last two decades, Manjil Earthquake, June 1990, and Bam Earthquake³, December 2003, were greater than the previous disasters in terms of property damage and loss of life, and since there is more evidence available about them, examination of and diagnosis of man-made factors in these two major earthquakes become especially important. The present article comprises three main sections. The first section focuses on the behaviour of buildings in the epicentres of the earthquakes, namely the provinces of Gilān, Zanjān and Kerman. The second section highlights the damage inflicted upon the buildings and their vulnerable weak parts, and the final section summarizes the ignored matters and concludes by providing regular strategy of diminishing the losses.

Key words: natural environment, natural disasters, earthquake, diagnosis, house.

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چکیده

مرور زلزله‌های ایران طی سه دهه اخیر از سال ۱۳۵۲ تاکنون نشان دهنده وقوع زلزله‌های بسیاری است که ۸ مورد آن دارای بزرگی بیش از ۷ بوده است. بررسی سوانح طبیعی بزرگ جهان در قرن بیستم میلادی نشان می‌دهد چهار مورد از بزرگترین زلزله‌های صد سال اخیر در ایران اتفاق افتاده است. برابر شواهد فوق و نقشه‌های تکتونیک، ایران منطقه‌ای با فعالیت لرزه‌خیزی زیاد است که وجود آن در کلیه عرصه‌های فعالیت انسانی خصوصاً معماری و ساخت و ساز همواره باید مد نظر قرار گیرد. پیشگیری از خطرات ناشی از سوانح طبیعی خصوصاً زلزله از طریق ملحوظ نمودن اصول معماری و شهرسازی و اجرای نظام کنترل ساخت و ساز شهری و روستایی از الزامات اساسی و راهبردی مهم در توسعه کشور است که می‌تواند به کاهش خسارات مربوطه و توسعه پایدار سرزمین کمک نماید. از این منظر بررسی نحوه آسیب پذیری بناها به هنگام وقوع زلزله و اتخاذ شیوه‌های مناسب با شرایط اجتماعی اقتصادی کالبدی و محیط طبیعی از مهمترین کارهایی است که باید مورد توجه قرار گیرد. نادیده گرفتن نقاط آسیب پذیر عناصر انسان ساخت از جمله بناها و بی‌توجهی به آنها باعث می‌شود تا زنجیره تداوم خسارات ناشی از زلزله کماکان ادامه یابد. نظر به اینکه از میان سوانح طبیعی دو دهه اخیر زلزله خرداد ۶۹ منجیل و دی ۸۲ بم از نظر شدت تخریب و تلفات بسیار فراتر از سوانح قبلی بوده‌اند و مستندات موجود در مورد آنها بیشتر از زلزله‌های گذشته است، آسیب شناسی عناصر انسان ساخت در این دو زلزله مورد بررسی و تأمل قرار گرفته است.

کلید واژه‌ها: محیط زیست طبیعی، بلائیای طبیعی، زمین لرزه، آسیب‌شناسی، مسکن.

Introduction

Destruction of urban and rural buildings by Manjil and Roodbār earthquakes which was repeated in Bam gives high priority to the diagnosis of man-made factors, especially architecture and construction methods. The earthquake which struck a vast area of north-western Iran in June 21, 1990 with a magnitude of 7.3 on the Richter scale was ranked 6th in the world in terms of magnitude and number of casualties, being the most devastating earthquake recorded in Iran in the 20th century. The official death toll of the earthquake was 36898 and the number of the wounded was officially announced 60000.¹ Although a main reason for the great loss of life could be the time of the earthquake (at 00:03 a.m. when most people are in bed), this can not justify the high death toll. Another significant point is that more than 214000 houses were completely destroyed or severely damaged. Bam Earthquake occurred at 6:00 a.m., December 26th, 2003, in the cold weather of the desert in Kermān province. The epicentre of the quake was the small town of Baravāt, 10 kilometres southeast of Bam. Although its extent and affecting zone was small, the intensity and duration of this violent earthquake was so great that a total of 22000 urban houses and 31124 rural ones were destroyed or seriously damaged.

Study of Behaviour of Buildings in Earthquake

The earthquake-stricken towns of Manjil, Roodbār, and Lowshān, Gilān Province, Tārom, Zanjān Province and Bam and Baravāt, Kermān Province which accommodate different ethnic groups of people, have unique climatic conditions, cultures and architectural varieties.

Gilān is a province on the border of the Caspian Sea with a high residential density. It has a moderate climate and large farms of rice, wheat and tea. The intensity of the quake was so high in this province that the towns of Lowshān, Manjil and Roodbār were destroyed to a large extent. Even the major city of Rasht, the centre of the province, did not escape the damage and a considerable number of houses and many public buildings were seriously damaged. The amount of damage in rural areas was very extensive too, resulting in the destruction of about 1100 villages (Cobun, 1990). Traditional houses of Gilān region are mostly two-storey buildings with walls made of stones or sun-dried bricks, wooden trusses, pitched roofs covered with corrugated asbestos sheets, ceramic pieces, iron sheets or asbestos-cement boards which are either with or without ties and bracing. In buildings that lack ties and bracing, the walls provide support against lateral loads (Coburn, 1990). So, in this type of building, the relative amount of walls increases. In houses where wooden planks had been placed in the walls, the amount of damage was lower. In some rural houses located at forest areas walls are made of logs and planks which are placed horizontally on top of each other and are connected to one another at the corners. Usually the distance between these logs are filled with construction materials and their surfaces are coated with mud. Another group of rural wooden buildings are made of wooden board structure. The sides of the boards are planked and lathes with a little. The space between the walls is coated with mud and their surface with *kahgel* (clay and straw mortar) (Zargar, 1993). The behaviour of wooden buildings against the earthquake has been better than other buildings in the area due to the low mass of wood.

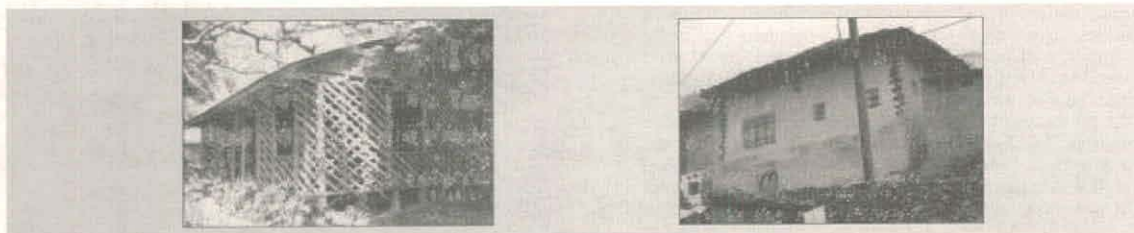


Figure 1- Two buildings with the above-mentioned structures: Zagme'ee or Kal be Kali houses (on the right) and Zagali houses adopted a building system which enough resistant against the earthquake.

The walls in most new buildings are made of bricks, concrete blocks and a mixture of cement and sand, having barrel-vault ceilings. These buildings could also be divided into two groups of with or without ties and bracing (Mimar, 1990). In many of these buildings, the relative amount of the wall (the ratio of the cross section of the walls bearing weight on top of the area of the building) had not been observed. At first the walls and then the ceilings collapsed in these buildings due to the small surface of

the bearing of the walls and the drift produced. The steel used in these buildings had sections of I and was only used in building barrel-vault ceilings. Limited use of steel in ceilings was due to two major reasons: on the one hand, steel is very costly; on the other hand, this way of use can speed up the work while exerting low level of skills for building such ceilings. Load-bearing elements of these buildings, particularly the ceilings and walls, had not been connected to each other properly and were destroyed mainly on the same points (picture of implementation details).



Figure 2- The heavy concrete ceilings and iron beams not connected at he vaulted ceilings are among the most important defects of new construction methods.

Connection breakage in brick barrel-vaults had resulted in the increase of damage. In this case, the connection between walls is lacking with a low rise (of 2 to 3 centimetres) in the section of the steel profiles about one meter from another. In other types of buildings constructed with horizontal and vertical ties and bracing, where execution details of connection, the quality of sand and grit used in the concrete and the ratio of section of steel to concrete had been observed, the building had demonstrated a better performance during the earthquake (Mimar, 1990). The buildings with steel and concrete structure were destroyed primarily on the joints between beams and columns. In steelwork structures most damage seems to have been inflicted to welded connections, and in structures with concrete footing beam or frame damage seemed to be caused by unauthorized decrease in the amount of cement, using unsuitable sand and grit, high ratio of water to cement, use of plain bars, decreasing the amount of steel used, ignoring recommended distance between bars and decreasing the number of stirrups.

Zanjān is considerably different from the other two provinces. Because of its geography and cold and

dry weather, especially in mountainous areas, the damage observed in this province were mostly in rural areas and included the regions of Tārom Olyiā and Soflā, and Roodbār and Alamoot .

The system of residential settlement in this province is much dispersed, and the villages are scattered over a large area, located several kilometres distant from each other, on the southward skirts of the valleys. The existence of water and soil resources has greatly influenced the system of residential distribution of villages; most of them are situated around springs and next to fertile lands and gardens; many of the villages are surrounded by lands with no vegetation. The amount of damage done to buildings, especially in the mountainous villages around Tārom was very high; about one half of the total number of 975 villages in the area was devastated or seriously damaged. The traditional houses in the region are generally one-story buildings with walls made of stone pieces and sun-dried clay bricks with flat roofs made of wooden beams of aspen and Tabrizi trees, covered with straw or bamboo and clay-straw mortar (Sartipipour, 1990). On stone beds, the buildings were generally constructed without foundations, and on

steep lands a stone footing course was implemented to function as a foundation and to produce flat level surface necessary for making walls.

On soft lands, the earth was excavated up to about 70 centimetres and a foundation of stones or *shefteh* (foundation paste) is put in it.

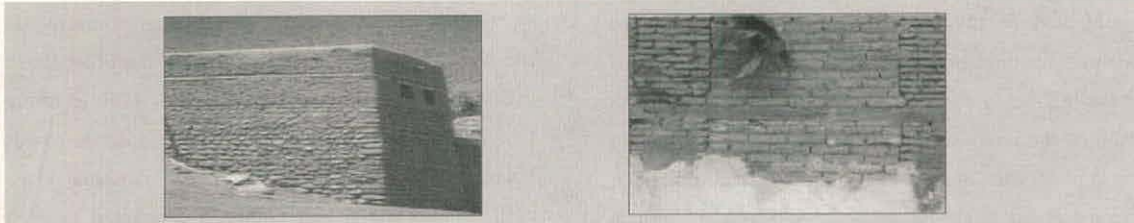


Figure 3- Picture on the right: The use of horizontal logs for strengthening walls with construction materials is a solution for increasing the building stability and resistance. Picture on the left: A rural house made of stone pieces with suitable joints at the corners with the rest of the stones lying in an oblique and regular manner (wedged left and right) with each row on top of the other

Kermān, lying in sharp contrast with the other two provinces, is located in a desert zone in central Iran with a hot and dry climate and cold winters. The system of the settlement in towns and villages in this province is scattered on a wide area of land, mainly based on the existence of underground water and dependent on the engineering of *qanat*. The amount of expansion and development of urban and rural settlements in this province depends on the amount of water obtained from underground resources. The town of Bam and its surrounding villages with an economy highly dependent on *qanats* and raising dates is

considered an important centre of date production in Iran and all around the world.

Arg-e-Bam (Bam citadel) which is considered to be the biggest and most beautiful mud-brick complex in the world is located at the centre of this town (Sartipipour, 2006). It is a great symbol of mud and architecture. The residential background this citadel dates back to thousands of years. Bam, with an antiquity of thousands of years and architecture of mud and clay, is considered a successful example of durable architecture and construction technology compatible with desert conditions.



Figure 4- Comparison of stability of steel barrel-vaults and the vaulted-ceilings of mud-brick in Bam Earthquake, and the effect of relative amount of walls

Traditional buildings in this area have been mostly built with mud and walls and clay dome or barrel-vault ceilings. Thick ceilings and walls of sun-dried brick structures in the interior provide protection against the cold weather and the sheer difference of temperature

of day and night. Low amounts of precipitation, wide range of temperature between day and night in this area which sometimes amounts to 50 centigrade degrees, as well as the property of suitable heat insulation of soil has lead to the widespread usage mud and sun-dried brick in the area (Sartipipour, IKE, 2006).



Figure 5- Use of steel below the standard amounts in concrete structures, lack of connection of columns with the foundation, and omission of wind brace in steel structure and the formation of soft storey

The behaviour of sun-dried brick buildings in the earthquake completely varied. While some buildings remained quite intact, some others were completely devastated. In these buildings, the vertical pressure is transferred through the walls. And due to the low elastic resistance of sun-dried brick and scarcity of wood in the area, the coverage of the roofs is obtained through domes and vaulted ceilings. It seems that the traditional culture of constructing buildings with clay in order to take advantage of its feature of transferring the vertical and gravity pressures has been followed;

however, the required measures to equip these walls against lateral pressures have been ignored due to lack of experience of earthquake. Though, few cases of application of plant fiber in walls with sun-dried bricks and proper building reactions were reported. Field observations showed that most earth buildings left intact or damaged less had geometric semi-square plans or had symmetric and light dump roofs. Behaviour of one-storey or two-storey buildings in this area was much like that of buildings in Gilān and Zanjān.



Figure 6- The effect of a geometrical form of the building on its stability, the right picture: a fair hall with the ceiling of space structure and a one-layer coating in newly repaired Arge Bam. The left picture: a mill building with annular barrel vault with a span of 10 meters.

Diagnosis of buildings

Taking building systems into consideration reveals that the most amount of damage relates to construction elements of ceilings responsible for transferring the force to the walls. The second greatest damage was due to the heavy weight of construction materials (Minke, 2001). Another source of damage was linked

to disqualified attention to execution details especially in connecting the ceiling to the walls. The next important problem in nearly all buildings associated with the absence of connection between force carrying elements and dividing walls or other elements which did give way to increased rate of damage and destruction.

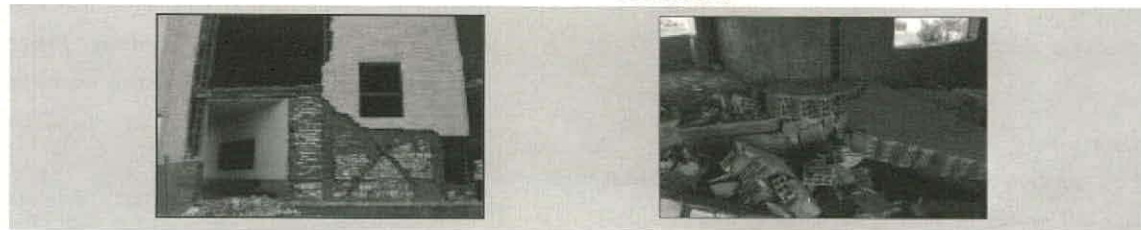


Figure 7: Following the earthquake, many housing and administrative buildings collapsed before the operation phase due to lack of connection between facades and dividing walls, and the structure.

Undertaking the review of local buildings shows that the most damage had been in buildings with the greater mass. In this types of buildings, lack of a connection between roofs (including pitched roofs covered with wooden beam and vaulted ceilings) with the walls and lack of unity for transferring force have caused destruction (Minke, 2001). Damage due to great mass of the building, heavy roofs, and loosely-

welded joints in new buildings was also quite obvious (vatr, 2005). The most amount of damage in Gilān was observed in the ground floor in traditional houses where the ground floor was made of construction materials while the second floor was made of wooden structure. In some cases, the damage or destruction of the building was because of landslide (in Gilān and Zanjān Provinces). In these cases, the buildings were

carried with the movement or dropping of the land. Gilan earthquake approved that building with wooden structures, both old and new ones, demonstrated a better structural behavioural in the earthquake and received less damage. Also, examination of geometry of buildings in both earthquakes reveals a substantial relation between geometrical form and the stability of the building. In this regard, sustained and stable buildings, both old and new, generally had symmetrical and purely geometrical forms. Another important feature is considering relative amount of wall and the effect of implementation details especially in the way the ceiling is connected to the walls and the walls to the foundation. Most of the destruction and damage to the buildings have been from this section.

Similarity in the way the buildings have been affected in the two earthquakes which was repeated in Bam shows that no serious measure has taken place to remove the problems. The least lesson taken from the earthquake in Manjil could be trying to support the weak parts of local buildings and preventing repetition of wrong implementation techniques in new buildings built after Manjil Earthquake. It seems that devising a construction mechanism with suitable technology aimed at developing local technology and what is current nowadays is among the most important measures which should be seriously considered.

Conclusion

Consideration of the geographical and climatic effects and differences of man made environment and the long background of the country in architecture and engineering have lead to a type of technology compatible and adapted to the environment (Native Architectur, 1986). The study of local architectural patterns with a few exceptions, which need adjustment with social changes and new needs, are generally indicative of their congruity with natural environment, tradition and life (Habitat, 1996). Examination of damage to buildings in Manjil and Bam support the

idea that two major construction principals, namely connections between the elements and elasticity of the parts, have been ignored in numerous cases. Not taking earthquakes as natural and indispensable features of natural environment in Iran seriously has led to increased mass of materials in manmade factors especially buildings. Moreover, failure in establishing links and consideration of implementation details and lack of unity in buildings are other reasons for increased amount of destruction. These defects can be removed to a considerable extent through understanding behaviour of the earth during earthquakes, reduce the weight of buildings, improving construction materials, attending to details of design and construction, and the use of adequate technology. In a similar way, reducing the mass of buildings, improving the material and considering details of execution in reconstruction of buildings while keeping their original forms, should be seriously taken into account.

In addition to the above cases, the following points should be considered to reduce destructive effects of natural disaster and improve the quality of reconstruction in the affected areas:

1. Running developmental workshops in cities and rural areas can improve the skills of the constructors in the right application of materials and correct construction of buildings. Public information on natural environment and the adverse effects of disasters on manmade environment should also increase.
2. Local engineering and architectural societies (NGOs) should be launched in cities and villages to employ the local people capacities and experts in this area and to prepare them confronting the disasters. This not only reduces damage and life losses by earthquake, but also paves the way for reconstruction of the devastated areas.
3. Considering the nationwide lack of construction materials and their high prices during the last decades which were intensified with the launch of reconstruction in damaged areas, designing an

effective mechanism of producing suitable construction materials is necessary. Environmentally speaking, the development, expansion and capitalizing on the production of construction materials with local origins which do not require sophisticated knowledge and ones which are not only resistant but also produced and supplied quickly, easily and inexpensively (such as strengthened construction bricks, light concrete blocks and substantiated earth bricks) is essential.

4. In choosing the right technology for reconstruction, environmental considerations such as avoiding pollution and bad effects of the production of materials and methods of construction on the natural environment and the possibility of recycling the material should be considered as determining factors. Considering the high rate of constructions of houses and the widespread employment of such construction throughout the country⁵, understanding methods of construction and local architecture and its environmental values, and taking preventive measures in removing building defects and incongruity between manmade and natural environments should be considered.

Notes

- 1-This paper is prepared on the basis of the author's field observations and interpretations conducted immediately after the outbreak of June 1990 Manjil, and December 2003 Bam earthquakes.
- 2- Collapse of concrete structures in the Earthquake of 2000 which had been used during the reconstruction of Qa'nat in 1979 is an evidence for this reality.
- 3- Bam Earthquake occurred in a region with a smaller area, but the great power of devastation in Bam area caused extensive financial damage and fatalities.
- 4- Reported by Iranian Red Crescent Center, and Gilan Governor Office (1990).
- 5- According to statistics in 1375 about 80% of current construction in the country has involved construction material.

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