Editorial Summary:
Bam Earthquake of 05:26:26 of 26 December 2003, Ms6.5

1. Introduction

The Magnitude $Ms = 6.5$ earthquake of 26^{th} December 2003 occurred at early morning (05:26:26 local time) along Bam fault with no recorded of any major earthquake, at least, approximately in past 2500 years; and while many residents of the Bam historical city were still sleeping. The traditional mud-brick and clay homes put up little resistance to the violent shaking, and as walls and roofs crumbled and collapsed; more than 100,000 of victims were trapped beneath the rubble and from them around 26,500 lost their lives. Close to 11,000 of the city's students perished, along with one to five of Bam's 5,400 teachers. Tens of thousands were left homeless and up to 6,000 children were orphaned. Arg-e-Bam (Bam Citadel), the largest mud-brick complex in the world and other historical buildings were almost totally destroyed. Bam earthquake not only shook the heart and mind of the Iranian, but the world and created on the biggest human solidarity. This earthquake have created a new initiative in Iran's risk reduction program and consequently provides a unique window of opportunity to raise international awareness of the importance of the effective implementation of a comprehensive earthquake risk reduction program in hazard-prone countries.

2. The Seismotectonic, Seismicity and Strong Ground Motion of Bam

The Bam region in south east of Iran is located in an active seismic zone, however the Bam city itself had no reported major historical earthquake before the event of 26/12/2003. The earthquake was associated with two fresh surface rupture 5*km* apart trending north-south and 2*km* wide zone of hairline fractures developed between the two main ruptures in the north of Bam. The Bam fault with a near north-south direction passes from the vicinity of the city of Bam (less that 1*km* distance to the east of Bam, and between the cities of Bam and Baravat. The other segment 5*km* to the west of the Bam fault passes through the city. The whole system of fresh ruptures associated with the main event is not direct manifestation of the earthquake faults but are secondary structures. No direct surface faulting were associated with the earthquake; however, the surface fissures created after the Bam earthquake are observed around the Bam fault between the cities on Bam and Baravat. Considering that the Bam earthquake was multiple event; the focal depth of the main event is estimated to be 8*km*, while the second event was 10*km*. *Mw*6.5 was calculated for this event based on the seismic moment of the main shock. Using the data from a dense network in the Bam, the focal depth distribution of the aftershocks show a nearly vertical alignment of aftershocks located between 6 to 20*km* depth. The focal mechanism of the main events and aftershocks indicate right lateral strike slip faulting on *N-S* trending faults which is compatible with the fault traces that were observed by the *IIEES* tectonic group.

The strong motion record obtained by *BHRC* in the Bam station shows the Horizontal *PGA* of 0.8*g* and 0.7*g*, and 1.02*g* for the vertical component. The effective duration of the earthquake were estimated between 7 to 10 seconds. Two strong phases of the energy have been seen in the accelerograms; the first is interpreted to represent a starting sub-event with right-lateral strike slip mechanism and located south of Bam. The preliminary observations on the strong motion record obtained in the Bam station, as well as the observed damages in the region shows a vertical directivity effects which caused the amplification of the low frequency motions in the fault-normal direction as well as the greater amplitude of the motion in the vertical direction. The demolished walls and building of Bam are representative for such effects in the up-down (vertical) and east-west directions (fault-normal). The attenuation of strong motion was rapid which was even faster in the fault-normal direction. This fact has been observed from the damage distribution as well. The dominant period of this earthquake (1*sec.* for the vertical component) is around the period of the adobe buildings, which can be one the main cause of their failure.

3. The Macroseismic Intensity and the Isoseismal Map

The macroseismic intensity of the earthquake is estimated to be $I_0=IX$ (in the *EMS*98 scale), where the strong motions and damaging effects seems to be attenuated very fast especially in the fault-normal direction. The intensity levels are estimated to be *VIII* in Baravat, *VII* in New-Arg (Arg-e Jadid) and the airport area. The intensity level was estimated to be around *IV-V* in Kerman and Mahan.

4. Geotechnical Aspects

There were not any major geotechnical failures observed in the Bam; However, many land subsidence due to collapse of Qanats (underground irrigation tunnels), local toppling and block slides along riverbanks or man-made channels were observed. For the purpose of geotechnical microzonation of Bam, seismic hazard analysis, geological studies accompanied by geophysical surveys and aftershock and microtremor measurements were carried out to provide preliminary site classification and *PGA* distribution maps for two return periods of 475 and 2475 years. Reasonable agreements exist between the site classification and 2475 years *PGA* distribution maps of the city and the damage distribution map of the recent earthquake. Almost all damages of the low rise buildings occurred in sites with stiff shallow and medium depth soils, which possess a considerable amplification potential in the high frequency range. The maximum value of the peak ground acceleration was evaluated in the south-east part of the city, where the highest value of damage percent (80-100) was experienced. The minimum value of the peak ground acceleration was evaluated in the north-west part of the city, where the least value of damage percent (20-50) was experienced. In addition, the 475 years *PGA* microzonation map could be used as a preliminary useful hint in reconstruction and urban planning of the city.

5. Structural Engineering Aspects

Existed buildings in Bam composed of Adobe and Masonry housing units (90%); Steel (8%) and Reinforced Concrete (2%). Based on the statistical evaluation of 550 buildings (74% :1-story, 22% :2-story and 4% :3 story or more) of the partially damaged, it was concluded that 62% could not be used for occupation, 34.8% could be retrofitted and 3.2% were safe.

The main reason for the failure of the adobe and masonry buildings were the heavy roofs and walls as well as the lack of structural integrity, specially in the newly build ones. The good performance of the arch roof of the old adobe buildings was good example of the importance of structural integrity. Most of the steel building were damaged due to lack of code implementation, poor workmanship, poor connections (specially Khorjinie or satchel connection), weld rupture, buckling (overall, out of plane and lateral-torsional) of the weak columns specially in the batten columns, rupture and plastic shear of the battens, local buckling and rupture of *X* bracing and lack of frame in one direction of the buildings. The buildings that had followed the minimum code requirements were not damaged. Performance of the concrete buildings were poor for the residential cases and good for the essential ones.

Up to 95% of the buildings and walls within the 2500-years-old-ancient-Arg-e-Bam (Bam Citadel), the largest adobe construction in the world, were collapsed. The failure were mainly due to improper and lack of seismic safety consideration in the restoration program.

6. Lifeline and Special Structures

The Lifeline systems of Bam were shut down due to various type of equipment failure; However most of the lifeline systems were restored within the first week after the earthquake. The performance of the bridges, roads, railways were good and slight damages did not cause interruption of their services. The failure of the Bam airport tower caused delay in using the airport facilities. However its rapid restoration of the airport played very important role in the rescue and relief operation. Without the airport the human casualty were become much more. Water distribution systems for both drinking water and agricultural water which were done through the traditional irrigation system (Qanats) were seriously damage. Water tower and underground water storage tank and deep well sustained some damage and in general had acceptable performance. Nonstructural damage in the *PTT* buildings caused the communication interruption. The cell phones started to work within a few hours. There were little damage to high voltage transmission lines and towers and moderate damage to electrical equipment in the Bam substation. Most factories and other industrial facilities were either not damaged or stayed intact. However, they remain dysfunctional due to loss of workers.

7. Conclusion

The Bam earthquake disaster, despite its high casualties and losses, provides a unique window of opportunity to raise international awareness of the importance of the effective implementation of a comprehensive earthquake risk reduction program in Iran as well as in hazard-prone developing countries. It gives a challenge to the governments to make the highest use of the existing know-how on earthquakes and its integration into development programs. It also compels the scientific and engineering community to provide more socio-economic-cultural compatible solutions to national needs. Moreover, the public at large should become more concerned about the hazard and increase its own preparedness level. The *UN* Strategy document, Bam Declaration and Recommendation for Bam citadel, Bam reconstruction paper and formation of the *UNESCO-UNDP-UN/ISDR-IIEES* Alliance for earthquake risk reduction in developing countries are sample of the initiatives for the better future.

Acknowledgment

JSEE Editors would like to thank all of the authors of this special issue of the ***JSEE* on Bam earthquake** for their valuable efforts, cooperation and contributions since the occurrence of the earthquake. Moreover, we would like to thank all of the reviewers and the editorial board for the timely and sincere efforts in reviewing the papers in the shortest time possible, which were extremely useful toward the improvement of the papers. Finally our thank to Ms. Khaledi for her hard works in putting the papers together in this nice format and make them ready on the occasion of “Special Session on Bam Earthquake” in the 13th world conference on Earthquake Engineering and Seismology (13 *WCEE*) in August 2004.

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