Preliminary Report on December 26, 2003 Iran Bam Earthquake

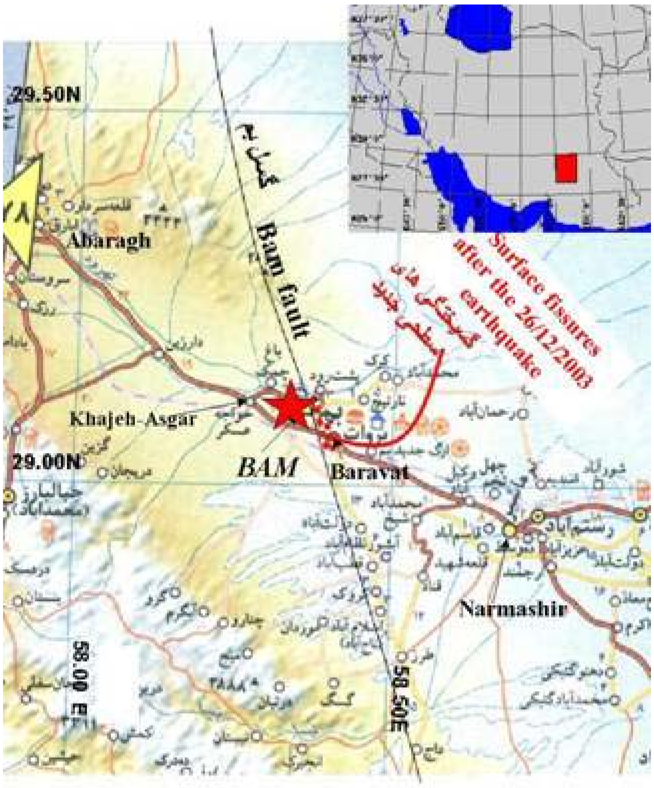
Prepared by JSCE Iran Bam Earthquake Disaster Investigation Team

Overview of the Investigation

On December 26, 2003, at around 5:26 am local time, an earthquake of magnitude 6.6 (*Mw*) occurred in the southeastern region of Iran, in the vicinity of Bam City with the population of 120,000 people, causing many adobe structure houses to collapse. As the earthquake occurred early in the morning, it caused a considerable life loss, with over 40,000 victims. Bam was known for its citadel, an ancient adobe structure fortress that was constructed over 2,000 years ago. However, this citadel suffered a catastrophic damage due to this earthquake.

Soon after the occurrence, the Earthquake Engineering Committee[1] and the Subcommittee on Earthquake Disaster Investigation[2] of JSCE began the examination on dispatching an on-site disaster investigation team. Upon consultation with JSCE Emergency Disaster Countermeasures Division, the dispatching of the investigation team was decided. The investigation took place from February 15 through 26, with partial cooperation from the JAEE[3] investigation team. The member list of the JSCE Investigation Team is shown in Table-1.

This is a preliminary report on the characteristics of the earthquake motion as well as an overview of the damage caused by this earthquake.



Bam Earthquake of December 26, 2003, Mw 6.5

Figure-1: Location of the epicenter[1)]

[1] Chairman : Yozo Goto, Director of Earthquake Disaster Mitigation Research Center, NIED

[2] Chairman : Prof. Masakatsu Miyajima, Kanazawa University

[3] Japan Assoc. of Earthquake Engineering (Leader: Prof. Kazuo Konagai, University of Tokyo)

Earthquake and the Earthquake Motion

This earthquake occurred at around 5:26 am on December 26, 2003. As Figure-1 indicates, its epicenter is in the south of Bam, a city located in the southeastern region of Iran. The depth of its hypocenter is approx. 10km. In Iran, the Building and Housing Research Center (BHRC) maintains a strong-motion network (ISMN) throughout the country that has recorded numerous strong-motion waveforms during this earthquake. At the proximity of the epicenter, a valuable record was obtained within Bam, located 14km from the epicenter. However, because the epicenter was in the region where towns are scattered, it was the only record obtained within the parameter of 50km from the epicenter.

Table-2 shows the maximum acceleration at various sites. In Bam, a vertical motion of over 1G is observed, and the horizontal motion has marked a very high value of 800gal as well. Figure-2 is the strong motion waveforms that BHRC disclosed. It may be considered that the horizontal component (L) expresses the characteristic of the site near the fault. As the strong-motion seismograph was placed under a desk, on the first floor of a two-storied concrete reinforced brick structure, there was no impact from falling objects. However, as the adjacent locker fell, there is a possibility that the record reflects the impact of this fall, or of the shaking of the structure itself, which was partly damaged.

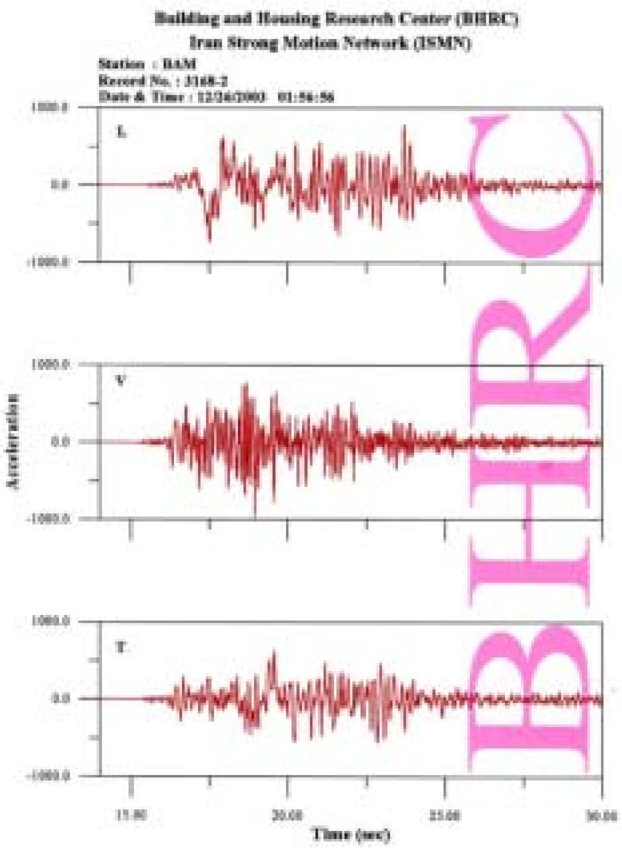


Figure-2: Strong-motion seismograms recorded in the city of Bam[2)]

(From the top: horizontal, vertical, horizontal-transverse components. The maximum rates are shown in Table-2)

The Bam fault lies approx. 2km east of the city of Bam. At the site, an almost continuous stretch of scarp that has been formed by the past fault movements extends in the north-south direction. This scarp has a relative height of 20m with its higher point on the west side. Photo-1 is an aerial photo showing the cities of Bam (western green area) and of Baravat (eastern green area). The white area stretching from north to south, in between the two cities is the flexural scarp. The Bam fault is a right lateral reverse fault but it is considered that the fault did not reach the ground surface and was limited to the development of the flexural scarp. Photo-2 shows a fissure that appeared on the road traversing the flexural scarp. It is not considered a slip surface of the epicentral fault but an open fissure caused by the development of the flexural scarp.

Photo-1: Aerial photo of Bam and Baravat

Photo-2: Crack on the road traversing the flexural scarp

Topography and the Geological Conditions

The City of Bam is located in the southwestern part of Lut Desert. The city is developed around oases in the periphery of the fault scarp at the edge of an alluvial fan. Although an outcrop is observed at the Bam Citadel in the northeastern part of the city, according to the preliminary figures we have obtained through microtremor observation, the thickness of the sedimentary layer does not simply increase from north to south. More details will be reported at a later time at the preliminary debriefing session, after organizing the results from microtremor observation and from other materials collected.

Damages to Public Infrastructure

Table-3 indicates the degree of damages seen on typical public infrastructures that we have investigated in Bam and in Baravat. The characteristic of these structures is that due to their importance, a relatively large number of them are concrete reinforced and thus, the damages to them are relatively small. Following is the characteristics of damages described by the types of representative structures:

1) Bridges

We have investigated concrete reinforced bridges at three locations around Bam. As a result, we have observed damage in only one of them, near the Bam Citadel, in which the girder has shifted 2 cm west in the direction perpendicular to the bridge axis (perpendicular to the fault) and a crack was observed on one abutment. All of the bridges had reinforced concrete girders and wall-type RC piers, which is a style commonly used in bridging small to medium size rivers in Japan as well. Due to the fact that the reinforced concrete girders have shifted, although slightly, it may be considered that the horizontal seismic coefficient equivalent to over 0.4 static friction coefficient was in action.

2) Water Tower

Damages were observed in a reinforced concrete water tower located at the center of the stricken area, where the concrete that was covering the lower end of its pillar was stripped off and the reinforcing steel bar (in the direction of the axis) was exposed and buckled (Figure-3). The pillars were placed octagonally, in a rigid-frame structure with mid-layer beams. In order to grasp the dynamic bearing capacity of the water tower, we have undertaken a static increasing horizontal seismic coefficient analysis using a frame model. Figure-4 indicates the relationship between horizontal seismic coefficient and horizontal displacement at the center of gravity of the water supply tank. The result of the analysis shows that after the point where the lower end of the pillar yielded, the slope of the curve became gradual. Therefore, it may be considered that the yield horizontal seismic coefficient of the entire water tower was approx. 0.37, and the horizontal acceleration equivalent to over 370gal of earthquake motion was in action. Moreover, the damages such as the stripped concrete cover of the western pillar due to tension, and the buckled reinforcing steel bar of the eastern pillar due to the compression suggest that the westward action perpendicular to the fault was dominant.

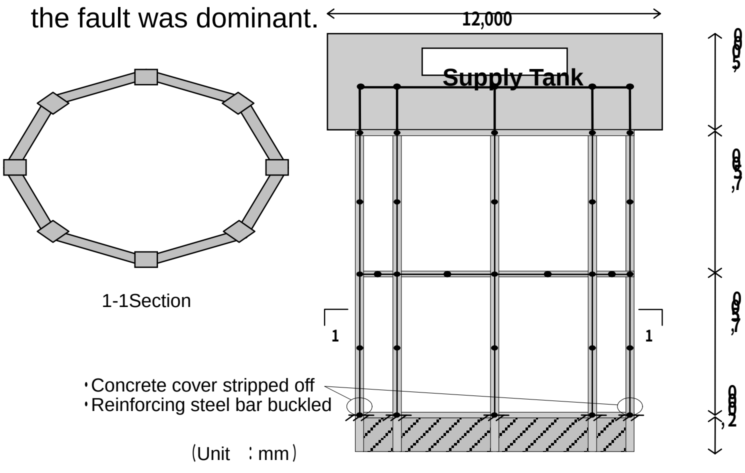


Figure-3: Structure of the Water Tower

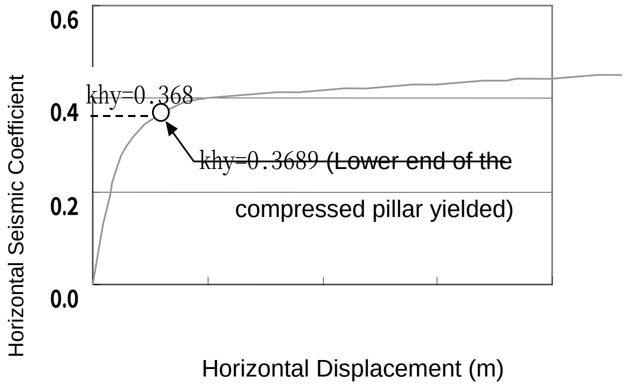


Figure-4

3) Mosques

As in other structures, reinforced concrete mosques have suffered smaller damages than brick or adobe structure ones. However, brick walls have collapsed even in reinforced concrete mosques. Photo-3 shows a mosque where the collapse of the wall has claimed 7 lives. Yet, compared to brick houses, these structures suffered smaller, B-degree damages. This may be due to the effect of the difference in the quality of building materials used. Whereas ordinary houses are built with bricks by the residents themselves, due to their large scale, mosques are built with high quality mortar by professional construction workers.

Photo-3: A damaged mosque

Damages to Lifelines

This earthquake caused the greatest functional damage on roads. Bam and the state capital, Kerman are linked by a two-lane road, which become congested due to relief / rescue activities soon after the earthquake hit. We have been reported that an approx. two-hour trip between the two cities at ordinary times took more than 6 hours due to congestion during the afternoon of the occurrence. Therefore, the air route was used as the alternative facility. Although the control tower of Bam's private airport had suffered damage, it was replaced by another control facility that was immediately installed on the ground and the special flights began to take off and land in the evening of the occurrence. Almost 500 departures and arrivals within the 12-hour period enabled the transport of patients in critical conditions to Kerman or the Capital, Teheran, as well as the transport of relief/rescue workers and materials to the afflicted area.

The water supply systems in both Bam and in Baravat suffered no damage in tanks and other facilities, except in the underground pipes. The underground pipes made of Asbestos-cement, P.V.C. and polyethylene were damaged at their T or straight joints as well as at their body. There have been a great number of collapsed houses and due to that, excavation work has been impossible in many areas. In many of these areas, temporary ground pipe systems have been introduced. For residents living in tents, water tanks like the one shown in Photo-4 were supplied.

Photo-4: Water tank supplied to the residents

The gas network is not established and in their place, compressed gas cylinders are used. As for the sewage, we have been reported that it is directly discharged at a considerable depth from the ground surface.

Damages to structures

There are many adobe structure houses in central Bam, and most of them have collapsed. In the same area, there are many non-reinforced brick houses, which have collapsed as well. The rate of collapse is said to amount to 80-90%. As shown in Photo-5, there are many areas that are covered with heaps of rubbles, and the next important task there would be to remove these rubbles and to plan the reconstruction. During the on-site investigation, we have undertaken in-person hearings on questionnaire seismic intensity and microtremor observation among

Photo-5: Collapsed adobe structure houses

others. From now, we plan to proceed with the examination on relationships among ground characteristics, earthquake motion and structural damages.

Acknowledgement

We would like to acknowledge and thank the great efforts of the members of Emergency Disaster Countermeasures Division, Earthquake Engineering Committee, and Subcommittee on Earthquake Disaster Investigation of JSCE in dispatching the investigation team. We would also like to thank Professor Kazuo Konagai of the University of Tokyo for his work as the contact with the local counterpart, and for leading the joint team during on-site investigation. Lastly, we would like to thank all those who were involved from IIEES (International Institute of Earthquake Engineering and Seismology), Teheran University, and BHRC for accompanying us on the on-site investigation, for making various arrangements, and for providing valuable information.

References:

1) Sassan Eshghi and Medhi Zare: Bam (SE Iran) Earthquake of 26 December 2003, Mw 6.5: A Preliminary Reconnaissance Report, 2004.
2) Building and Housing Research Center: The Very Urgent Preliminary Report on Bam Earthquake of Dec. 26-2003, 200

Table-1: Member list of the investigation team (* different schedule)

Title	Main Areas of Investigation	Name	Affiliation
Team Leader	Site characteristics, Lifeline	MIYAJIMA Masakatsu	Kanazawa University
Vice Team Leader	Structural damage Emergency response	MEGURO Kimiro	University of Tokyo
Member	Damage distribution	HAKUNO Motohiko	Kogyokusha College of Technology
Member	Structural damage	KOSA Kenji	Kyushu Institute of Tech.
Member	Ground destruction	TOBITA Tetsuo	Kyoto University
Member	Remote sensing	TAKASHIMA Masasuke	University of Tokyo
Member	Reconstruction strategy	YOSHIMURA Miho	University of Tokyo
Member	Adobe structure	MAYORCA Paola	University of Tokyo
Member	Site characteristics	FALLAHI Abdolhossein	Kanazawa University
Member*	Emergency response Reconstruction plan	HAYASHI Akio	Pacific Consultants, Co. Ltd.
Member*	Lifeline	KUWATA Yasuko	Kobe University

Table-2: Maximum acceleration obtained and the distance to the epicenter

Observation Station	Distance to the epicenter (km)	Maximum Acceleration (gal)			Elevation (m)
		Horizontal (L)	Horizontal (T)	Vertical	
Bam	14	799.06	636.37	988.50	1094
Mohamad	60	123.52	71.40	70.74	1961
Jiroft	88	40.33	28.30	31.81	725
Golbaf	99	30.78	29.46	13.70	1698
Rein	102	21.94	18.08	22.95	2195
Jushan	127	24.99	36.64	17.52	1650

Table-3: Degree of Damage of Typical Structures

Kinds of Structure	No.	Principal Material	Degrees of Damage	Note
Bridges	No. 1	RC	C	14 spans (simple girders)
	No. 2	RC	D	3 spans (simple girder)
	No. 3	RC	D	7 spans (simple girder)
Water Tower	No. 1	RC	C	Reinforcing steel bar buckled
City Hall	No. 1	Adobe	A	Total collapse
Mosques	No. 1	Brick	A	Center pillar made of steel
	No. 2	Adobe	A	Center pillar made of steel
	No. 3	RC	B	Reinforcing steel bar buckled
	No. 4	RC	C	Occurrence of crack on the pillar only
	No. 5	Brick	B	Steel center pillar, wall collapsed
	No. 6	Adobe	A	Total collapse
	No. 7	Brick	B	Center pillar made of steel
	No. 8	Brick	B	Center pillar made of steel
	No. 9	RC	C	Occurrence of crack on the pillar only

Degrees of damage: A= Collapse, B= Medium, C= Light, D= No Damage