EARTHQUAKE ENGINEERING RESEARCH INSTITUTE
499 14th Street, Suite 320
Oakland, California USA 94612-1934
Phone (510) 451-0905, Fax (510) 451-5411

Slides on the Hyogo-ken Nanbu (Kobe) Earthquake
January 17, 1995

Set I: An Overview

Slides contributed by: Craig Comartin, James Jirsa, Charles Kircher, Charles Scawthorn, Paul Somerville, and T. Leslie Youd.

INTRODUCTION

The January 17, 1995, Hyogo-ken Nanbu earthquake left more than 5,400 dead, nearly 27,000 injured, and over 300,000 homeless. More than 56,200 building were destroyed. It was the most damaging earthquake to strike Japan since the great Kanto earthquake destroyed large areas of Tokyo and Yokohama and killed approximately 150,000 people in 1923. Current estimates of losses in the city of Kobe (population 1.4 million) are about 200 billion dollars.

The earthquake was assigned a Richter magnitude 7.2 by the Japan Meteorological Agency (JMA). Seismological analyses indicate a moment magnitude of 6.9. The hypocenter of the earthquake (34.6° N, 135.0° E, focal depth = 10 km, origin time 5:46:52 JST) was located about 20 km southwest of downtown Kobe between the northeast tip of Awaji Island and the mainland. Based on the distribution of aftershocks and teleseismic waveform modeling, the rupture length of the earthquake is inferred to have been in the range of 30 to 50 km, produced by bilateral rupture from the hypocenter. The rupture of this strike-slip earthquake directly into downtown Kobe appears to have contributed to the high level of destruction that occurred.

The earthquake occurred in a region where a complex system of active faults had been previously mapped. Its mechanism is compatible with the tectonic environment of western Japan as revealed by historical seismicity.

The areas most affected by the Hyogo-ken Nanbu earthquake include the Awaji Island and the southern portion of the Hyogo-ken prefecture that borders the Osaka Bay. Other areas affected by the earthquake include north-western portions of the Osaka-fu prefecture and the south-western portion of the Kyoto-fu prefecture.

Slide 1: Map of Kobe and vicinity. Kobe is located near Kyoto and Osaka on the inland sea of Japan (North ↑).

Slide 2: Map of earthquake epicenters and location of aftershocks. Aftershocks show a rupture of 50 km of length occurring bilaterally from the epicenter. The depth of rupture is 10 km.

Slide 3: Mainshock epicenter, aftershock zone, and peak ground motions (cm/s/s), superimposed on a map of active faults. The aftershock zone is based on locations by the Disaster Prevention Research Institute, Kyoto University, using the microearthquake networks of Kyoto, Tokyo, and Nagoya Universities. Strong motion data represent different measures of ground motion. Italicized values indicate inexact station locations. (Modified from K. Koketsu, Earthquake Research Institute, University of Tokyo.)

Slide 4: Scarp of the Nojima fault on Awaji Island showing both vertical and horizontal offset. Marine seismic surveys have found a 300-meter long offshore extension of this rupture. The survey also found two fault rupture segments that span a length of about 7 km in the region offshore from the northeast tip of Awaji island, parallel to the Nojima fault but offset from it by about 5 km. Near the onshore projection of these underwater rupture segments, a small amount of right-lateral faulting has been observed in a road in the Suma ward in western Kobe.

BUILDINGS

The most extensively and severely damaged structures were traditional Japanese homes, wood-frame buildings with weak walls and heavy clay tile roofs (known as Shinkabe and Okabe), and to smaller commercial buildings constructed with limited engineering design. Severe damage and often partial or full collapse of large commercial and residential buildings occured throughout central Kobe. Preliminary assessment indicates theat the single most significant reason for the extent of severe building damage caused by the earthquake is the proximity of affected cities to fault rupture. While evidence of liquefaction was observed in areas of heavy building damage, ground shaking appears to be the dominant contributor to damage of engineered buildings. In the Nagata and Suma wards of Kobe, fire following the earthquake contributed significantly to the proportion of buildings damaged.

Slide 5: Collapse of unreinforced masonry wall. This type of damage was the first to be observed when entering Kobe from the east.

Slide 6: Collapse of Shinkabe style residence in Nishinomiya. Shinkabe is the oldest style of Japanese construction, and consists of post-and-beam vertical load-carrying system with lateral resistance, utilizing a bamboo lattice work in which silty clay is placed. This clay is also used in the roof along with heavy tile.

Slide 7: Damage to Okabe style residence. Later style Japanese construction. In Okabe, the exterior of bamboo-latticed mud is replaced with a thin, timber lathe stucco system. Exterior stucco is unreinforced. Note extensive dry rot and pest infestation. Dry rot and water damage in the wood posts and sill plates are widespread due to lack of water proofing.

Slide 8: Failure of "modern" wood-frame house. Access to damaged buildings like this one was not prohibited, and people returned to cracked, crumbling and dangerous homes to seek shelter and to retrieve belongings.

Slide 9: Damage to traditional and more modern construction in Kobe. The typical new wood-frame house is now closer to those in California with a mix of post-and-beam and stud-wall construction, and light asphalt shingle roof covering. Two levels are predominant in modern prefabricated timber housing because of the high cost of land.

Slide 10: Another catastrophic collapse of a residence.

Slide 11: Typical smaller commercial/mixed occupancy row of adjacent low-rise buildings, with open front at the first floor. The most common form of damage to this type of buildings was failure of a soft or weak first story. Such failures either caused collapse of the building or more commonly, as in this case, affected a permanent offset of the first story.

Slide 12: Collapse of a typical multi-story apartment building in Nishinomiya.

Slide 13: The collapse of this modern apartment building was partly due to the overturning of shear wall.

Slide 14: Close-up of the collapsed apartment building in slide 13. Note lack of hold-down detail at the end of wall.

Slide 15: A relatively tall, reinforced-concrete shear wall building had completely tipped over into the street. The roof of this building cut through the building across the street, in what might be considered an extreme case of pounding damage.

Slide 16-17: A number of buildings built on city-block corners sustained partial collapse at the corner of the building, or failed completely.

Slide 18-20: Partial or full collapse of a single story in buildings was the common failure for most of the larger buildings. The particular story that sustained partial of full collapse varied from building to building. First-story failure was more common than mid-level or uppper-story collapse.

Slide 21: Upper-story collapse of a six-story, reinforced concrete building. In this case, the collapsed floor could be associated with a structural irregularity, such as a set back.

Slide 22: Mid-level collapse of hospital building due to interaction with an adjacent structure.

Slide 23: The larger buildings were often out-of-plumb, or leaning, usually because of partial collapse of a floor on one side of the building or by permanent offset of the structural system. Although many modern buildings were damaged, few collapsed.

Slide 24: Severe damage to relatively modern hotel structure in downtown Kobe. While the majority of partial or complete collapses appear to be older, reinforced-concrete buildings (pre-1975), severe structural damage was also observed for buildings of steel or composite construction.

Slide 25: Typical street scene in downtown Kobe showing tilting commercial structures.

Slide 26: Building damage data as of January 21, 1995. Virtually all the damage occurred within 5 km of the fault.

Slide 27: Damage by building type.

INFRASTRUCTURE

The earthquake caused devastating damage to elevated expressways, railway systems, highways, ports and harbors.

Slide 28: Perhaps the most memorable image flashed around the world after the earthquake, was a bridge on the Hanshin expressway which "rolled over." This is an aerial view of that collapsed section of the Hanshin expressway. This spectacular failure occurred at the location where the superstructure deck changed from steel to concrete.

Slide 29: The columns in this segment of the Hanshin expressway are cast monolithically. Between each of these segments there is a simple span deck section which is connected by four bolts across the joint. The whole deck remained intact; none of the segments pulled apart.

Slide 30-31: Nearly every column along the elevated Hanshin expressway through Kobe was damaged. For the concrete columns, there was inadequate transverse reinforcement, making the columns very weak in shear, causing the longitudinal steel to birdcage and concrete to fail at low stresses. Note lack of cross ties and large spacing of horizontal ties.

Slide 32: Damage to steel girders and loss of bearing at expressway ramp.

Slide 33: Failure of steel plate box columns were found. No internal stiffeners or concrete fill in this column. The plate thickness was approximately 1 inch.

Slide 34: Single column bents as well as seat width for the superstructure were inadequate to sustain the seismic forces. Many spans fell off their bearings, and many bents collapsed.

Slide 35: Longitudinal failure. The eastern portion of the Hanshin expressway is nearly normal to the propagation of the fault and the movement was largely longitudinal.

Slide 36: A bus filled with holiday skiers stops just short of disaster on the Hanshin expressway.

Slide 37: Aerial view of the Hanshin expressway with two spans fallen off supporting piers. Several of those collapses occurred at the locations right next to a canal. Soil conditions may have contributed to those failures.

Slide 38: A major steel arch bridge on the Harbor Highway with an approach span down, somewhat similar to what happened on the Bay Bridge between Oakland and San Francisco.

Slide 39: the water line going to Rokko Island underneath this bridge has fallen and broken.

Slide 40,41 Rail facilities were hard hit, and more casualties and fatalities would have resulted if the quake had occurred during commute times.

Slide 42: Brittle fracture of steel column in railway bent.

Slide 43: Distorted rail tracks.

LIQUEFACTION

Widespread ground failure occurred throughout the strongly shaken region along the Osaka Bay. On the Rokko and Port Islands, reclaimed lands in Osaka Bay near Kobe, liquefaction caused subsidence in the range of 50 to 300 cm, and large volumes of silt were ejected. Lateral spreading of soils occurred in many parts of the extensive port facilities in Kobe, rendering many of them inoperative. Also large deformations of road pavements and of the ground around buildings have been responsible in part for the severe damage including tilting, collapse of structures, and failure of many bridges.

Slide 44: Many large container cranes were damaged on Rokko Island. The damage to the cranes is primarily due to rails spreading and settling. Crane damage consisted of buckling of legs at the portal ties.

Slide 45: Detail of buckled crane column on Rokko Island.

Slide 46: Liquefaction and lateral spreading damaged the crane rails.

Slide 47: Liquefaction and lateral spreading caused the settlement between the legs of the crane. The sea wall to the right has moved approximately one meter toward the water. The crane rocked as the sea wall moved and the crane jumped off the rail.

Slide 48: Liquefaction settlement adjacent to pile supported building on Rokko Island. Most pile supported structures, such as this administration building, have performed well. The grade adjacent to the building has settled about a meter, yet the building had no visible damage.

Slide 49,50: Widespread ground failure at Port Island.

Slide 51: Failure of bulkheads at Port in downtown Kobe. This was typical of many of the bulkheads and docking facilities in the downtown area.

FIRES

Slide 52,53: Aerial view of the city devastated by the post-earthquake fires. By the time the fires died out, large areas of Kobe had been destroyed.

Slide 54: All fires were burning freely, several with flames 20 ft. or more in height. Fire spread was via radiant heat and flame impingement, building to building in the densely built-up areas.

Slide 55: Burnt-out area of Nagata ward. People searched for personal possessions in the rubble of collapsed houses.

Slide 56: Map of fires in Nagata ward. Final burnt area in Kobe is estimated at 1 million sq. meters, with 50% of this in Nagata ward. The ignition sources of various fires may be assumed to include electricity, gas (propane and city gas), and chemical spills/reactions. Wind conditions were low and prevented the fires from spreading further.

EMERGENCY RESPONSE

This earthquake called for more than normal emergency response activities within and between jurisdictions; the scope of the system failures created a disaster that called for major adjustments in leadership and delivery mechanisms.

Slide 57: Search and rescue operation in Nishinomiya.

Slide 58: The lack of emphasis on controlling traffic flow has hampered the ability of emergency responders to get to the damaged or high hazard areas to carry out first response activities, such as fire suppression or rescue. Emergency vehicles with flashing lights were stuck in traffic.

Slide 59: Distribution of food and water.

Slide 60: Photograph found amongst broken tiles in the burned out area of Nagata ward.

****

Prepared by Elizabeth M. Arscott, EERI

References:

The Hyogo-ken Nanbu Earthquake of January 17, 1995, Preliminary Reconnaissance Report. C.D. Comartin, M. Greene, S. Tubbesing, tech. eds. Earthquake Engineering Research Institute, February 1995.

Technical Briefing on the Kobe Earthquake, February 10, 1995, San Francisco. Presentations at the EERI Annual Meeting by Patricia Bolton, David Bonneville, Craig Comartin, James Jirsa, Charles Kircher, Charles Scawthorn, Paul Somerville, and T. Leslie Youd.