
# 1995 Kobe Earthquake 10-year Retrospective

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# INTRODUCTION

A Mw6.9 (Ms7.3) earthquake struck central Honshu, Japan, shortly before dawn on January 17, 1995. The earthquake was centered at the northern end of Awaji Island, on a shallow strike-slip system known as the Nojima fault. The strongest ground motions were directed at the heavily urbanized flatlands that lie between Osaka Bay and the Rokko Mountains in the southern part of Hyogo Prefecture. All urban lifeline and transportation systems, including Japan's high-speed Shinkansen (rapid rail) system pass through this densely developed strip. Known as the Hanshin region, the cities of Kobe (1.3 million people) and Osaka (2.6 million people) dominate both the region's politics and economy.

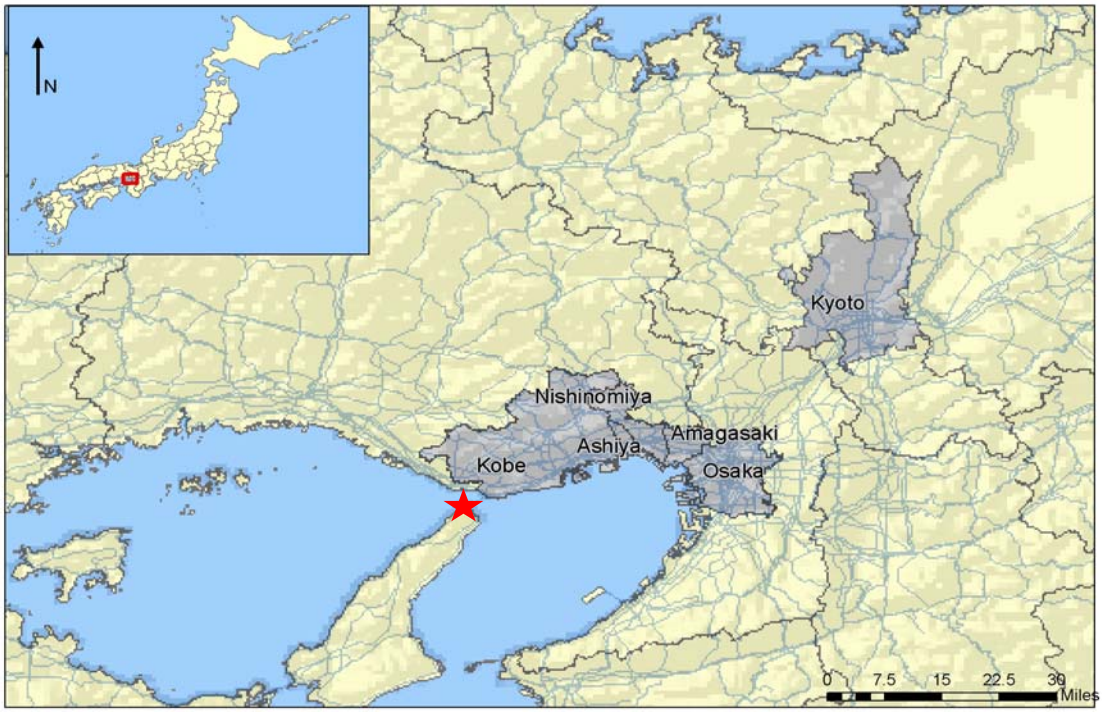


*Figure 1: The Hanshin region is located in central Honshu and is Japan's second largest regional economy*

# EARTHQUAKE CHARACTERISTICS

At an estimated depth of 16 km (10 miles), the Nojima fault ruptured 40 km (25 miles) from the northern end of Awaji Island northeast through the city of Kobe. Nine km (6 miles) of surface fault rupture was observed on Awaji Island, with offsets of 1.2 to 1.5 meters (0.7 to 0.9 miles). This permanent land offset is well-preserved in the construction of the Akashi Kaikyo suspension bridge that spans the 4-km (2.5-mile) Akashi strait between Awaji Island and Kobe. Bridge construction was underway at the time of the earthquake. The two bridge piers and suspension cables were in place, but the road bed had not yet been installed. The fault ruptured across the strait between the two piers and an extra meter had to be added to the center span, reinforcing the bridge's notoriety as the world's longest suspension cable bridge at 3,910 meters long overall.

*Figure 2: The Akashi-Kaikyo suspension bridge opened in 1998, linking Kobe with Awaji and Shikoku islands with the aim of extending industrialization and economic growth in this region of Japan (Honshu-Skikoku Bridge Authority, 2005)*

Many strong motion instruments were installed throughout the Hanshin region, which provided valuable information on ground motion characteristics. Figure 3 shows that ground motions for the Kobe earthquake reached seismic intensities of VII – the highest level on the Japan Meteorological Agency's (JMA) seismic intensity scale. Ground accelerations in the epicentral area were as high as 0.8g, and stations located 20 km (12 miles) from the fault rupture ranged from 0.2g to 0.3g.

There was considerable variability in ground motions across the impacted region, caused in large part by to the directivity of the fault rupture and the sensitivity of site responses to local soil

conditions and topography. The fault rupture directed strong ground motions toward Kobe's downtown district of Sannomiya, contributing to the high level of damage there. Widespread liquefaction occurred in the large deposits of soft alluvial soil and fill at Kobe Port and elsewhere around the margins of Osaka Bay. Other areas with poor soils and a high water table, including areas along the fault rupture and regional drainageways, also experienced ground failures and liquefaction.

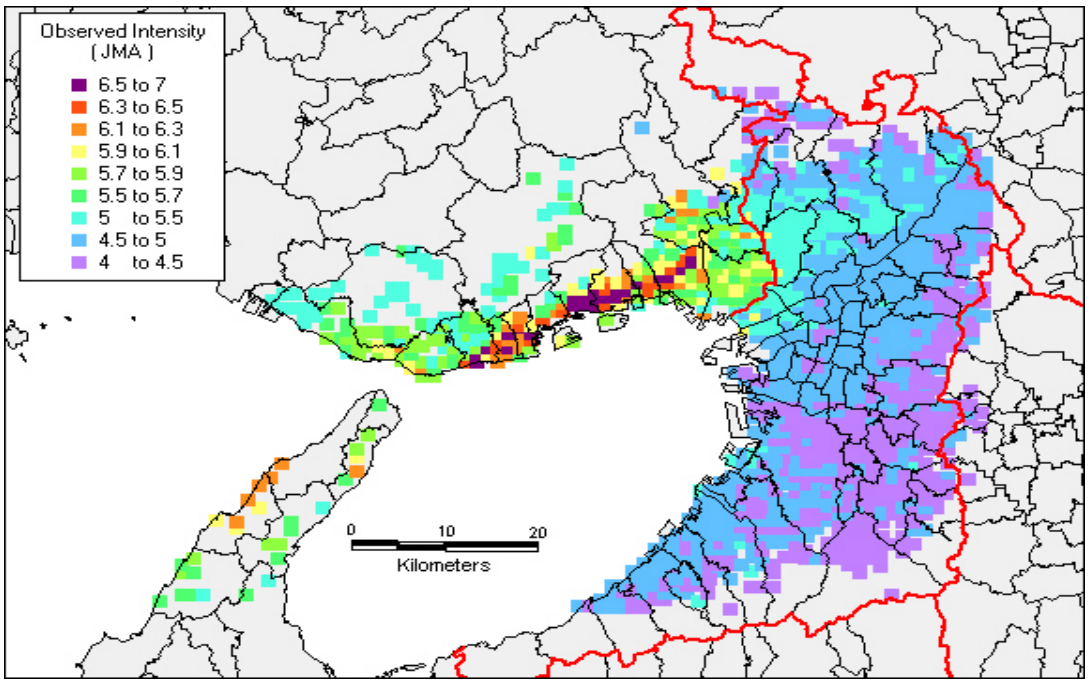


*Figure 3: Observed intensity (JMA scale) from the Japan Meteorological Agency*

# EARTHQUAKE IMPACTS

Losses from the Kobe Earthquake (also known as the Great Hanshin Earthquake) were truly immense. In all, over 6,400 people were killed and 15,000 injured. Fires consumed 82 hectares (203 acres) of urban land, and more than 400,000 buildings were damaged, of which 100,000 collapsed completely. A similar number were partially damaged, and thousands more sustained minor damage (see Figure 4). Two hundred thousand housing units were either partially or completely destroyed, and 85 percent of the region's schools, many hospitals, and other major public facilities sustained heavy damage.

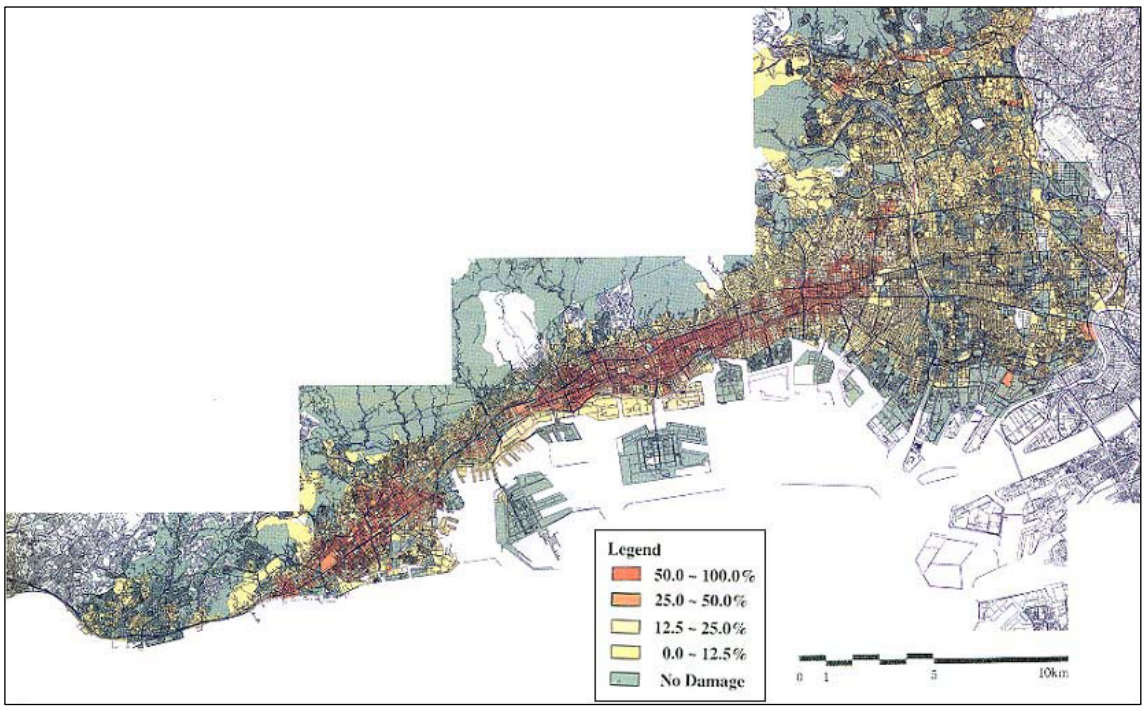


*Figure 4: A regional building damage survey was conducted by hundreds of volunteer professionals and engineering students shortly after the earthquake (Building Research Institute, Ministry of Construction, 1995)*

Most of the damage was caused by strong shaking and subsequent ground deformation and the destruction was concentrated in older, densely developed neighborhoods. Many of these neighborhoods had old wooden houses and buildings constructed in the massive rebuilding period after World War II, but before the 1981 update of seismic safety standards in the national Building Standards Law. The region's traditional wooden houses had heavy clay-tiled roofs designed to withstand the region's strong winds. Lacking internal partition walls that provide lateral strength and bracing, however, over 60 percent of the wooden structures in the impacted region were seriously damaged or collapsed. Non-ductile concrete, multi-family dwellings (particularly those built before 1981) also sustained heavy damage. A much higher proportion of structures built after 1981 survived the earthquake with relatively minor damage.

There was widespread water, gas, and sewer system damage as well as extensive damage to rail, road, and port facilities. More than 845,000 households lost gas service for as much as 2.5 months. Restoration of water and wastewater systems to nearly 1.27 million households took as long as 4 months in some parts of the region. Reconstruction of rail lines and roads were accelerated, but still took many months to complete. Three major east-west freeway routes through the region collapsed, the Japan Rail (JR) Sanyo and Shinkansen lines and stations were damaged, Kobe's subway and stations collapsed, and the monorails to Rokko and Port islands in Osaka Bay were also damaged.

At the time of the earthquake, Japan and the Hanshin region were in the midst of a recession and Kobe's economy was transitioning away from heavy industry and toward office, service, and retail sectors. The Port of Kobe, Japan's leading container shipping port, was heavily damaged and repairs took almost a year to complete. Chemical and steel manufacturers in the Hanshin industrial zone were damaged and inoperable for several months. Small and medium-sized businesses were also hit hard. About half of the region's famous sake breweries were seriously damaged, and one-third of the shopping districts and half of all the neighborhood markets were also impacted.

Unemployment rates rose quickly, and 80 percent of the city's 2,000 small and medium sized businesses failed. Over 48,300 temporary housing units were constructed, many of which operated for more than four years. Another 14,000 public housing units were used temporarily to house victims of the disaster. Kobe's heavily damaged central core had been losing affluent population to new suburbs prior to the earthquake, and the conditions accelerated after the earthquake.

While the true cost will never be known, the total economic losses from the disaster have been estimated at $150 billion, with more than $100 billion in infrastructure and property damages and as much as $50 billion in economic disruption. The total loss of transport infrastructure, the port closure, manufacturing shut-downs, and other business and institutional impacts diverted substantial sales, employment, income, and investment to competing regions in Japan and elsewhere.

Insurance losses to domestic carriers were about $3 billion, with a similar cost to the international market for claims arising from additional shipping costs, business interruption, and inventory losses. Japan's central government paid over $780 million in residential earthquake insurance scheme claims. Much of the remaining losses were claims paid on large commercial properties, particularly for multi-national operations.

# Reconstruction Process and Funding

The widespread destruction necessitated a substantial reconstruction effort, unlike anything experienced in any other post-World War II industrialized society. Japan's central government provided the majority of funds, allocating more than $58 billion in the first three years to reconstruct basic infrastructure, public facilities, and housing.

Immediately following the earthquake, Japan's central government implemented a two-month moratorium on rebuilding so local governments could focus first on planning. Hyogo Prefecture and the City of Kobe adopted complementary plans in March 1995, prioritizing projects that would do more than simply replace what had existed before the earthquake, but also aimed to stabilize the economy and attract new businesses.

Seventeen priority restoration districts were initially established and large urban redevelopment and land readjustment projects were identified within these districts. Reconstruction approaches such as land readjustment and urban redevelopment had been used extensively in Japan in previous decades to modernize land ownership patterns and facilitate the massive rebuilding following World War II. A total of 30 priority restoration districts were eventually recognized by local authorities, including some that had been established before the earthquake.


*Figure 5: Boundaries of the restoration promotion area (blue) in a portion of central Kobe with several of the priority restoration districts outlined (red)*

Post-earthquake land readjustment projects used central government funds to widen roads, add parks and open spaces, and construct other public facilities. In doing so, each property owner in the project area received a new parcel that was proportionately smaller than the original parcel. Where streets were added or realigned, an owner's new parcel was not necessarily in the original location. In some cases, buildings in readjustment project areas that survived the earthquake subsequently had to be demolished or relocated to make way for land replotting, new or widened roads and parks. In

urban redevelopment projects, all properties in the project area were purchased and the area reconstructed with large, mixed-use commercial and residential developments.

In general, all priority restoration district projects were large-scale public investments that significantly altered the character of pre-existing neighborhoods. Central government funds mainly paid for the public facilities constructed in the projects (such as land acquisition for road and infrastructure construction), but did not explicitly cover private construction. The funding terms also tended to favor full reconstruction, with limited funding available for repairs. Public assistance for residents and businesses was generally quite limited and many had to rely upon personal savings, combine resources, or rebuild smaller spaces in order to finance their reconstruction.

In April 1995, Hyogo Prefecture and the City of Kobe established the Great Hanshin-Awaji Earthquake Disaster Reconstruction Fund as a special supplementary resource to support victims, housing reconstruction, and other cultural, educational and industry restoration projects. Private banks provided ¥900 billion ($9 billion) in long-term loans to the prefecture and city, and in turn the central government established a similarly-sized fund to ensure against default. Over time, the reconstruction fund provided interest-free, long-term loans to more than 30,000 businesses and households, and supported other reconstruction activities that were not covered by the central government programs.

Rather than simply aiming to restore the economy to pre-event levels, Kobe and Hyogo Prefecture sought to create new growth through the restoration projects, and the central government's initial prioritization and infusion of funding for infrastructure rehabilitation was essential to the region's recovery. At a macro-economic level, the strategy worked fairly well. By 1999, Kobe's economy had recovered 75% to 90% of pre-event capacity, depending upon the sector. One notable exception is the Port of Kobe which permanently lost container shipping business to other Asian ports.

*Figure 6: By January 1999, freeways and rail lines had been rebuilt and recovery was well underway in the central Sannomiya business district of Kobe*

This wide-scale rebuilding inevitably took time to accomplish, and in 2003, many projects were still in the construction stages. The rebuilding moratorium was extended for up to two years in the land readjustment and urban redevelopment project areas to allow for planning and land negotiations. To help stimulate individual rebuilding, the government eventually had to provide housing rent subsidies and also enact a construction bonus allowing individuals to add floor area to their pre-earthquake housing size. Coupled with the public housing projects already under construction, this resulted in an unintended housing surplus that will take years to absorb. By April 2001, nearly 169,000 housing starts had been reported in the City of Kobe, which was more than twice the City's initial goal set in the 1995.

*Figure 7: In 2003, several land readjustment and urban redevelopment projects were still in the midst of reconstruction*

# INSURANCE INDUSTRY CHANGES SINCE THE 1995 EARTHQUAKE

In 1995, Japan's insurance industry was still heavily regulated with an insignificant amount of primary insurance provided by overseas carriers. The Japanese primary market was comprised of a small number of large carriers that relied upon overseas reinsurers to absorb catastrophe risks. At the time, only about 7 percent of homeowners carried earthquake insurance, and in Kobe the residential penetration was only around 3 percent. In the immediate aftermath of the 1995 disaster, demand for earthquake cover doubled to 15 percent of Japanese households. The increased demand strained domestic carriers as they sought to buy sufficient reinsurance and this led primary carriers to pursue alternative risk transfer deals as well as risk swaps.

Japan's residential earthquake insurance scheme, first introduced in 1966 following the 1964 Niigata Earthquake, established the Japan Earthquake Reinsurance Company Ltd., which, in turn, is reinsured by Japan's central government. The scheme offers a limited earthquake endorsement to the basic fire policy (in contrast to the U.S., fire following earthquake in Japan is not covered under the basic fire policy but rather requires the earthquake endorsement). Today, residential earthquake insurance in Japan covers both property and alternative accommodations, paying claims on a basis of tiered damage, as shown in Table 1. The policy limits are ¥50 million (US$500,000) on buildings and ¥10 million ($100,000) for contents. Since 2001, earthquake premium rates have also been based upon earthquake resistance classifications in an effort to promote higher quality housing.

| | Full Damage | Half Loss Damage | Partial Loss Damage | Limits |
|---|---|---|---|---|
| Residence | > 50% loss of value of the structure | >20% and <50% loss of value of the structure | >3% and <20% loss of value of the structure | ¥50 million |
| Household Goods | >80% loss of value | >30% and <80% loss of value | >10% and <30% loss of value | ¥10 million |
| Payment | Full value of insurance policy | 50% of value of insurance policy | 5% of value of insurance policy | |

*Table 1: Definitions of damage payment terms for residential earthquake insurance in Japan*

In 1998, Japan initiated primary insurance deregulation and international insurers were granted licenses to accept direct risks. Although this has led to greater choice for Japanese insurance buyers, it has not had a significant effect in earthquake coverage. Commercial lines are not reinsured by the central government, but capacity is limited by governmental intervention. Because of the very limited commercial capacity in Japan, some risk is placed offshore.

# LESSONS LEARNED

The 1995 earthquake was the most significant seismological event in Japan since the 1923 Great Kanto Earthquake. As a result, the event instigated many new research programs in all aspects of earthquake engineering, seismology, and disaster management both in Japan and around the world. The earthquake illustrated the importance of hazard mitigation for complex urban environments dependent upon a sophisticated array of transportation, communication, and infrastructure systems. It also illustrated how the degree of damage clearly differs depending upon a combination of hazard, exposure, and vulnerability and the need for more probabilistic approaches to risk assessment.

*Figure 8: At 5:46 am, on January 17, 2005 thousands filled the grounds of Kobe city hall to commemorate the 10-year anniversary of the earthquake and the 6,400 lives lost*

It was also the first real test of Japan's post-1981 building code. The structures built to this newer code generally performed well. Code changes enacted in the early 1980s prohibited the use of non-ductile reinforced concrete structures in favor of ductile reinforced concrete structures. These newer structures provided greater flexibility, allowing structures to withstand the strong ground shaking levels experienced in Kobe.

The 1995 earthquake also illustrated several structural shortcomings which Japan's central government and engineering community moved quickly to address, adopting several new laws and key code amendments in the first years after the earthquake. Design standards to prevent soft story failures were reviewed and revised. Moreover, the detailing, material strength, and hardware requirements, as well as the foundation and shear wall design for wooden buildings have also been significantly improved. To enhance overall construction quality, interim construction inspections are now required for all new buildings, in addition to the construction completion inspections that were enforced prior to 1998. And, as of late 1995, all pre-1981 buildings in public use must have a seismic evaluation and retrofits are required if needed. In recent years, Japan's engineering community has been moving away from safety-based design guidelines in favor of performance-based designs. Investors are increasingly opting to construct higher performance buildings to mitigate potential operational risks such as business interruption.

The surface rupture of the Nojima fault also highlighted the active crustal faults hazards in Japan, and the need to incorporate these sources into national seismic risk assessment programs that until then had been dominated by the major offshore subduction zone interface events. As a result, the Japanese government has undertaken a major research project to map active faults and develop comprehensive seismic hazard maps. These maps are now close to completion and will be incorporated into the updated RMS® Japan Earthquake Model scheduled for release in autumn 2005. The maps will include recent research into active faults as well as the latest understanding of the risk posed by subduction interface and intraslab events. They will also include background seismicity to account for earthquakes on unidentified seismic sources.

# FUTURE CONCERNS

Started in 1979, Japan's national seismic risk reduction program has had its funding levels increased substantially in recent years, and its breadth of coverage has been expanded to prepare for a broader range of potentially catastrophic earthquake scenarios. Central government planners are especially focused on integrated disaster risk reduction efforts for the major Tokai, Tonankai, and Nankai earthquakes scenarios, which threaten Japan's heavily populated eastern coast of central Honshu. These catastrophic scenarios have probabilities of occurrence in excess of forty percent in the next 30 years. Results of the government's fault research program are also starting to emerge. In early January 2005, a government panel announced that the 71-km Rokko-Awajishima fault zone has a one percent probability of generating a maximum Ms7.9 earthquake within the next 30 years, significantly more energy than this same system released in the 1995 Kobe Earthquake (Ms7.3).

Residential earthquake insurance penetration in Japan has been steadily increasing, exceeding 16 percent in 2003. Penetration rates have been higher in more historically earthquake-prone regions of Japan, such as Tokyo. The liability of the residential insurance scheme has traditionally been set to cover potential claims from a repeat of the 1923 Kanto Earthquake. When any earthquake occurs and claims exceed ¥75 billion ($75 million), the central government will cover between 50 to 95% of the cost, with only a fraction of the excess loss paid by the Japan Earthquake Reinsurance Company and direct writers. In early 2005, in response to public pressures following the Niigata-Chuetsu Earthquake and the Asian tsunami disaster, the central government announced plans to increase the government's limit by over 11 percent to ¥5 trillion ($50 billion). Even with the added reinsurance cover, financing the recovery for future catastrophic urban earthquakes, as illustrated by the 1995 Kobe Earthquake, will be quite substantial.

RMS estimates that a recurrence of the Ms8.2 Kanto Earthquake of 1923 could cause insurance losses in excess of $100 billion today. International concern about Japan's market risk for earthquakes is growing, and reports indicate that some businesses in the Kanto region have had difficulty getting earthquake insurance. In response, Japan's central government has been developing new strategies that encourage businesses to implement risk reduction measures and undertake business continuity planning. The autumn 2005 upgrade of the RMS Japan Earthquake Model will include high-resolution, third-generation modelling advances that will enhance individual risk underwriting capabilities in Japan and allow businesses to better assess the cost-effectiveness of alternative risk reduction strategies.