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EARTHQUAKE DISASTER RISK MITIGATION BEFORE AND AFTER THE 1995 KOBE EARTHQUAKE

Tsuneo KATAYAMA[1]

SUMMARY

Before the 1995 Kobe earthquake, we always referred to the 1923 Kanto earthquake whenever we talked about destructions of damaging earthquakes in Japan. We often thought, however, that, since structure's strength had increased and preparedness efforts had improved, a disaster like the Kanto earthquake would not happen again.

However, having faced the Kobe disaster with more than 6,000 fatalities, we have come to think how self-conceited we had been to the earthquake safety of our structures and communities. Before the Kobe earthquake, we were beginning to place more emphasis on economic and social issues of earthquake disasters than on their technical and engineering aspects.

In my opinion, earthquake risk before the Kobe earthquake generally pivoted on lifelines, networks, systems and simulations. Although these problems are still important, after the Kobe earthquake we have come to realize that strength of structures is the crucial component in Japan's earthquake risk mitigation even today. Thousands of the traditional Japanese wooden houses were totally destroyed, and a number of non-ductile reinforced concrete bridges and buildings built according to old building codes collapsed.

It is essential to know how structures collapse under strong ground motions, how to distinguish weak structures from strong ones and how to strengthen bad and weak ones. This is why we are now constructing the world's largest, three-dimensional shake table "E-Defense." And in particular, unless we significantly decrease the number of the weak houses, which is estimated at more than 10 million in all Japan, there will be another Kobe disaster in the future.

In this paper, I am going to summarize the changes that have taken place in the fields of seismology and earthquake engineering in Japan after the 1995 Kobe earthquake. However, these changes have been so many in number and are related to so many different sectors of society that I will not be able to identify all of them in a comprehensive manner. What I am going to describe in this paper is only part of the changes and developments which have taken place close to my personal activities.

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[1] President, Independent Administrative Institution, National Research Institute for Earth Science and Disaster Prevention, Tsukuba, Japan

WHY IN KOBE?

At 5:46 in the early morning of January 17, 1995, a magnitude 7.2 earthquake rocked the city of Kobe and its vicinity. It was Tuesday, and most of the people were still deep asleep after a three-day long holiday. The earthquake was officially named the Hyogo-ken Nanbu earthquake, but it is better known as the 1995 Kobe earthquake worldwide. "Buildings were toppled, houses were in rubbles, infernos swallowed entire towns, elevated highways and railways collapsed, and crumbled cliffs buried houses. Everywhere people died," reported Asahi Evening News on the next day of the earthquake.

Although the earthquake affected Hyogo, Kyoto, and Osaka prefectures, damage in Hyogo prefecture, especially in the city of Kobe, was by far the largest. Kobe is Japan's sixth largest city with a population of 1.6 million (1993) on an area of 546 km^2, and when nearby cities and towns are included the population reaches almost 2 million. Ranked as the sixth largest cargo port in the world, about 12 percent of Japan's exports pass through Kobe. It handled about 40 million tons of international container cargo in 1993, with sea links to about 500 ports in 135 countries.

The earthquake caught the residents of the Kansai (Osaka, Kyoto, and Kobe) region off guard. Nobody imagined that such a devastating earthquake could strike the Kansai region. In general, most attention had been focused on plate boundary earthquakes taking place in subduction zones. Moreover, until then, anti-earthquake policies had been directed toward the Kanto area with special emphasis on Tokyo, and people found that Kansai had been a blind spot, in that both officials and citizens were largely unprepared.

Immediate responses in the heavily hit areas were concentrated to search and rescue, and firefighting. Although local governments fell into chaos with many officials themselves becoming victims, Hyogo Police Department established disaster guard headquarters at 6:15 a.m., Hyogo prefectural government and Kobe city independently established their emergency response offices at 7:00 a.m.

The nation was appalled by Tokyo's lack of leadership and absence of crisis management in the initial hours after the earthquake. Despite the rapid distribution of shaking intensity on national television, the government completely failed to grasp the full extent of the earthquake damage. During the cabinet meeting in the morning, it was decided to establish major emergency response headquarters, and the first meeting of the headquarters held in the afternoon agreed to help municipal governments in the heavily affected area with respect to rescue operations and earliest possible recovery.

The earthquake was a fresh reminder that big cities now are full of dangerous and disparate factors beyond comparison with those that existed at the time of the 1923 Great Kanto earthquake. The region's infrastructure, including water and gas networks, telephone lines, power cables, highways and railways were crippled, paralyzing business and financial operations.

DEATH TOLL CONTINUED TO INCREASE

The death toll reported in the morning after the earthquake was 1,812. But this was only the beginning. It continued to increase, reaching 5,502, making it the worst earthquake since the 1923 Great Kanto earthquake. As of January 11, 2000, five years after the earthquake, the death toll reached 6,432, including those who died of causes indirectly related to earthquake. More than 99% of the death casualty occurred in Hyogo prefecture, and 71% of the total death in Kobe.

The earthquake was the first in the modern history of Japan that seriously hit a heavily populated urban area, and the size of the damage was beyond all the expectations. About 100,000 houses and buildings were totally destroyed, directly causing about 80% of the fatalities in the early hours after the earthquake.

The majority of these houses were the old-style wooden houses built before 1970 according to the old building code. Almost all completely destroyed houses/buildings concentrated in Hyogo prefecture, and about 60% of them were located in Kobe where about 10% of the houses/buildings were completely destroyed.

In Kobe alone, more than 100 fires are reported to have occurred during the day of the earthquake. There was almost no water for fire fighting in the city. In Hyogo prefecture, about 7,000 houses/buildings were completely burnt down, killing 559 people.

The Kobe earthquake inflicted direct and indirect damage of about 200 billion US Dollars. Based on the data of the damage reported by January 25, 1995, the survey and research division of Tokai Research and Consulting Corporation estimated that the damage amounted to about 37% of the total property in the stricken region, 0.6% of the total property in Japan, or 1.6% of Gross Domestic Product (GDP).

If the earthquake had taken place not at the dawn but at other hours, the devastation would have been much more extensive. Engineers forecast that damage could be even worth if such an earthquake attacks Tokyo, the capital of Japan, sociologists and economists forewarn that the earthquake would destroy the brain of the nation, and seismologists alert that an earthquake of the size of the Kobe earthquake may take place anywhere in Japan.

After the Kobe earthquake, many new policies have been introduced and a number of innovations and developments have been made in science and technology in the fields of seismology and earthquake engineering. At one time, the people of Japan seriously felt that their lives and properties are vulnerable to destructive earthquakes wherever they live. Within about 10 years after the Kobe earthquake, however, people are already beginning to forget the lessons they have learned from the disaster.

WOODEN HOUSES FOUND VULNERABLE

I was totally dismayed and at a loss when I witnessed many structures in Kobe collapse in such a miserable manner. Before the Kobe earthquake, I tended to think that structures in Japan had become strong enough to resist a most powerful earthquake such as the one that devastated Tokyo and Yokohama in 1923.

The truth, however, was that we were only lucky that strong earthquakes did not take place near our urban areas for nearly half a century. During the same period of time, Japan's earthquake engineering research and technology significantly advanced. I think these experiences misguided people, especially those who know more about earthquakes. By simply combining these two independent facts, we were beginning to wrongly believe that Japanese structures had become strong enough to survive even severe earthquakes. At least, I never thought that the Kobe event would become such a calamity.

The Kobe earthquake clearly indicated that there were millions of old and/or weak houses, mostly of wooden, in large urbanized areas in Japan, and that our earthquake-resistant design codes were defective.

After the Kobe earthquake, engineers and officials realized the importance of the assessment of earthquake strength of existing houses and their strengthening, if necessary, according to the results of the assessment. Major revisions of the Japanese Building Code took place in 1971 and 1981. Especially, majority of the houses built before the 1971 revision were found vulnerable. Although the Building Code does not require existing houses to be strengthened according to the most recent code, unless these houses are properly strengthened, the tragedy of Kobe will repeat.

In October 1995, the Seismic Rehabilitation Promotion Act for Existing Buildings was established, and the government started to promote assessment and strengthening of old houses against earthquake effects. It is not easy to estimate the number of houses and buildings which require urgent strengthening. According to one such estimate, there are 24 million houses and buildings built under the old building codes, and about a half of them need urgent strengthening. In comparison with this huge stock of vulnerable houses and buildings, the number of those assessed and found sound and the number of those assessed and strengthened are appallingly small.

After the Kobe earthquake, a number of municipal governments inaugurated systems to financially support those who wish to strengthen their houses.

Yokohama is one of the most advanced cities in this respect. In October 1995, Yokohama started to offer a free assessment and a special loan system with a maximum of 6 million Yen. Because there were such a small number of citizens who applied for this system, the city newly established in July 1999 an aid system with a maximum subsidy of 2 million Yen for the households with an average income. In the last 5 years from 1999 to 2003, the number of citizens who applied to the free assessment is about 6,000, and those who applied to the aid system is only about 600. If we assume that the number of vulnerable houses is proportional to population, there may be more than 300,000 vulnerable houses in Yokohama, implying the number of citizens who have used the subsidy system is only 0.2% of the owners of vulnerable houses.

The problem is not simply that of engineering and technology but that of policy and incentive. Under the present system, if a strengthened house is damaged during a future earthquake, there is no compensation for the owner. Some specialists say that, unless this situation changes, the massive gap will remain between the number of old/weak buildings and that of assessed/strengthened buildings.

BRIDGES HAD BEEN CONSIDERED EARTHQUAKE-RESISTANT

In 1924, one year after the Kanto earthquake, seismic effects were first introduced in the design of highway bridges in Japan. Since then more than 10 major and minor revisions had been made before the 1990 specifications was established which was in force at the time of the Kobe earthquake. This specifications included ductility check of reinforced concrete piers, soil liquefaction, dynamic response analysis, and various kinds of anti-seismic details such as unseating prevention devices.

Although I suspected that some of the Japanese bridges were less earthquake-resistant than the others, I was sure that the Japanese bridges would not collapse in such a way that some of the US bridges did during the recent earthquakes.

There was a misjudgment among Japanese engineers. Since the 1923 Kanto earthquake, most of the Japanese structures were designed to large static horizontal forces. The seismic factors of 0.2 to 0.3 were four to five times greater than those used for many of the US structures constructed before the 1971 San Fernando earthquake. This was generally considered as one of the reasons why Japanese structures were more earthquake resistant than similar structures in the US.

It should have been noted, however, that the first exclusive specifications for the seismic design of bridges was established in 1971, and that the detailed ductility check method for reinforced concrete piers was introduced for the first time in the 1990 specifications. Brittle reinforced concrete structures will eventually fail in shear in a catastrophic manner.

Even before the Kobe earthquake, repeatedly since 1971, Japanese bridges had been systematically assessed for their earthquake-resistant capacity and retrofitted as part of the comprehensive earthquake disaster prevention measures for highway facilities.

During the first series launched in 1971, about 18,000 highway bridges were assessed for their earthquake vulnerabilities and about 3,200 bridges were found to require retrofit. Subsequent assessments were made in 1976, 1979, 1986 and 1991, by expanding the types of bridges to be assessed and also by increasing the check items. In the 1986 series, about 40,000 bridges were assessed and 11,800 were found vulnerable. In the 1991 series, about 60,000 bridges were assessed and 18,000 bridges were found to require retrofit. At the end of 1994, only several weeks before the occurrence of the Kobe earthquake, about 32,000 bridges had been retrofitted in total [1].

BUT THEY WERE HEAVILY DAMAGED

By the Kobe earthquake, however, collapse and near collapse of superstructures of highway bridges took place at 9 sites, and other destructive damage at 16 sites. Although the ground motions in the epicentral area were much stronger than those specified in the design specifications, modes of collapse clearly illustrated that the earthquake-resistant design specifications was defective.

Immediately following the earthquake, a committee was set up in the Ministry of Construction to investigate the damage inflicted upon highway bridges by the Kobe earthquake. The committee inspected a total of 3,396 bridge piers in the area of destructive damage. On February 27, 1995, the committee approved a special guideline for the reconstruction and repair of the highway bridges damaged by the Kobe earthquake. This guideline had also been used tentatively to retrofit existing bridges and to design new highway bridges until the new specifications was drawn in November 1996.

In addition to the fact that the strong ground motions which were found larger than those specified in the design codes, the committee pointed out the following findings [2]:

1) Reinforced concrete piers were damaged at their mid-height, because longitudinal reinforcement bars were terminated without enough anchorage length.
2) While piers designed according to the 1964 or 1971 specifications were damaged, heavy damage was not found for those designed according to the 1980 or 1990 specifications.
3) Many damages were found at bearing supports and restrainers. Some unseating prevention devices were not effective.
4) Liquefaction-induced ground flow caused instability of piers.

RETROFIT PROGRAM AND REVISION OF DESIGN SPECIFICATIONS

A 3-year seismic retrofit program to be completed in the fiscal year of 1997 began to strengthen the piers of extremely important bridges designed by the pre-1980 design specifications. About 30,000 bridge piers were assessed and retrofitted. The main purpose of retrofitting RC piers was to increase their ductility. The existing columns were jacketed by steel plate, and epoxy resin or non-shrinkage concrete mortar was injected between the plate and the RC column. A small spacing was provided at the bottom of the jacket to prevent excessive increase of flexural strength. Different retrofitting methods were used for different types of piers.

After the Kobe earthquake, adoption of two levels of ground motions with two levels of structure's importance has become common for the design of most of the public structures. The level of the higher ground motion corresponds to an earthquake of very rare occurrence. Structures with higher importance should survive this level of ground motion with minor damage, but substantial damage is tolerated for structures with lower importance as far as life safety is secured.

In the case of highway bridges, depending on their importance, bridges are categorized into standard bridges and important bridges. All bridges should behave in an elastic manner without significant structural damage for moderate ground motions generated by earthquakes with high probability of occurrence. For very strong ground motions induced by earthquakes with low probability of occurrence, important bridges should survive critical failure, while limited damage is tolerated in standard bridges.

Two types of very strong ground motions are considered. They are those induced by an M8-class plate boundary earthquake, and those generated by an M7-class earthquake taking place at a very short epicentral distance. The former assumes the ground motions expected in Tokyo by the recurrence of the 1923 Kanto earthquake, and the latter typically corresponds to the ground motions in Kobe by the 1995 Kobe earthquake.

E-DEFENSE - A THREE-DIMENSIONAL, WORLD'S LARGEST SHAKE TABLE

The Kobe earthquake have shown that ground motion beyond general estimation occurs in the area near the seismic fault, and such motion is capable of causing severe damage to even modern structures. Although many structures collapsed or were heavily damaged in Kobe, there was hardly any person who observed the process of these failures in a scientific manner. The purpose of building "E-Defense" is to make clear why, how, and to what extent real structures are damaged under strong 3-D ground motions [3]. Failure mechanisms and collapse processes should be examined by full-scale collapse tests to eliminate scaling problems inherently involved in scale-model tests. 3-D motion is necessary to simulate the processes of destruction under the condition of real earthquake motions.

In March 1996, about a year after the Kobe earthquake, the Minister of Science and Technology Agency (STA) asked one of the Minister's Councils to examine how future earthquake disaster mitigation strategies ought to be and to report the results to the Minister. In the final report submitted to the Minister in September 1997, the Council proposed to build a 3-D full-scale earthquake simulator in Miki city to the north of Kobe.

After having successfully completed the feasibility studies by 6m x 6m table with 4 horizontal and 4 vertical actuators, the design and construction of E-Defense officially started in 1998.

The foundation for the shake table and other major buildings is a huge reinforced concrete block with 90m x 65m x 25m (H), and weighs about 200,000 ton-f. The first batch of concrete was cast in June 2000. The construction of the buildings and the assembly and equipping of the large actuators and hydraulic components including pipelines was completed in June 2003. There are several buildings: an experiment building in which the shake table and the actuators are installed, a control and measurement building, a hydraulic power supply building, a test preparation building, and an electric power supply building.

As of February 2004, having almost completed the purification of oil as well as the inner surfaces of the hydraulic equipment and pipes, the fabrication of the 20m x 15m x 5.5m (H) shake table is in progress. 32 boxes manufactured in the factory have been brought into the experiment building and are welded together into a large shake table. The final stage will be the performance tests of the total shake table including control and measurement systems. E-Defense will be completed in the beginning of 2005, the 10th year after the calamity of the Kobe earthquake.

Table 1 is the basic specification of E-Defense, and Figure 1 shows its schematic drawing. The maximum test weight is 1,200 ton-f which roughly corresponds to a real-sized 4-story reinforced concrete (RC) building with a floor area of 20m x 15m. The maximum acceleration, velocity, and displacement in the two horizontal directions are 0.9G, 200cm/s, and 1m, respectively, and those in the vertical direction are 1.5G, 70cm/s, and 0.5m, respectively. High velocity and large displacement amplitude is needed to simulate future great earthquakes with long-period components of ground motion.

Table 1 Basic Specifications of E-Defense

Table size	20m x 15m	
Maximum test weight	1,200 ton-f	
Drive mechanism	Accumulator charged/ Electro-hydraulic servo control	
Drive direction	**Horizontal**	**Vertical**
Maximum displacement	± 100 cm	± 50 cm
Maximum velocity	200 cm/s	70 cm/s
Maximum Acceleration	900 cm/s^2	1,500 cm/s^2
Maximum Allowable Moment	**Overturning**	**Yawing**
	15,000 ton-f.m	4,000 ton-f.m
Frequency	0-15Hz (with accuracy) 15-30Hz (can be driven)	
Wave distortion	≤ 15 % (in useful domain)	

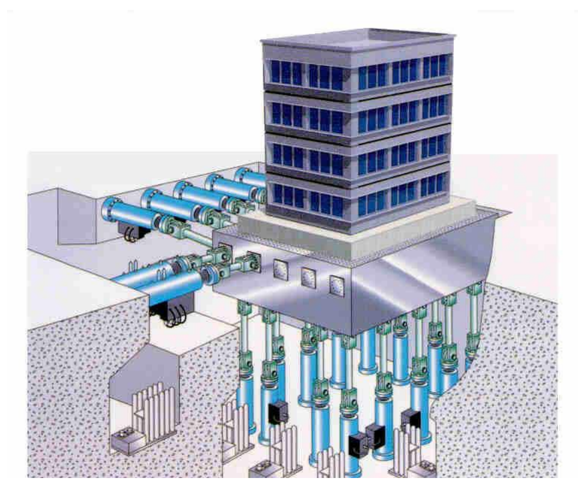

Figure 1 Schematic Drawing of E-Defense

The control technique and measurement system will be the most important items in the performance tests to be carried out before the completion of the whole system. Stable and robust control of the table should be verified. Any 64 channels can be used by researchers from a total of 440 channels to control the motion of the table, and the number of the channels available for measurement purposes is 896.

In the first two years after the completion, NIED is planning to test 1) RC buildings, 2) soil-pile-structure systems, and 3) traditional Japanese wooden houses. As an example, Figure 2 shows the RC frame model to be tested by E-Defense. This six-story RC frame will consist of 2 x 3 spans and the space between the columns will be 5 m in both directions. The total height will be 18 m, and the total weight about 1,000 ton-f. The purpose of full-scale tests is to investigate the 3-D dynamic failure mechanism of RC structures by alleviating any difficulties arising from the limitation of the scaled-models. As a preparatory research for the full-scale tests, shake table tests of 1/3-scale models have been conducted by using an existing shake table. Results of these tests will give preparatory information on experimental technology, failure mechanism and processes of RC buildings before the full-scale tests.

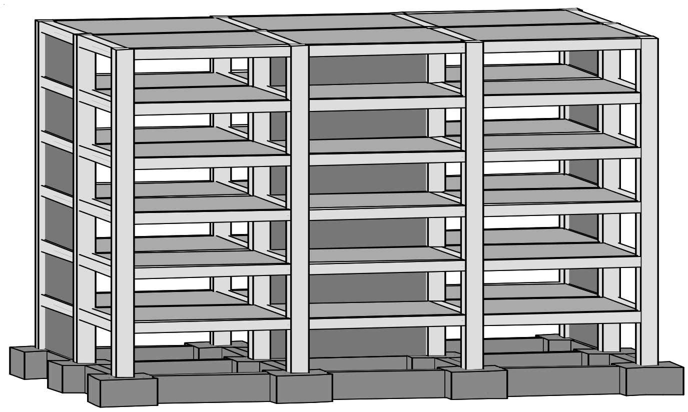

Figure 2 Full-scale RC Building Frame to be Tested by E-Defense (Height=18m, Weight=1,000 ton-f)

The shake table being the largest and one of the most valuable research assets for the earthquake engineering community in the world, we are seeking international collaboration. For this purpose, we are currently developing ED-net, E-Defense network, to connect E-Defense with possible users in Japan and overseas.

HEADQUARTERS FOR EARTHQUAKE RESEARCH PROMOTION

After the Kobe earthquake, Japan's strategy for earthquake disaster mitigation has greatly changed both in research and practice. Disaster prevention measures in Japan are carried out according to the aims outlined in the Basic Disaster Prevention Plan, often referred to as the constitution for disasters related issues, established by the Central Disaster Prevention Council. Earthquake disaster prevention measures are also included in this framework as its earthquake disaster prevention section. This Basic Plan was revised in June 1997, and it presents disaster prevention measures, disaster emergency measures, disaster relief and reconstruction measures, tsunami countermeasures and wide-ranging earthquake countermeasures.

Although there had been several nation-level organizations related to scientific research in seismology, it was strongly realized after the Kobe earthquake that a single national body for the scientific studies of earthquakes is necessary. On this recognition, in June 1995, five months after the earthquake, the Special Measures Law on Earthquake Disaster Prevention was proposed by Parliamentary Members, and it was enacted on July 18, 1995, six months after the calamity in Kobe. According to the Special Measures Law, the Headquarters for Earthquake Research Promotion (hereinafter simply referred to as the Headquarters) was established in the Prime Minister's Office to carry out the basic and comprehensive research in seismology. The Headquarters' business was decided to be administered by STA.

The Headquarters has been entrusted to undertake the following tasks:

1. Formulation of comprehensive and basic policies,
2. Coordination of administrative works of relevant Ministries,
3. Formulation of comprehensive survey and observation plans,
4. Collection, analysis and evaluation of the results of surveys and observations, and
5. Public relations based on the comprehensive evaluation of the most recent observations.

KIBAN PROJECT INITIATED

The first activity of the Headquarters was construction of seismometer networks, and a GPS-station network, both uniformly covering the whole area of Japan, and active fault survey.

Even before the Kobe earthquake, many research organizations including the National Research Institute for Earth Science and Disaster Prevention (NIED), the Japan Meteorological Agency (JMA), and universities were independently operating seismometer networks in many areas of Japan. The total number of seismometers was about 500, but none of the networks covered the whole area of Japan densely and uniformly. The Headquarters compiled a report on the fundamental policy for earthquake observation program in June 1997, and set up the "Fundamental Survey and Observation Plan for Earthquake Research" on August 29, 1997, which is often called as the Kiban project. Kiban in Japanese means "fundamental."

The Kiban project identified the following five programs as having high priorities:

High sensitivity seismic observation (Hi-net),
Broadband seismic observation (Freesia or F-net),
Strong-motion earthquake observation (K-NET and KiK-net),
Crustal deformation observation by GPS (GEONET), and
Active fault survey on land and in coastal regions.

Kyoshin Net (K-NET) was the first among the various networks established after the Kobe earthquake. Kyoshin means "strong-motion" in Japanese. K-NET was established by NIED in June of 1996, before the Kiban project officially started in 1997. About 1,000 digital strong-motion seismometers were installed all over Japan at an average station to station distance of about 25km within 1 and a half years after the earthquake. The seismometer has a maximum measurable acceleration of 2,000 cm/s^2, and is installed on the free field. After receiving the provisional source information from JMA, the control center at NIED in Tsukuba starts to acquire and compile the strong-motion records by telephone lines.

Each seismometer has two communication ports, one directly connected to a modem belonging to a local municipal government and the other connected to the NIED control center in Tsukuba. The former port may be used if municipal governments want to directly use the data for their disaster assessment and management. A set of strong-motion records is made available on the Internet within several hours after the occurrence of an earthquake. The number of records obtained during an earthquake differs from several tens to several hundreds according to the size of the earthquake. A map showing the distribution of maximum accelerations is also made available on the Internet.

3,000 SEISMOMETERS AT 1,800 LOCATIONS

NIED had been operating a high sensitivity seismometer network since 1978 for the purpose of the prediction of the Tokai earthquake in the central part of Japan. Because of this experience, NIED was appointed as the responsible organization for the construction and operation of new seismometer networks proposed by the Headquarters.

The Hi-net system utilizes velocity-type seismometers to obtain precise information on earthquake activity and subsurface ground structure. Because most of the urban areas in Japan are situated on deep and soft sediment, seismometers are encased in anti-pressure vessel and installed at the bottom of a bore hole at a depth of 100m or deeper to eliminate noises caused by human activities. Some of the bore holes are as deep as 1,000m or more. To accurately determine the focal depth, seismometers are located at an average spacing of 15 to 20km.

The original sampling frequency and the resolution of A/D converter are 2kHz and 24bits, respectively, which are usually transformed into a data set with 100 Hz sampling frequency and 27bits resolution. Event waveform data and continuous waveform data are stored in a disk server which is able to store six months continuous data for the all stations. All data are also saved in digital linear tape library system as a backup. At each of the Hi-net station, two strong-motion acceleration-type seismometers are installed, one at the bottom of the bore hole and the other on the free field. This additional strong-motion seismometer network is named KiK-net, i.e. Kiban K-net.

F-net is a system of broadband seismometers under a NIED special project entitled FREESIA (Fundamental Research on Earthquakes and Earth's Interior Anomalies) all over Japan. The system deploys a very broadband seismometer with a natural period of 300s as well as a velocity-type strong-motion seismometer with a maximum measurable velocity of 0.4m/s. These seismometers are installed at the end of an about 40m-long horizontal tunnel specially excavated.

F-net records can be used for research on earthquake source mechanisms and the structure of the earth's mantle and core. On-line data from F-net is used to automatically determine moment tensors by inversion using long period waves with natural periods between 20s and 50s. On receiving an e-mail notice of earthquake occurrence from JMA, data set is automatically retrieved for waveform inversion, data quality is examined, filtering coefficients and data windows are determined. Results of inversion are automatically displayed on the Web within 5 minutes after the arrival of the e-mail from JMA.

As of January 2002, NIED maintains and operates a total of about 3,000 seismometers at about 1,800 locations. They include 1) K-NET with 1,034 strong-motion seismometers, 2) Hi-net with 560 high sensitivity seismometers, 3) KiK-net with two strong-motion seismometers at each Hi-net station, 4) F-net with 75 broadband seismometers, and 5) the network in the central part of Japan operated by NIED since 1978.

Figure 3 shows the distribution of the seismometers currently operated by NIED. Most of the records from these networks can be freely accessed at (http://www.bosai.go.jp/jindex.html) for scientific studies and engineering applications. Users are only requested to acknowledge the data source and to send a copy of their publication to NIED.

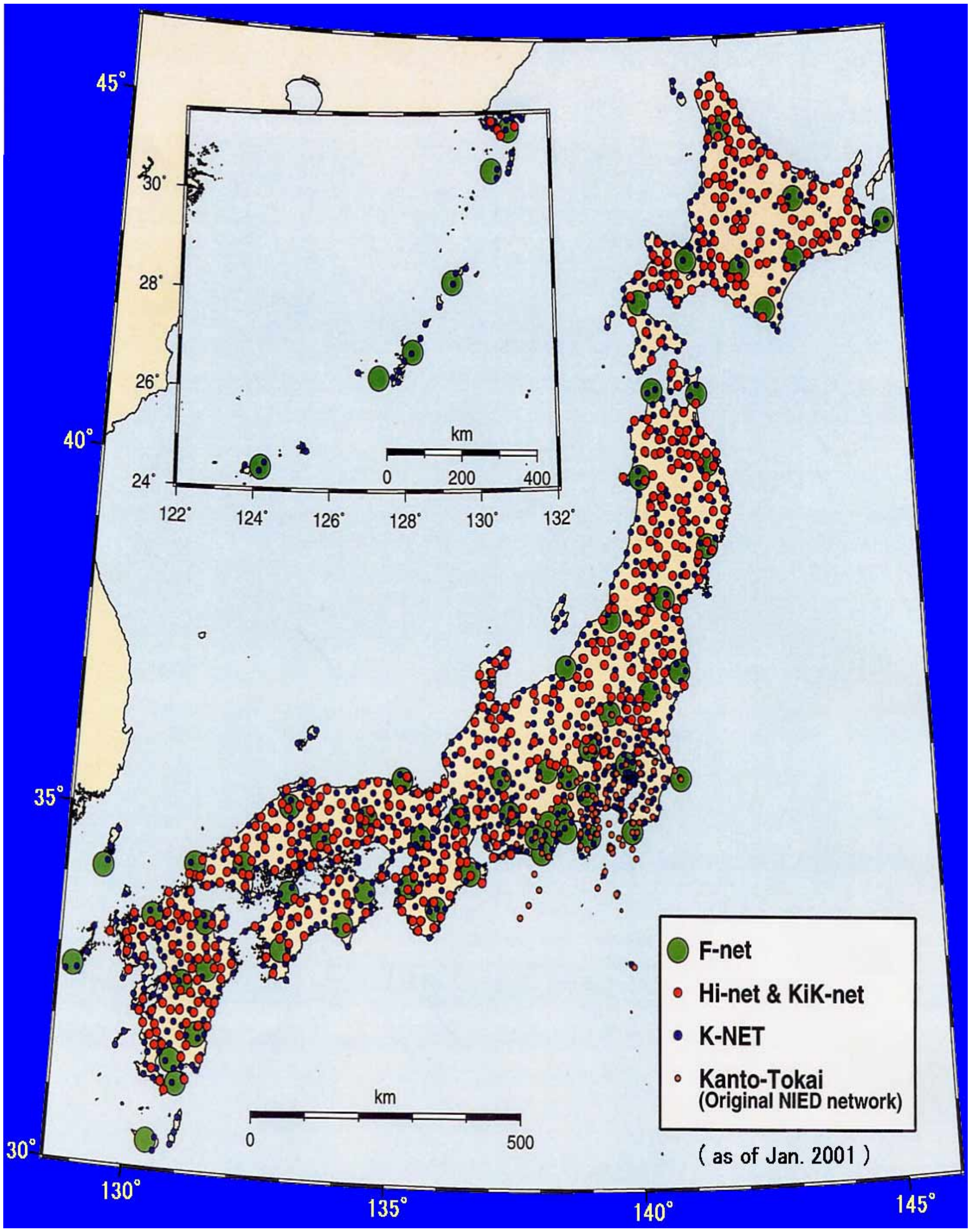

Figure 3 Distribution of Seismometers Operated by NIED

GEONET – A NATIONWIDE GPS PERMANENT ARRAY

The Geographical Survey Institute (GSI) is the only national surveying and mapping organization in Japan under the auspices of the Ministry of Land, Infrastructure and Transport. GSI operates a nationwide GPS permanent array called GEONET (GPS Earth Observation Network) to continuously monitor the relative displacement between the stations at a sampling interval of 30s. Monitoring of Japan's whole land by GEONET contributes to researches in seismic and volcanic activities. GSI supplies to public such data as the daily changes of distances between stations, the crustal deformation over the most recent month, and the crustal deformation over the most recent one year, through the Internet at (http//mekira.gsi.go.jp).

GEONET has been built up in several steps [4]. GSI installed 110 stations in the southern Kanto and Tokai areas, central Japan, from 1993 to 1994 to acquire information for predicting probable earthquakes in these areas. In 1994, 100 continuous GPS stations were added to cover the areas where the initial 110 stations had not been installed. After these 210 GPS stations started to operate in the whole area of Japan at the beginning of October 1994, although as two separate networks, several large earthquakes took place in and around Japan including the Hokkaido-Toho-Oki earthquake (October 4, 1994, M8.1), and the Sanriku-Haruka-Oki earthquake (December 28, 1994, M7.5).

For these earthquakes, GEONET clearly detected co-seismic crustal deformations, and very timely demonstrated advantages and effectiveness of permanent GPS networks. After the Kobe earthquake, the previous two systems were integrated, and additional 400 stations were established. The operation of the integrated network GEONET started in March 1996. A GPS antenna is installed at the top of a 5 m tall stainless steel pillar with a 2m deep concrete block base, and a GPS receiver, communication equipment and a backup battery are set up in the pillar at each station. The number of stations gradually increased, and GEONET now covers the whole area of Japan with more than 1,200 continuous permanent GPS stations with the mean distance between the stations of about 25 km.

Data for 10 days are stored on site to assure data availability even if data communications are lost by accident. The data observed at each station are transferred to GSI in Tsukuba once per day by public telephone lines, and then converted into the RINEX format and stored in a database. These data are analyzed routinely in two ways. First, quick solutions are calculated by using "combined orbit information" which is a combination of rapid and predicted orbit information provided by the Center of Orbit Determination in Europe, Astronomical Institute, University of Berne. After obtaining precise orbits from the International GPS Service, the final solutions of GEONET are computed two weeks after the observation.

ACTIVE FAULT SURVEY

Based on the recommendations by the Kiban project, the Headquarters set up a plan to survey 98 major active faults in Japan for studies of paleo-earthquakes associated with these faults [5]. Mainly on the basis of the survey results and investigations on historical earthquakes, the Headquarters' Earthquake Research Committee has been assessing the earthquake potential for each of the 98 active faults, and disseminates the results as the long-term earthquake forecast to the public. The information from the fault-survey is being used as a basis to perform a new probabilistic estimate of the seismic hazards throughout Japan. This work will be completed by March 2005.

The size of a probable earthquake is estimated from the empirical relationship between earthquake magnitude and fault/source area. The location of an event is fairly precisely estimated from active fault data and historical earthquake catalogues, except for certain types of earthquakes such as deep events. For the time of occurrence, however, we can only provide a probabilistic estimate.

As of the end of February 2004, activities of 49 faults have been reviewed. Table 2 shows the distribution of these 49 active faults on land with respect to the magnitude of the earthquakes these faults generate and the probability of occurrence of the earthquakes in 30 years. The numbers in this table should be carefully interpreted, because, in most cases, magnitude and probability in the original survey are given as a range. When, for example, the original estimation is given as $6.8<M<7.5$ with nearly $0\%<P<7\%$, $M=7.5$ and $P=7\%$ are used in the Table

Table 2. Distribution of Magnitude and Probability of Occurrence for 49 Earthquakes Identified by Active Fault Survey

Magnitude M	P (%) = Probability of Occurrence in 30 years					Sum
	$P \cong 0$	$P < 1$	$1 \leq P < 5$	$5 \leq P < 10$	$10 \leq P$	
$6.5 \leq M < 7.0$	2	0	1	0	1	4
$7.0 \leq M < 7.5$	3	4	6	4	0	17
$7.5 \leq M < 8.0$	3	6	4	8	0	21
$8.0 \leq M$	0	3	1	1	2	7
Sum	8	13	12	13	3	49

Out of the 49 expected earthquakes, 16 or 33% of them have occurrence probability of greater than 5%. Especially, for the three earthquakes with P greater than 10% in 30 years, the probabilities in 50 years are estimated as 18%, 20%, and 23%. It may be interesting to note that the causative fault of the Kobe earthquake was estimated to generate M7.3 earthquake with the occurrence probability of 0.4%-8% in 30 years by the same method used for the reviews of active faults. The average recurrence time for this particular fault was estimated as 1,800-3,000 years.

In general, however, plate boundary earthquakes taking place in the coastal areas have much higher probabilities of occurrence. Most of them are several tens of percent, and there are a few earthquakes for which the probability is estimated even greater than 90 % in 30 years.

BASIC COMPREHENSIVE POLICY AUTHORIZED

Although the Headquarters was entrusted to formulate comprehensive and basic policies as its highest priority mission when it was established soon after the Kobe earthquake, official discussion on the basic policies had to wait until October 1997. A sub-committee of the Headquarters' Policy Committee had 11 meetings and published a report, "The Promotion of Earthquake Research – Basic comprehensive policy for the promotion of earthquake observation, measurement, surveys and research" (hereinafter simply referred to as the policy report) in April 1999. In my opinion, the policy report has, among others, highlighted two important points as a guideline for the activities in the earthquake science to be carried out during the next 10 years.

Firstly, the report emphasized the significance of the promotion of close cooperation of all organizations of all levels on a wide range related to earthquake disaster mitigation research and practice. It is particularly important to promote cooperation between researchers in seismological science and earthquake engineering, i.e. scientists and engineers. It is also important for scientists and engineers to have a good understanding on social science-related subjects such as people's mental and behavioral problems during a disaster and economic issues following an earthquake. A diverse group of institutions and their researchers must work in cooperation with one another.

Results of observations and researches should be distributed to and shared by all parties involved. Because earthquake research is very wide-ranging, it does not fit into the framework of one ministry or one government office. Also, it takes on many forms, from research in universities and national research organizations to that in research institutes of private companies. Accordingly, it is essential for all the related ministries and government offices to cooperate with the aim of the Headquarters to further earthquake research. It is necessary to quickly and smoothly put into practice outcomes of research based on the ideas of researchers in universities and other institutions. Dialogues and cooperation must be encouraged among the national and municipal governments, and individuals conducting earthquake research.

As explained earlier, the Central Disaster Prevention Council establishes the Basic Disaster Plan that outlines the most basic guideline for the earthquake disaster prevention measures in Japan. It is vital for the Headquarters to take into account the Basic Plan outlined by the Central Disaster Prevention Council.

In addition to this Council, there had been three nation-level organizations related to scientific research of seismology before the Kobe earthquake. They were the Geodesy Council established in May 1949 in the Ministry of Education, the Coordinating Committee for Earthquake Prediction established in April 1969 as a private advisory panel of the Director of GSI, and the Earthquake Assessment Committee for the Area under Intensified Measures against Earthquake Disaster established in August 1979 as an advisory panel of the JMA's Director. Even after the Headquarters inaugurated a new era in the national policy of earthquake-related researches, these three organizations still exist with some of their activities overlapping. This seems to illustrate that coordination among relevant organizations, under the auspices of different National Ministries in particular, is very hard to achieve.

RESEARCH REQUIRING IMMEDIATE PROMOTION

Secondly, the policy report has identified major fields of earthquake research to be advocated by the national government in the immediate future. They are:

1) Compilation of earthquake hazard maps by integrating the results of active fault surveys, long-term evaluation of earthquake occurrences, and estimation of strong ground motions,
2) Promotion of real-time transmission of earthquake information,
3) Promotion of observation and related research in the intensified-measures areas for probable earthquakes, and
4) Promotion of observation and research for earthquake prediction.

According to item 1) above, earthquake hazard maps are being compiled by using the most advanced methods and the best available data by the Headquarters with the cooperation of related research organizations including NIED. Two kinds of maps are being compiled in this project. One is the probabilistic seismic hazard map for the whole area of Japan, in which results of active fault survey, long-term evaluation of earthquake occurrence, underground structures, and all data presently available are integrated by the most recent methodology to assess strong ground motions. The other is a hazard map for each specified seismic source, often called a scenario earthquake map. The probabilistic seismic hazard map will be used to assign nationwide priorities for areas to intensify observations or countermeasures, to make rational land planning, or to determine rational seismic forces in design specifications. On the other hand, the scenario earthquake map will be useful to establish disaster mitigation policy of each individual municipal government.

The Tokai earthquake is one of the uncommon earthquakes for which a name is given before its occurrence. Item 3) above emphasizes the importance to reinforce observations of earthquakes and crustal deformations in the Tokai area, central Japan. Since seismologists totally failed to predict the Kobe earthquake, "Earthquake Prediction" was almost becoming an obsolete concept. However, prediction is the ultimate goal to protect human lives from earthquakes. Item 4) above has officially revived the importance of prediction study in the field of seismology.

REAL-TIME SEISMIC INFORMATION FOR DISASTER MITIGATION

From February 2004, JMA started to operate a so-called Nowcast Seismic Information System in central Japan on the experimental basis by considering future practical use of real-time earthquake data dissemination.

As explained previously, extensive seismometer networks have been constructed nationwide after the 1995 Kobe earthquake. According to the recommendations in the policy report, a research project also started in April 2003 to best utilize the records from these networks for real-time estimation of earthquake information to take imminent countermeasures for the seismic disaster mitigation and response purposes.

This project aims at developing systems for real-time determination of seismic parameters and their transmission, before the strong shaking arrives at a site of interest, to those organizations and individuals who want to use these data for disaster mitigation purposes. The systems are being developed by the cooperation of NIED, JMA, and a research consortium with the participation of private companies and organizations.

First of all, an algorithm had to be developed to determine the size and the location of an earthquake at the earliest time after its occurrence. Accurate and rapid determination of these focal parameters has been made possible by a new algorithm developed in NIED [6]. This algorithm utilizes data obtained by Hi-net, and it is built on the idea to use non-arrival data as well as arrival data.

At present, the algorithm is able to determine and disseminate the seismic intensity and the expected arrival time at a site of interest within several seconds after an earthquake occurrence is detected. Then, the transmitted parameters are used by relevant application systems developed by groups of users to initiate various kinds of disaster mitigation countermeasures including automated or semi-automated emergency responses. Under the project, 14 prototype systems are being developed with the cooperation of private companies and organizations who are members of the consortium.

Although the performance of the present algorithm is considered adequate to be used for practical applications, it should be noted that such a system be never perfect. There always is a small probability for the algorithm to give wrong information. The system is not able to give enough warning time if an earthquake occurs at very short distances. Since large earthquakes have larger rupture length with the result of larger rupture time, there is an intrinsic limitation to evaluate the magnitude in a short period. Therefore, it may be necessary for the users to understand and accept the intrinsic limitation of the real-time information.

LIFELINES WERE DISRUPTED

The Kobe region's civil infrastructure was crippled, paralyzing business and financial operations. However, this was not a surprise to me. I was rather surprised by the fact that people had not expected lifeline disruptions which had often taken place even in weaker ground motions than those experienced in Kobe.

Immediately following the earthquake, power outage affected about 2.6 million customers. Since major power generating stations and major transmission lines were not damaged, the number of customers without power decreased to 1 million by 7:30 a.m., and 0.5 million by 8:00 p.m. Although about a dozen distribution transformer stations were affected, the most heavily damaged were poles and wires. It took six days to resume supply for the whole service area.

As to the telecommunications systems, it had been believed that systemic as well as structural damage would be small even during a large seismic disaster. This proved to be partially true because the system did not completely collapse. Although there was extremely heavy traffic congestion during the days following the earthquake, the overall system remained intact.

Water supply systems were severely damaged. Supply stopped to almost all people in the heavily affected area. The number of households without water was about 1.36 million in all stricken areas. About 253,000 households or 39% of the total households in Kobe were without water. There was almost no water from hydrants for fire fighting in the whole area of the city. Supply was resumed to essentially all households by the end of February, about six weeks after the earthquake.

City gas systems took about three months before the supply was restored. Neither production facilities nor high pressure transmission lines were damaged. Damage concentrated to small-sized pipes in low pressure distribution lines. On the day of the earthquake, five blocks, each with 100,000 to 220,000 customers, had to be isolated. Shutting off relevant valves to isolate these blocks started six hours after the earthquake and the last block was isolated fifteen hours after the earthquake. The isolation left about 860,000 customers without gas supply.

It has been reconfirmed that lifelines are vulnerable to earthquakes. This is true for a weaker ground motions compared with those recorded in Kobe. The periods of disruptions of lifelines may be several months for gas systems, several weeks for water systems, and from a week to ten days for power systems. Telecommunications systems may not completely collapse but heavy traffic will certainly take place and will make ordinary communications extremely difficult.

SEISMIC MONITORING OF CITY GAS NETWORKS

After the Kobe earthquake, a system called SIGNAL developed and operated by the Tokyo Gas Company since the previous year of the earthquake attracted the attention of many disaster mitigation specialists [7]. Although numerous breaks in distribution and service pipes were anticipated soon after the earthquake occurrence, it took 6-15 hours before supply to heavily-hit blockss were shut off. Fortunately, there were no fires or explosions directly related to the damage to the gas supply system. The importance of quick collection of damage information, however, was strongly realized.

SIGNAL is an early damage assessment system based on extensive seismic monitoring and GIS to perform damage estimation of the city gas supply network soon after the occurrence of an earthquake. The result is used to make help decisions for whether or not to isolate the blocks in hard-hit areas by suspending gas supply. The system is developed over the whole service area of the Tokyo Gas Company with 8.7 million metered customers. It deploys 331 seismometers located at district regulator stations which measure the peak ground acceleration, and the spectrum intensity is computed at each site. These values are sent to the supply control center by the company's radio to make damage estimation for pipes and customers' houses together with GIS-based inventory data.

After the Kobe earthquake, several major city gas companies introduced similar systems in their service areas.

GIS AND REMOTE SENSING TECHNOLOGIES

After the Kobe earthquake, a number of new research organizations were established to deal with new fields in earthquake engineering. One such organization is the Earthquake Disaster Mitigation Research Center (EDM) established by STA. Creation of EDM was also suggested by the same report (September 1997) that recommended construction of E-Defense. By recognizing the tremendous socio-economic impact of the Kobe earthquake on modern urban regions, research emphasis began to shift from structural technologies to the entire earthquake disaster management systems.

EDM, first set up in the framework of the Institute of Physical and Chemical Research (RIKEN), was established in Miki city near Kobe in January 1998. It was transferred to NIED in April 2001. EDM moved its office from Miki to Kobe in April 2003. EDM is a small organization with only about 20 researchers, but it has a unique mission, “Frontier research on earthquake disaster mitigation for urban regions.”

Since its establishment, EDM has been actively engaged in such researches as damage survey by aerial photographs and satellite images, remote sensing technologies for earthquake damage detection, automated detection of damaged buildings using aerial high-definition television images, GIS-based disaster mitigation planning support system, et al. As can be seen from these research titles, uses of satellite images, remote sensing technologies, and Geographical Information System (GIS) are typical keywords in the EDM’s researches.

One example of EDM’s unique research aims to develop an information management system that can be operated during chaotic period of disasters by developing the risk adaptive information technology by space-time management. The system is expected to be utilized by municipal governments in their daily routine activities as well as in the response for the emergency when an earthquake occurs.

Under normal circumstances, it is indispensable for municipal governments to keep track of change with time in the context of information management. When an earthquake strikes, these temporal changes even multiply in number and variety. A team in EDM investigated spatial temporal information processing and proceeded to design the system base. The format of the space-time information processing system-base has been developed. The information environment consists of the municipality’s information processing and a disaster management information center that will support municipality. These can be operated under the confused situation during disasters.

EARTHQUAKE INSURANCE AT THE TIME OF THE KOBE EARTHQUAKE

Fewer households in the region than in other parts of the country were insured for the earthquake damage because the area was considered a low risk region. Some 4.9 percent of households in Osaka prefecture have earthquake insurance, in comparison with 13 percent in Shizuoka prefecture where a big earthquake is expected. "It appears that almost nobody thought they would sustain damage in an earthquake," an insurance agent said.

Earthquake insurance had been available in Japan since 1966 following the 1964 Niigata earthquake. The original system, however, had been modified several times until the Kobe earthquake occurred to solve some of the problems identified in damaging earthquakes during the 30-year period.

The earthquake insurance policy at the time of the Kobe earthquake may be summarized as follows.

Earthquake insurance was separately purchased for the house and the properties. The maximum policies to be purchased by homeowners were 10 million Yen[*1] for the house and 5 million Yen[*2] for the properties. Earthquake damage was classified into three grades; (1) Complete collapse for which the full amount of insurance both on the house and the properties may be collected, (2) Partial collapse for which 50% of the insurance on the house and 10% of the insurance on the properties may be collected, and (3) Slight damage for which 5% of the insurance both for the house and the properties may be collected.

Assessment and authorization of damage is always difficult. In the case of damage to houses, complete collapse is defined as the loss sustained by the major structural members of a house exceeding 50% of its current price, partial collapse between 20% and 50% of its current price, and slight damage between 3% and 20% of its current price.

Earthquake insurance was and still is an addendum to fire insurance policies, and the minimum and the maximum earthquake insurance were 30% and 50% of the fire insurance, respectively. The premium greatly differed in four rate zones, the highest being 4,750 Yen[*3] per one million Yen of fire insurance coverage for wooden houses (1,800 Yen[*4] for non-wooden houses) and the lowest being 1,600 Yen[*5] for wooden houses (500 Yen for non-wooden houses).

The total amount of insurance to be paid for one event was limited to 1,800 billion Yen[*6]. When this maximum amount were to be paid, about 15%[*7] was to be paid by insurance companies, and the rest by the government.

EARTHQUAKE INSURANCE AFTER THE KOBE EARTHQUAKE

Following the Kobe earthquake, a total of 76 billion Yen was paid for about 64,000 earthquake insurance policies. But it was recognized how low the subscription rate of earthquake insurance was in the affected area, and for the country as a whole. Only 3.7% of the homeowners in the Kinki region, which includes Hyogo, Osaka and Kyoto prefectures among other four less affected prefectures, were found to have their homes insured for earthquake loss. The average subscription rate in Japan was 7.2%, with the highest being 12.5% in the Kanto region where the greater Tokyo area is located.

The premium of earthquake insurance tends to be expensive because more of the insured party live in higher seismic zones. It was debated that the maximum insurance of 10 million Yen to be collected for the total collapse of a house was too small to rebuild an average residential house whose cost was estimated at least at about 17 million Yen.

Subscription rate greatly increased after the earthquake. It increased from 7.2% to 10.8% for the whole Japan, 12.5% to 16.4% for the Kanto region, and from 3.7% to 9.0% especially for the Kinki region where the most heavily affected prefectures were located.

To solve some of the problems encountered after the Kobe earthquake, a new system was introduced in January 1996 with the following numbers (To avoid repetitions, only those numbers that appeared previously with asterisks are shown):

- [*1] Maximum policy for a house: 10 million Yen−>50 million Yen
- [*2] Maximum policy for properties:5 million Yen−>10 million Yen
- [*3] Premium per 1 mil. Yen coverage (Wooden, Highest Rate Zone): 4,750−>4,300 Yen
- [*4] Premium per 1 mil. Yen coverage (Non-wooden, Highest Rate Zone): 1,800−>1,750 Yen
- [*5] Premium per 1 mil. Yen coverage (Wooden, Lowest Rate Zone): 1,600Yen−>1,450 Yen

[*6] Total amount paid in one event: 1,800 billion Yen−>3,100 billion Yen
[*7] Amount paid by insurance companies: 15%−>13.3%

Because some numbers and part of the system have been changed after the above-stated revision, the following discussions do not always apply to the most present state of the earthquake insurance in Japan. However, I personally think that remaining problems have not basically changed.

PROBLEMS STILL REMAIN IN EARTHQUAKE INSURANCE

It is expensive to purchase earthquake insurance. To collect 17 million Yen, which is an average cost of a 100 m^2 house, it is necessary to purchase at least 34 million Yen fire insurance policy. The following example shows the premiums for fire and earthquake insurance for a 100 m^2 wooden house in Tokyo in the highest premium zone:

(a) Premium for fire insurance:
34 million Yen x 1,700 Yen/1 million Yen = 57,800 Yen
(b) Premium for earthquake insurance:
17 million Yen x 4,300 Yen/1 million Yen = 73,100 Yen

The maximum insurance that can be purchased has been significantly increased after the Kobe earthquake. However, opinions differ about this issue. Some people argue whether or not it is reasonable to pay a maximum earthquake insurance of 50 million Yen, because, to collect this amount, a householder has to purchase a fire insurance of 100 million Yen, which is much too expensive for most houses in Japan. Others say that people with the most to lose - those with a better home and more properties in it - purchase insurance. Although those with more resources have a greater propensity to purchase earthquake insurance, the present system still does not stimulate the incentive of those who own better housing stock under favorable environment.

The premium of the present earthquake insurance distinguishes only two types of houses (wooden and non-wooden) in four rate zones. There have been discussions that more factors be considered to classify different types of houses and environments. They are, for example, age of building, local soil condition, demographic condition including population density, et al. Insurance should be purchased at a lower cost for better houses in better surrounding conditions.

The purpose of insurance is the mutual assistance among people at large. Therefore, the rationality of the system and the uniformity to all potential subscribers should be the key issues. However, the former is not always compatible with the latter. If one pursues a scientific and rational system to an extreme, the premium for old and poor housing stock will become relatively more expensive in spite of the fact that the financial losses associated with an earthquake can result in collapse of their daily lives and long-term economic prospects for the less wealthy families.

Occurrence of a large earthquake is a very low-probability event even for a country like Japan. But once such an event occurs, the impact will be felt by a large number of people. Levels of objective risk are difficult to grasp, and vulnerability of individuals and households to earthquake hazards cannot be easily perceived. The financial benefits of insurance to the society as a whole are generally difficult to calculate.

Although a number of problems have been raised regarding to earthquake insurance after the Kobe earthquake, it seems difficult to reach any practical conclusion at this moment. Views differ in whether or not a policy goal is universal coverage, or whether or not nation-backed, mandatory insurance coverage is desirable. However, it may be important to note that, because universal coverage does not distinguishes good and bad houses, it may undermine the incentive of the good people who are willing to spend their own money to strengthen their houses. This argument is significant, because insuring a house does not increase its earthquake resistance.

A BEGINNING RATHER THAN CONCLUSIONS

What were the reasons that we had to suffer such a calamity like the Kobe earthquake? What did we overlook during the period when our science and technology was making such a big improvement?

It was true that the ground motions were strong, much stronger than what most of our seismometers had previously recorded in Japan. However, this was not unexpected. Because seismometers before the Kobe earthquake were sparsely set, ground motions in the epicentral area were rarely recorded. We should have realized that much stronger ground motions take place in the epicentral area of a moderate or a large earthquake.

Structures designed according to our most recent specifications have been found to have high level of earthquake resistance. But, we should have realized that there are a large number of old/weak/low-quality structures in large cities. Many wooden houses were built according to pre-1971 building codes. There were a huge number of reinforced concrete structures which had been designed and constructed without paying due attention to ductility. Hundreds of bridges had been constructed before we learned the lessons of the 1971 San Fernando earthquake or even those of the 1964 Niigata earthquake.

And, all of these trouble makers are found in a large number especially in large cities. We should have understood that urban areas are full of potentially hazardous structures. Large earthquakes had not occurred near large cities in Japan for almost half a century. And during this period, earthquake engineering and technology had made great advancement because of the bubbling economy in the country. Many of the experts seemed to be so simple-minded to believe that Japanese cities had become earthquake-resistant.

In this review, I have summarized, though not comprehensively, some of the changes that took place after the Kobe earthquake in the fields of seismology and earthquake engineering. The changes have been many, but at this time, it is difficult to make a set of conclusions. In my opinion, now is still the time to make a beginning. Earthquake disaster mitigation is and, after all, will continue to be an unrefined or unpolished fields of science and technology. Then, how should we make a beginning?

Our basic stance is to accept that we know so little. When we face the nature, we are so small and powerless.

One of the biggest mistakes we had made before the Kobe earthquake was that we were beginning to wrongly think our structures had become strong enough to outlive most violent ground motions. We have to start a new generation of earthquake engineering in which structures, information and socio-economic issues are fully integrated to solve the urban seismic mitigation problems. Here, it is particularly important to consider structures as vulnerable components.

It is also essential to realize that seismic disaster mitigation is an “art” or “skill” rather than science, as “Art of Navigation” is a more fitting concept than “Science of Navigation” for most of us. Art seems to put more emphasis on experience than on theory. In the new generation of earthquake disaster mitigation, it is important to place appropriate balance between science and experience, or science and art/skill.

GOVERNMENT'S STRUCTURAL REFORM AND DISASTER RELATED ORGANIZATIONS

Due to the government's structural reform which took place on January 6, 2001, the old system of Prime Minister's Office and 22 Ministries changed to a new system of Cabinet Office and 12 Ministries. Most of the governmental offices were reorganized, and on April 1, 2001, many of the national research organizations changed to Independent Administrative Institutions. With respect to some of the organizations strongly related to natural disasters and their mitigation policies, the following reforms have taken place.

The Science and Technology Agency (STA) merged with the Ministry of Education, Culture, and Sports to become the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The National Research Institute for Earth Science and Disaster Prevention (NIED), which had been a national research organization under the auspices of STA became an Independent Administrative Institution in the framework of MEXT without changing its name.

Because the Ministry of Transport and part of the National Land Agency merged with the Ministry of Construction to become the Ministry of Land, Infrastructure and Transport, both the Japan Meteorological Agency (JMA) of the Ministry of Transport, and the Geographical Survey Institute (GSI) of the Ministry of Construction became national enterprises in the newly formed Ministry.

The sections related to disaster response and mitigation in the National Land Agency was transferred to the Cabinet Office.

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