Art of Predicting a Major Quake

By Yoshiro Yanagawa

Japan is one of the most earthquake-prone countries in the world. About 10% of the world's earthquakes have their source in and around the Japanese archipelago. On average, giant earthquakes of magnitude 8 (magnitude measured by Japan's Meteorological Agency on the Tsuboi formula, which is almost equivalent to a magnitude on the Richter scale) originate in Japan and its surrounding seas once a decade and big earthquakes of magnitude 7 about once a year.

Devastating quakes hit Japan quite often. During the past 100 years, Japan has been rocked 10 times by earthquakes which killed more than 1,000 people. The worst was the Great Kanto Earthquake, which struck on September 1, 1923, devastating the Tokyo metropolitan area. Its epicenter was located in the northern section of Sagami Bay, and its magnitude was 7.9. Tokyo and neighboring Kanagawa and Chiba prefectures were violently shaken, and over 250,000 houses were damaged or destroyed. More than 140,000 people were either killed or unaccounted for. The biggest loss of life was caused by fires which broke out immediately after the earthquake. The fires continued burning for 46 long hours, reducing almost half of Tokyo to ashes.

These big earthquakes claimed many lives and played havoc with homes, buildings and social infrastructure. If signs of a quake could have been detected beforehand and precautionary measures such as fire prevention taken, damage would have been greatly reduced. It is impossible to prevent earthquakes, but it has been a long-cherished dream of the Japanese to be able to predict them. In former times, people prayed to the gods and Buddha or went to fortunetellers. They also closely watched the behavior of the catfish, which was believed to signal a forthcoming quake. Giant earthquakes, however, did not heed people's prayers and hit all of a sudden without notice, causing terrible damage and loss of life.

In the early years of the Meiji era, scientific study of earthquakes commenced in Japan under the guidance of foreign scholars. Learning through experience, such as the devastating blows of the Great Nobi Earthquake of 1892 in Nagoya and its environs and the Great Kanto Earthquake of 1923, Japanese seismologists made progress in their research. All this while, the biggest objective of seismology was always the prediction of an earthquake.

Much of the mechanism of earthquakes still remains unsolved. However, thanks to the plate tectonics theory developed in the latter half of the 1960s, a considerable part of the mechanism underlying violent oceanic quakes, which occur repeatedly off the Pacific coast of Japan, has become known.

Creeping threat

According to plate tectonics, the earth's surface is covered with a dozen or so thick rock plates, and earthquakes originate at the edges of these plates. The Pacific coast of Japan lies along such an edge: the ocean plate is creeping under the continental plate on which the Japanese archipelago rests and is building up pressure at the point of contact. When this pressure reaches its limit, the rock formation in the crust of the earth fractures, and this is believed to cause an earthquake.

A giant oceanic earthquake originates when seismologic energy accumulates in the earth's crust over a span of 100 to 200 years. It is believed, therefore, that an oceanic earthquake does not occur all of a sudden but that there are warning signs such as small tremors that can be observed. This led to the theory that if the changes taking place in the earth's crust over a long period of time and microtremors are observed precisely and accurately, signs of an impending giant earthquake might be detected.

In 1976, a group of seismologists announced that there was a possibility that a giant oceanic earthquake was imminent in the Suruga Bay area of Shizuoka Prefecture. Their announcement is now known as the "Tokai Earthquake theory." This gave rise to mounting public requests for a practical earthquake prediction system, which resulted in the enactment of the Large-scale Earthquake Countermeasures Law designed to link earthquake prediction with disaster prevention.

This was the world's first attempt to give a legal framework to earthquake prediction. Research currently under way in the United States, the former Soviet Union and China is producing considerable results. In China, the oceanic earthquake that hit Liaoning Province in 1975 was accurately predicted moments before it occurred. However, Japan is the first country to establish a practical earthquake prediction system as a legal institution of the state.

There are three elements essential in earthquake prediction: how big, when and where. The Japanese law applies to giant oceanic quakes thought to be most susceptible to detection, and to the Suruga Bay area, where violent tremors have repeatedly occurred. Not all earthquakes that might occur in Japan are thus covered by this law but only quakes that might originate in the Tokai region centering around Shizuoka and Hamamatsu. This leaves the most difficult point in predicting an earthquake: when it might happen.

If it is announced that "a mega earthquake will occur in the Suruga Bay area," the prediction can serve as a warning for the distant future, but it is meaningless from the standpoint of taking disaster prevention measures immediately before the earthquake's occurrence. Although the most difficult part of earthquake prediction is to tell exactly when a quake will occur, the law was enacted on the premise that this is within the realms of possibility.

Photo: Kyodo News Service

The earthquake Prediction Council convenes at the Meteorological Agency when specific abnormalities are detected in observation data.

At present, various observation instruments are in operation at scores of places in a wide area extending from the Tokai District to the southern Kanto District centering around Tokyo. They include seismographs to detect small quakes and microearthquakes, submarine seismographs installed along a 160 kilometer stretch of ocean floor south of Omaezaki, linear strain seismographs to detect distortion in the earth's crust, tiltmeters to measure inclination of the ground, instruments to measure the ground's expansion and contraction, and tide gauges to measure changes in tidal currents. These instruments comprise a seismological observation network of the highest density in the world. All are linked by telemeter to the Earthquake Observation Room in the Meteorological Agency in central Tokyo. Minute-to-minute observation data are monitored around the clock, and studied intensively at this center.

Prediction panel

When specific abnormalities are detected in the earthquake observation data, the director general of the Meteorological Agency convenes the Prediction Council for the Tokai District. This council consists of six seismologists living in Tokyo and its environs who must rush to the Meteorological Agency when summoned.

Flow of Earthquake Prediction

Spotting of abnormalities
↓
Summoning of the Prediction Council
↓
Prediction Council meeting
↓
Compilation of information on earthquake prediction
↓
Report to the prime minister
↓
Cabinet meeting
↓
Issue of Earthquake Warning Statement

The Prediction Council studies the observation data, and if it concludes that there is a great possibility of a major earthquake occurring in Suruga Bay and the sea area south of it in the following two or three days, the prime minister is immediately informed. After an emergency Cabinet meeting, the prime minister will then issue an earthquake warning statement.

Immediately such an earthquake warning is issued, all railway trains in "the areas designated for reinforced earthquake countermeasures"–totaling 169 cities, towns and villages in six prefectures–will go to their nearest stations at reduced speed and stop there. Buses and shipping will come to a halt. Schools will be closed, and hospitals will stop treating outpatients, except for emergency cases. Department stores and banks will close and almost all business firms will cease operations. Road vehicles will be banned from entering the designated areas, and traffic at all major intersections, designated evacuation roads and emergency transport roads will be restricted. In the neighboring areas, including Tokyo and Nagoya, public transport facilities will in principle be kept operating but considerable confusion is anticipated.

When an official earthquake warning is issued, an unprecedented state of emergency will prevail. Japan's most vital traffic arteries, such as the Shinkansen bullet train and the Tokyo-Nagoya National Expressway, run through the Tokai District, and many factories are located there. If physical distribution of goods and supplies, movement of people and economic activities in this region should come to a halt, the impact will be immeasurable, paralyzing the entire nation and sending ripple effects even overseas.

But at the same time, if an earthquake can be predicted accurately and adequate disaster prevention measures taken, loss of human life might be avoided and structural and other physical damage dramatically reduced. The problem, of course, is the accuracy of earthquake prediction. Complete accuracy in earthquake prediction cannot be expected. Seismologists who are members of the Prediction Council say they do not mind making a wrong prediction that misses, but they do not want to miss any warning signs. But the economic and social damage from a wrong prediction could be equally great.

The decision whether to issue an earthquake warning is extremely important. If it were known for sure that when observation data show abnormalities beyond a specific level an earthquake will follow, there would be no problem. But such a sure-fire cause-and-effect relationship has not yet been ascertained. Ultimately, the decision will be no more than a judgment by the six members of the council. They are being required to make an agonizing decision.

What happens if an earthquake does not hit even three days after the official earthquake warning? This, too, is an extremely difficult decision–probably even more agonizing than deciding whether or not to issue the earthquake warning itself. Society cannot endure a long period of suspension of normal human and economic activities. Even after an official warning of danger, if nothing happened after three days, there would be sure to be a big public outcry demanding that the warning be lifted.

If the abnormalities which were judged to be warning signs of a major earthquake disappeared, the warning could be lifted without any misgivings. But if the abnormalities continued, the council would face a big dilemma. The nature of this dilemma can be understood from the case of the volcanic activities of Mount Unzen in Nagasaki Prefecture continuing since early summer of 1991. Local residents are seeking early lifting of the government's warning, while scientists insist that they cannot declare that it is safe to return yet. Sandwiched between the local residents and the scientists, the local government's agony continues.

In the case of Mount Unzen, the volcano's activities day after day are visible, making it easier to convince local inhabitants of the need to continue the state of emergency. In the case of a possible Tokai earthquake, however, any official warning has to be issued on the basis of observation data which are not visible to the general public. This lack of visible evidence would make it very difficult to convince the public of the need to continue a state of emergency over a long period.

Two-stage warning

If the Prediction Council lifted an earthquake warning under pressure of public opinion and a giant earthquake occurred immediately afterward, the result would be tragic and disastrous. Under the law pertaining to earthquake prediction, a state of alert is started simultaneously with the issue of the earthquake warning, but the alert is lifted as soon as the warning is called off. The problem may lie in this procedure.

A possible solution might be to institute two stages of earthquake warning just as there are two stages in a storm warning—a torrential downpour warning and a torrential downpour alert. When scientific indicators point to a possible giant earthquake, a warning might be issued first, and when data show that a quake is imminent the warning might be switched to an alert. If an earthquake does not occur after a warning is issued but the observation data still do not justify a total lifting, the alert can be eased to a warning. In the warning stage, for example, railways would be allowed to continue operations, though at a reduced speed. But when an alert is issued, all trains would be required to stop operations. When the alert is eased to a warning, trains could resume operations at a reduced speed.

This earthquake prediction scheme—made into a practical system in Japan for the first time in the world—is a very ambitious step, but still has much room for improvement.

American and Japanese seismologists engaged in a debate on earthquake prediction in the British science journal *Nature* in its July 25 and October 17, 1991 issues.

Robert Geller, assistant professor in the Science Department of the University of Tokyo, sharply criticized Japanese earthquake prediction. Geller, a graduate of Stanford University, said that Japanese seismologists collect a mountain of data and try to find warning signs to use in predicting an earthquake, but that they have not yet established what constitute reliable and clear signs. He said that both the Japanese government and people should know that it is impossible to predict an earthquake under such circumstances, and what is really needed is basic seismologic research.

Dr. Kazuo Hamada of the National Research Center for Disaster Prevention of the Science and Technology Agency retorted, "The earthquake which happened in the sea near Izu-Oshima Island in 1978 was predicted one and a half hours in advance. The consensus in Japan is that a possible earthquake in the Tokai District could be predicted shortly before it happens."

Many Japanese seismologists believe it is possible to predict a Tokai earthquake. But some scholars have expressed negative or skeptical opinions. The time may have arrived to reexamine the technology and system of earthquake prediction in Japan. But whatever the case, neither overconfidence nor extreme skepticism should be allowed to affect the assessment.

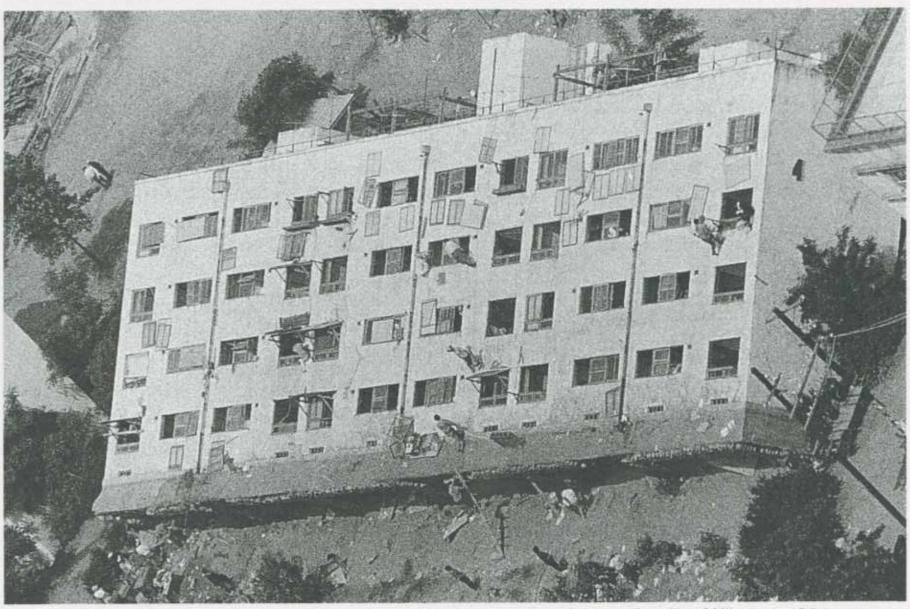
Photo: Kyodo News Service

An apartment building that was literally knocked over by a large earthquake near the city of Niigata in 1964.

Yoshiro Yanagawa is a news commentator on disaster prevention issues at NHK (Japan Broadcasting Corporation).