Progress in JR West's Earthquake Countermeasures

After JR West's experiences of the Great Hanshin Earthquake in January 1995, the Seibu Tottori Earthquake in October 2000, and the Geiyo Earthquake in March 2001, the company drew up a disaster management manual and established a working group to examine and promote earthquake countermeasures, such as improved aseismic structural design, earthquake detection systems, etc., from both the 'hardware' and 'software' aspects.
In addition, the company also established the disaster prevention business plan when new legislation about earthquake countermeasures was passed in July 2003 based on a review of the tsunami regulation, assuming the occurrence of earthquakes in the Tonankai and Nankai regions. Moreover, JR West is dealing in earnest with concrete disaster countermeasures, such as introduction of new earthquake guidelines for the future.

Introduction

The Great Hanshin Earthquake on 17 January 1995 disabled the San'yo Shinkansen for a long period of time; it was a huge crisis in our company's history because the San'yo Shinkansen is the mainstay of our business as the major transport artery between East and West Japan and in the Kinki region. Neither was it the only earthquake to adversely impact our business; the relatively powerful Seibu Tottori (M6.2) and Geiyo (M6.7) earthquakes in October 2000 and March 2001, respectively, caused quite a lot of damage to our lines, and the financial losses due to stopped operations and recovery costs had a very severe effect on our financial condition. Based on these experiences, we realized that the most important thing for any railway business is to put priority on being able to offer safe and stable rail transport, and we are now making every effort towards this goal. This article explains one part of our strategy.

Earthquake Response System

JR West established a crisis management system at its Head Office for dealing with the impact of major operations accidents unrelated to natural disasters based on its in-house Major Accident Crisis Management Manual. However, based on what we learned from the 1995 Great Hanshin Earthquake, we discovered that the crisis management systems in the existing manual were inadequate for responding to the very many unforeseen circumstances that occur after a major earthquake. To overcome this problem, we established the Major Disaster Countermeasures Working Group with responsibility for developing crisis management countermeasures premised on the future occurrence of a major natural disaster. This group examined earthquake disaster countermeasures from 'software' and 'hardware aspects,' such as first-response steps, communications networks with built-in fail-safe redundancy, etc., and we are working hard to give concrete form to the Working Group's results.
In particular, after we discovered that our old system did not give adequate consideration to the importance of the first-response system, we decided to create a Major Earthquake First Response Manual based on the assumption that an earthquake of M5 or more had struck somewhere in the JR West operations area, causing damage not just to railways in the area but also impacting the entire infrastructure of the region. In these circumstances, managers and staff must first get to their offices despite a likely loss of all public transport infrastructure—the manual explains that past experience has shown that bicycles and motorbikes can be effective means of emergency first-response transport. Furthermore, a Head Office Emergency Response Section is to be set up temporarily in Shin Osaka General Control Center until the arrival of the Railway Operations General Manager or the Transport Safety Manager at Head Office when the Emergency Response Section will then be transferred to the Head Office Accident Response Room. Control links between Head Office and the regional and branch offices are secured by using the TV Conferencing System. Within about 3 hours after the disaster, the Emergency Response Section is transferred to the Directors' Board Room, creating a system for circulating all the collected information between all relevant parties. However, in the event that the Head Office has been so severely damaged that it cannot perform its duties, the Kyoto regional office will assume the duties of Head Office and all Head Office functions will be transferred to Kyoto.
A disaster response system has also been established at each branch office based on local characteristics. To increase the ability of individual employees to perform their duties independently yet effectively, close links with government bodies, such as the fire department have been planned, while at the same time offering rail employees periodic and hands-on training in disaster response techniques.

Earthquake Countermeasures

This next section explains some actual earthquake countermeasures proposed by the Major Disaster Countermeasures Working Group.

Strengthening elevated sections

Following the extensive failure of reinforced concrete pillars during the 1995 Great Hanshin Earthquake, the so-called 'concrete-ramen' pillars supporting the elevated sections have been reinforced

Figure 1 APAT Concept

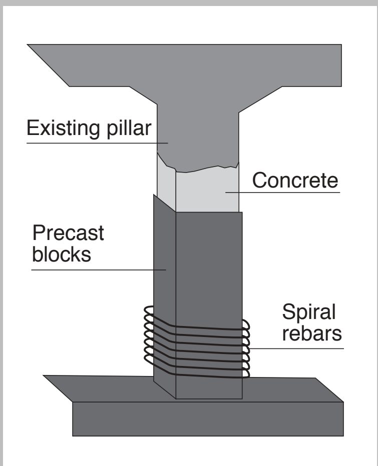
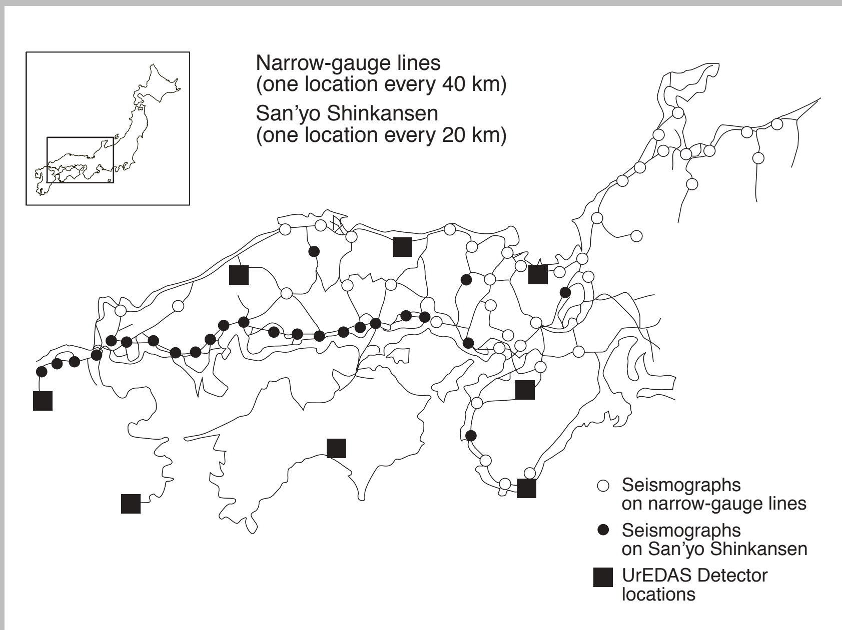


Figure 2 Locations of Earthquake Seismographs in JR West Operations Region



with steel sheathing and spiral rebars using the Aseismatic reinforcements by Precastblocks and Additional Tendons (APAT) method. In particular, this method offers an easy but low-cost method for strengthening supporting infrastructure under elevated sections while also providing other advantages, such as easy visual inspection. In this APAT method, the short pillars of existing elevated sections are sheathed in comb-shaped Precast blocks and then a spiral of galvanized steel rebars is wound around the outside of the pillar to ensure the pillar strength (Fig. 1).

This method has been applied to the elevated sections of the San'yo Shinkansen in the Keihanshin region around Kyoto, Osaka and Kobe, as well as to specific localities where there are known earthquake fault lines. It has also been applied as an earthquake countermeasure to shear-failure type pillars supporting elevated sections of conventional narrow-gauge lines with high transport volumes in the Kinki region. Following the 2001 Geiyo Earthquake, the same reinforcing countermeasures are being applied to the San'yo Shinkansen west of Okayama.

Bridge collapse countermeasures

The entire San'yo Shinkansen has been the target of plans to prevent bridge collapse; bridge abutments and columns have been strengthened and stoppers have been installed to prevent girders moving and the work is now complete.

Urgent Earthquake Detection and Alarm System (UrEDAS)

Ever since the earliest days of rail operations, earthquake seismographs (detectors) have been installed at power substations alongside the tracks to detect earthquakes, cut the power and stop trains by applying the emergency brakes (Fig. 2). However, after the Great Hanshin Earthquake, JR West has placed the entire San'yo Shinkansen (Shin Osaka to Hakata) under the protective guardianship of its Urgent Earthquake Detection and Alarm System (UrEDAS)

UrEDAS detects the early tremors of an earthquake from the fast P-waves that cause little shaking or damage but arrive before the slower and more destructive S-waves. It uses this data to calculate the earthquake's magnitude and epicentre, and then sends a signal to stop or at least slow nearby shinkansen (Fig. 3).

Earthquake early warning transmission system

When the earthquake seismographs installed alongside narrow-gauge tracks detect an earthquake of a magnitude exceeding a preset value, the operation of all trains is suspended. However, some consideration must be given to prevent secondary disasters occurring while trains are stopped or slowing down, so an earthquake early warning transmission system has also been installed in the Kinki region where trains run at very high operations frequencies. This system has seismographs installed at 16 locations covering the urban network, and the information from this network and the shinkansen UrEDAS network is linked by communications lines with the central information controller in Shin Osaka General Control Center so that information (acceleration in gal) about an earthquake can be grasped immediately by the control centre (dispatchers). When any one of the seismographs detects an earthquake with an acceleration larger than 40 gal, all train drivers in the operations region affected by the earthquake are sent an 'Earthquake Train Stop' message automatically via the train radio to bring trains to a stop. Moreover, to guard against major earthquakes with an acceleration exceeding 250 gal that cause damage over a widespread area, wireless base stations at 12 locations covering the entire same region automatically broadcast an emergency 'Emergency Train Stop Signal' on the train radio indicating that a major earthquake has occurred and bringing all trains to a stop (Fig. 4).

Additionally, the communications circuits linking the central information controller in Shin Osaka General Control Center with the regional dispatch offices are constructed as loops using multiple redundant routes, so that communications will continue functioning even if a major earthquake disables normal links.

Figure 3 UrEDASU System

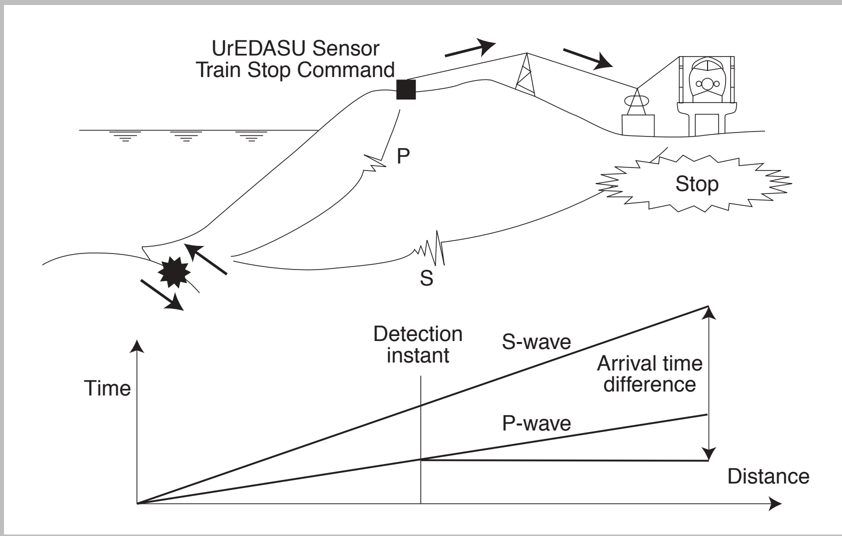
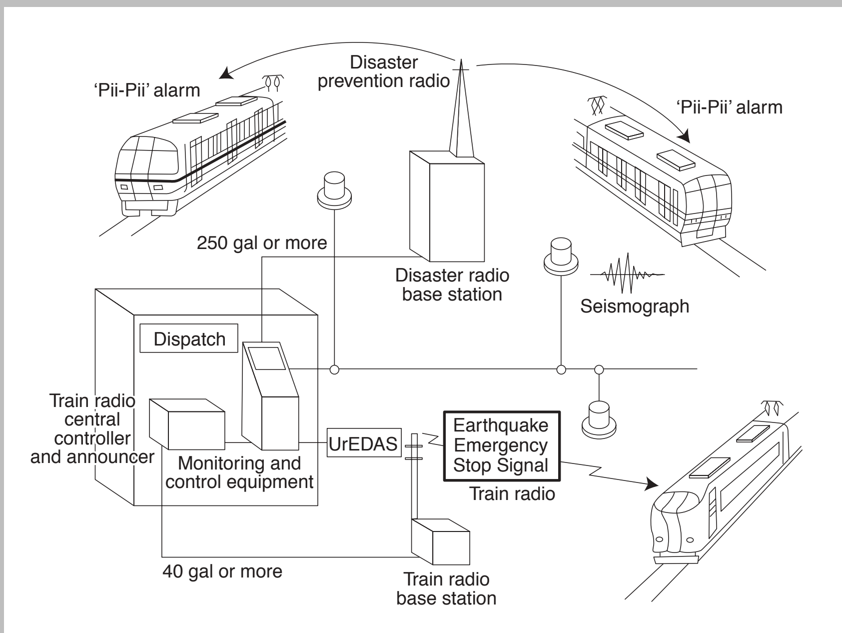


Figure 4 Configuration of Urgent Earthquake Detection and Alarm System (UrEDAS)



Backup Shinkansen General Control Center

The operations of the San'yo Shinkansen are closely integrated with those of the Tokaido Shinkansen, so the Tokyo General Control Center performs centralized management of dispatching (trains and passengers), operations, infrastructure, power supply, signalling and communications, etc., to assure operational safety and stability. However, if the Tokyo nerve centre was seriously damaged by a major earthquake, there is no doubt that considerable time would be required for recovery, but operations on the San'yo Shinkansen would still have to run normally. As a countermeasure, JR West has cooperated with JR Central in building the Backup Shinkansen General Control Center with the same functions as the Tokyo General Control Center in Osaka—a long way from any possible damage occurring during any future major earthquake in the Kanto region. In the event that the Tokyo General Control Center is put out of action by a disaster, normal shinkansen operations will still be assured by handing over to the Backup Shinkansen General Control Center. To assure a smooth handover of functions, some experienced dispatchers from the Tokyo General Control Center are always on standby in Osaka. In normal circumstances, only part of the facilities and infrastructure at the Osaka Center is in use for dispatching related to engineering works in the west-Japan region.

Multiple redundant communications links

An earthquake usually causes major damage to communications links, which can easily paralyze the functioning of an organization. Based on what JR West learned from the 1995 Great Hanshin Earthquake, we have installed new optical fibre communications lines along the tracks of the urban network in the Kinki region with multiple branches so that even if some are severed in a disaster, information can still flow over alternate routes. In addition, we have also prepared similar multiple redundant routes for the train-radio infrastructure.

Other countermeasures

As a final step, we are also upgrading the earthquake resistance of all-important structures like the Shin Osaka Center and the Fukida System Center.

Future Earthquake Countermeasures

The July 2003 passage of the Law for Promoting Earthquake Countermeasures in the Tonankai and Nankai Regions designated part of the JR West operations area as requiring disaster countermeasures, so we have started examining our disaster planning. In addition, we are also examining disaster countermeasures targeting safe and stable operations in accordance with new technological advances. The next part of this article gives some concrete examples of our progress.

Earthquake countermeasures in Tonankai and Nankai regions

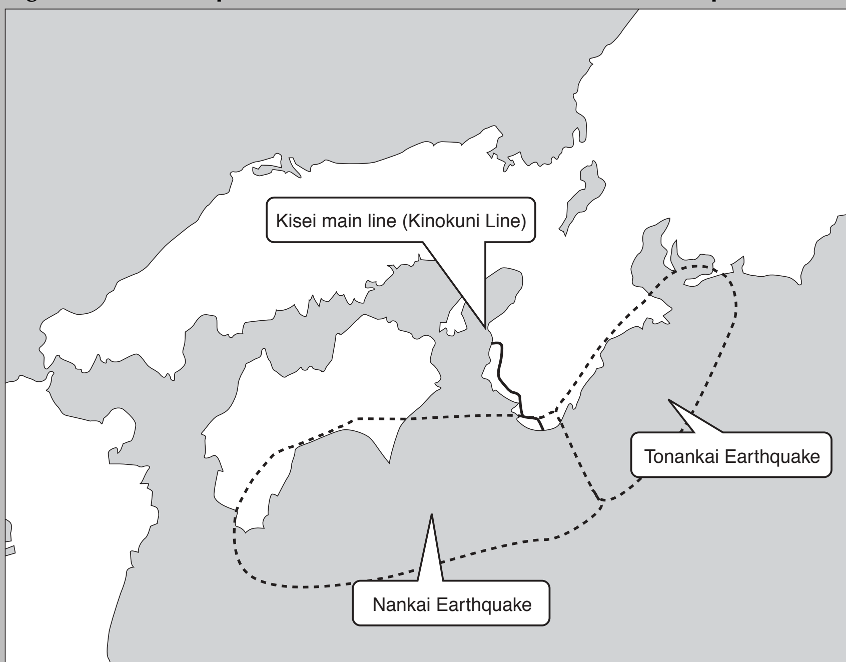
In 2003, we disseminated information about the damage from an expected earthquake in the Tonankai and Nankai regions. If an M8.6 earthquake struck the Tonankai and Nankai regions simultaneously, the scale of the damage would be much worse than that caused by the M7.3 Great Hanshin Earthquake and would be wide ranging, extending over an area from the Kanto region to Kyushu (Fig. 5). JR West is carrying out concrete investigations to minimize damage based on local disaster prevention promotion measures.

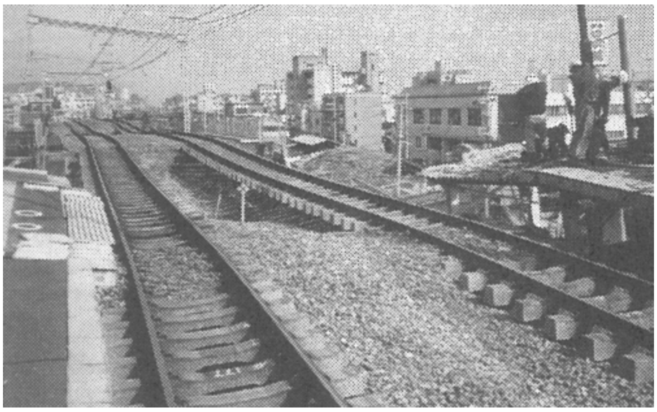
Tsunami disasters

With respect to operations restrictions caused by tsunami tidal waves, after a tsunami warning is issued by the Railway Meteorological Office, etc., each JR West branch company will establish a tsunami countermeasures division and trains running on coastal track sections where the tsunami is forecast to strike will be stopped at stations, etc., before the tsunami reaches land. However, in the case of an earthquake striking the Tonankai and Nankai regions, we can predict the magnitude and epicentre under the Pacific Ocean and can forecast the time until the tsunami arrives, which is likely to be quite short if the epicentre is relatively close to a coastal line. Moreover, tsunami require different disaster planning countermeasures to general earthquakes, such as creation of hazard maps for specified regions showing expected flood depths.

For this reason, in addition to preparing new infrastructure to improve the performance of train radio on specified track sections in the disaster countermeasure regions, etc., we are also working with local government bodies in examining the need for new manuals describing evacuation procedures, etc. With respect to countermeasures for securing safety, based on the Tonankai and

Figure 5 Possible Epicentres of Future Tonankai and Nankai Earthquakes





Track being hanging on air due to damaged embankment near Shin Osada Station on Kobe Line (JR West)

Ballasts being run out of track due to disruption of slope at Settsu Motoyama–Sumiyoshi section on Kobe Line. (JR West)

Nankai Disaster Countermeasures Promotion Plan, JR West established and reported the disaster prevention business plan to the Prime Minister in July 2003. In addition, the plan's overview can be seen at the JR West homepage (http://www.westjr.co.jp/english/global.html).

Introduction of new earthquake indexes

The index used for restricting operations when an earthquake strikes is maximum ground acceleration caused by the earthquake movement, measured in gals. However, if we consider the damage to track infrastructure caused by an earthquake, a more useful index expressing the damage caused by the earthquake would take into consideration both the natural frequency of structures and the duration of the ground acceleration. Using Systeme Internationale (SI) units and measured seismic intensity, provides a more accurate forecasts of earthquake–induced structural damage and offers more efficient ways to restrict rail operations without compromising safety. Currently, JR West is examining how to introduce a new system based on the kine when old accelerometers are replaced at the end of their service life.

New early earthquake warning systems

Introduction of new early earthquake warning systems is becoming more important with plans to increase train operation speeds. The San'yo Shinkansen has been using the UrEDAS system for a number of years. During this time, we have seen changes related to new technologies, such as earthquake monitoring systems based on R&D by seismologists and the Meteorological Agency. In these circumstances, some research bodies are making progress with new early warning systems and JR West is examining introduction based on these trends.

Conclusion

Japan sits on the edge of the Pacific tectonic plate and has many active volcanoes and fault lines, resulting in large numbers of earthquakes that cause a lot of damage. Earthquakes are an irresistible force of nature and the best we can expect to do is to take hardware and software countermeasures that will ameliorate the damage as far as possible. However, there is no possibility of reducing damage to zero levels. As a result, operations restrictions based on various devices and systems must play an important role in assuring safety.

For the future, we must continue to be vigilant in maintaining and managing civil engineering structures by using both up-to-date technologies and rational operations restrictions to ensure that we can always offer our customers safe and stable transport by rail. ■

Acknowledgments

This article was written by the JR West Railway Operations Headquarters Transport Safety Department and was originally published (in Japanese) in the *JR Gazette* in 2004.