Introduction

Research on railway disaster prevention began in 1988 at the Safety Research Laboratory that was formed in response to a train collision accident that occurred at Higashi-Nakano Station. A string of disasters including the July 13, 2004 torrential rains in Niigata and Fukushima, the Niigata Chuetsu Earthquake on October 23 of the same year, and the December 25, 2005 derailment of the “Inaho” limited express on the Uetsu Line prompted the disaster prevention research team of the Safety Research Laboratory to be spun off as the Disaster Prevention Research Laboratory in 2006.

The Disaster Prevention Research Laboratory is currently working as a three-group organization made up of weather, terrestrial phenomena, and wind committee projects. Research is being conducted mainly on themes such as railway-related natural disasters, issues related to operation control under wind that require quick actions, and urban disasters.

This article gives an overview of railway disaster-related R&D that the Disaster Prevention Research Laboratory is working on.

Laboratory organization and past results

The Disaster Prevention Research Laboratory works in a three-group organization of 11 people made up of the director and eight other researchers plus a technical advisor specializing in geomorphology and a special researcher specializing in radar meteorology. Research is proceeding in “methods of observing and detecting meteorological and terrestrial phenomena,” “clarifying mechanisms by which disasters occur and methods of assessing their risk,” and “proposing disaster prevention measures and establishing technical standards”, with the aim to prevent railway accidents due to natural phenomena.

Results up to now (including those as the Safety Research Laboratory) include introduction of bridge pier scour monitors, risk level assessment such as assessment of impact of earthquakes on the shinkansen, assessment of slope safety by remote sensing, introduction of a strong wind warning system, introduction of spectral intensity (SI) type seismometers, trials of a gust warning system, and introduction of a method of operation control under rainfall using effective rainfall volume.

There are currently four major areas of specific research. The first is the area of continuous research on items such as rainfall, snow melting, and slope disasters that occur frequently. The second is the area of disasters such as earthquakes and tsunamis that are large in scale when they occur. The third is operation control under wind that is a management issue. And, the fourth is the field that includes urban disasters where the form by which disasters occur is changing with recent environmental changes.

This research is separated into fundamental research and applied research according to importance in terms of management, level of urgency, and difficulty of the research. Research is also being conducted jointly with specialty research institutions such as the Railway Technical Research Institute, Meteorological Research Institute of the Japan Meteorological Agency, and National Research Institute for Earth Science and Disaster Prevention, along with universities such as the University of Tokyo, Kyoto University, Niigata University, and Ritsumeikan University.

Overview of research in individual areas and details of major research themes

3.1 Rainfall, snow melting, slope disasters

Research in rainfall-related themes is going forward on the state of rainfall records and operation control as worksite support after introduction of effective rainfall as an index in 2007 and on review of optimal control values from studies of disaster occurrences. Other research ongoing includes that on the state of localized short-term torrential rainfall that has come to be frequently seen across Japan, on rainfall volume prediction by meteorological radar and prediction of flood discharge from localized torrential rainfall, risk analysis related to railways, and study of countermeasures.

Research in snow-related themes is going forward on concepts...
for avalanche warnings in areas of heavy snowfall and concepts for operation control related to slope disasters in snowmelt periods, estimation of snowmelt volume, models of infiltration to slopes including rainfall and proposal of control methods from the results of those models.

As a slope disaster-related theme, we are going forward with development to the EADaS method for assessing the types of disasters that can occur at a select place on a line section and the risk level of those disasters. EADaS is a reference system for predicting possible geomorphic disasters at a given site in Japan on the basis of the combination of Environment, Agent, Disaster mode and Structure at the site. This theme covers general railway disaster assessment technology for terrestrial phenomena led by the laboratory’s technical advisor.

3.1.1 Research on localized torrential rainfall
JR East predicts flooding by a model for analyzing flood discharge in a specific region using information gained by meteorological radar on rainfall that spreads out over an area. The prediction is used to assess the level of risk to railway facilities and study countermeasures against such risk. We completed assessment of accuracy of rainfall volume analysis by meteorological radar and a prototype of the discharge analysis model by fiscal 2010 in joint research with the National Research Institute for Earth Science and Disaster Prevention. In work to come, we will specify an area along a railway line, analyze radar-measured rainfall volume, and study accuracy to verify validity of the flood discharge analysis method.

3.1.2 Research on a method of estimating snowmelt volume
In joint research with Niigata University and other parties, we took field measurements of factors such as temperature, insolation, and rainfall. And by fiscal 2009, we created a model formula to estimate from that data snowmelt volume, volume of water infiltrating the snow layer, and volume of water infiltrating the ground from the under accumulated snow and verified the effectiveness of that model formula.

In fiscal 2010, we took observation data for snowmelt volume at four locations on the Tadami Line. At two of those locations, we conducted field tests where snowmelt volume from measurement data was estimated and displayed in real time at a civil engineering technology center. In the future, we will go forward with development to set operation control criteria that includes rainfall in the snowmelt period.

3.1.3 EADaS system development
The EADaS method is an assessment method for extracting the types of disasters that can occur at a select place on a line section based on data such as topographical and geological maps and quantitatively expressing the risk level of those disasters. While assessment methods up to now required specialists with knowledge of topography and geomorphology, we have succeeded in developing an expert system for comprehensive assessment of risk level for railway disasters related to terrestrial phenomena formulated as a system that can be used by anyone with a certain level of basic knowledge on topography and geomorphology.

Up to this fiscal year, we assessed disaster risk levels of line sections selected for trials. Next, we will hold on-site meetings with field and branch office personnel to review the results, verify assessment results, and clarify what needs to be improved before introduction. Our goal is to introduce EADaS by as early as fiscal 2012.

3.2 Earthquakes and tsunamis
In the event of an earthquake greater than a certain scale where trains have to be stopped, visual inspections are carried out on the entire section that needs to be checked for structural damage. Much time is thus required before service can be restored. But timely analysis of data from outside seismometers densely placed over an entire area including along the railway line would allow us to make more detailed assumptions of damage than by using just data from our own seismometers along the line. We are proceeding with research on a method to use the outside seismometer data to narrow down the structure inspection area and conduct efficient inspections. Results of verification using past earthquake data showed that we could reduce the time required for inspections by up to 40 to 50%.

We are also working on research to assess structure vulnerability to disasters as a method to identify soundness of and degree of damage to structures. This assessment entails detailed monitoring of structural behavior by a variety of sensors in earthquakes and
during normal train operation.

The tsunami which struck as a result of the March 11 Tohoku earthquake resulted in more than 24,000 people dead and missing in a broad area from the Sanriku coast to the Boso peninsula. Damage to railways too was extensive, with seven line sections from the Hachinohe Line to the Joban Line suffering damage. Although trains and structures were destroyed, fortunately no passengers or crews were lost. As a result of that disaster, research started in fiscal 2011 on risk assessment and measures for train and passenger evacuation in case of tsunami occurrences.

3.2.1 Research on assessing vulnerability of structures to disasters
In assessing the soundness of viaducts and other concrete structures, we must note that damage seldom occurs suddenly in normal use due to the design method, structure, and material characteristics of those structures. It is difficult to assess damage that progresses gradually, so we assess by analyzing detailed inspection data for those structures. In the event of an earthquake, we conduct detailed inspections of entire structures by mainly visual inspection because it is difficult to predict or estimate structural damage. Much time is thus required to complete inspections.

In light of that situation, we are working on research for methods to identify the status of structures and also to efficiently identify the presence of damage and where the damage occurred in an earthquake. This involves placement of inexpensive simple sensors at weak points of applicable structures and continuously monitoring and analyzing response from train vibration and seismic vibration.

We have been able to calculate the displacement of railway structures from measurement data of train vibration using acceleration sensors in field tests. In the future, we will conduct long-term monitoring tests of structural displacement from seismic vibration and train vibration by placing optical fiber sensors on Shinkansen viaducts in addition to simple sensors.

![Fig. 4 Research on Assessing Vulnerability of Structures to Disasters](Image)

3.3 Strong wind and gusts
Operation control by a single anemometer can ensure the safety of a train against wind for strong winds such as seasonal winds and typhoons. However, in gusts such as tornados and downbursts, operation control by conventional anemometers has proven difficult in ensuring train safety.

Train operational safety in strong winds is secured by operation control using the instantaneous wind speed value of a single anemometer and critical wind speed of overturning calculated by the so-called Kunieda formula model. The anemometer is placed by empirically determining the place along the line where strong winds occur.

The December 2005 derailment on the Uetsu Line prompted the setting of lower wind speeds for operation control under wind for safety reasons, which has greatly affected stable operation on many line sections.

The railway accident report of the Aircraft and Railway Accidents Investigation Commission (current Japan Transport Safety Board) pointed out that the accident occurred because the train "received localized gusts". But operational control by predicting gusts such as tornados and downburst that generate and disperse locally in a short time is difficult. We thus started full-scale research in 2006 on strong winds where operation control by anemometers is possible and gusts where operation control by anemometers is difficult.

3.3.1 Research on new methods for operation control under wind
With instantaneous speed by a single anemometer, the current method used for wind observation in operation control under wind, we may not be able to rationally assess the wind force over the entire length of a train that is connected to train safety when running. Moreover, the formula for calculating critical wind speed of overturning by the so-called Kunieda formula model is based on the results of research in the early 20th century, so it has problems including not taking into account conditions such as train body shape, forms of structures such as embankments and viaducts, and wind direction. That formula thus cannot always rationally assess the phenomenon of a train overturning due to wind.

We are thus working on research in wind observation using the University of Tokyo's wind tunnel for themes such as a method of measuring the value for operation control under wind by multiple anemometers and a method for predicting wind conditions taking into account differences in characteristics of anemometers, terrain, and structures. We are also working with the Safety Research Laboratory on studies for introducing a new formula for calculating critical wind speed of overturning (Railway Technical Research Institute Detailed Equation).

The effectiveness of the new method for operation control under wind using multiple anemometers and the Railway Technical Research Institute Detailed Equation was confirmed by a committee that included outside experts. We plan to conduct trial introduction of this method in some line sections as early as next year.

![Fig. 5 Research on New Methods for Wind Observation](Image)
3.3.2 Research on gust detection

We are researching gust detection methods using Doppler radar as a measure for detecting and predicting gusts. The research is being carried out jointly with the Meteorological Research Institute of the Japan Meteorological Agency. In that, we have dispatched a special researcher who is an expert in that field to the Shonai region where observations are being made on vortexes of gusts such as tornadoes and downbursts. Research on evaluation of lightning strike location used in assessment along with Doppler radar observation data is also being carried out with the Kakioka Magnetic Observatory of the Japan Meteorological Agency to improve accuracy of detection.

Research up to now has shown a variety of characteristics of gusts observed in the Shonai region including (1) gusts accompany formation of cumulonimbus clouds and active lighting activity, (2) vortex size is small at a few kilometers or less and (3) most gusts make landfall from the Sea of Japan side.

Issues with detection by Doppler radar include that (1) vortexes generated in the upper atmosphere are not necessarily accompanied by gusts at ground level and (2) not all vortexes that cause damage at ground level can be detected. In the future, we will conduct research with aim of early practical implementation of Doppler radar. This includes studying radar detection and data analysis methods as well as studying analysis methods which use lighting observation results in a complementary manner.

By fiscal 2010, we had developed a method for assessing passenger flow that uses three analysis model tools in analysis: an overall model, partial model, and congested period model. This year, we will study and verify analysis of specific stations and aim to introduce the method at an early date.

Fig. 6 Research on Gust Detection by Doppler Radar

3.4 Urban and other disasters

Stations with in-station commercial facilities in large urban areas have become complex and large in recent years. As more and more passengers stop by those facilities, there is concern about the flow of passengers when evacuating in unforeseen situations. We are thus researching simulation and prediction methods for passenger flow in stations at emergencies.

We are also researching quantitative assessment of slope failure prevention effects and wind blocking effects of forests that are starting to receive attention recently from an environmental perspective.

3.4.1 Research on passenger flow in stations at emergencies

Structures of terminal stations in the greater Tokyo area are becoming increasingly complex due to factors such as constructions for barrier free structural design and development of station commercial facilities. Moreover, increasing numbers of passengers gather at those stations with station development, so methods for analyzing passenger flow risks in emergencies were needed.

Research on disaster prevention at JR East is conducted for natural phenomena where events are hard to re-create and for massive engineering structures. Observation and identification of mechanisms for those phenomena is extremely difficult, and much time is required in research to identify the phenomena and find countermeasures against them.

On the other hand, possibility of disasters occurring due to climate change and environmental change is changing greatly, so research on staying ahead of changes is needed. Falling behind in dealing with those changes will result in accidents where the damage from disasters is immense and the possibility of risk to human live is large.

In the future, we will proceed with R&D with a goal of even safer and more stable railways in conjunction with changes to the global environment and shifting social needs.

Fig. 7 Research on Method of Assessing Passenger Flow at Emergencies

Fig. 8 Research on Effects of Slope Reinforcement by Forest Root

4 Conclusion

Research on disaster prevention at JR East is conducted for natural phenomena where events are hard to re-create and for massive engineering structures. Observation and identification of mechanisms for those phenomena is extremely difficult, and much time is required in research to identify the phenomena and find countermeasures against them.