Interpretive Article

Challenge to Predict Natural Disasters and Current Status of Research

Makoto Shimamura
Safety Research Laboratory, Research and Development Center of JR East Group

Natural disaster endangers safe train operation. In particular, rainfall, strong wind and earthquakes have a serious impact on the daily lives of the passengers.
JR East has been committed to the study of disaster prediction in order to establish an operation control method as a measure against natural disaster to ensure safety in the event of a natural disaster and to avoid excessive safety measures. This paper discusses the challenge to the study subjects and the current status of the research work.

1 Introduction

Unfortunately, modern science and technology are unable to predict natural disasters with pinpoint accuracy. It is necessary to work out an approach for separate prediction from temporal and spatial aspects. Temporal prediction is to estimate the transition of the possibility of disaster occurrence in a special area as a whole along the time axis. It does not address predicting where in the area an individual disaster occurs. By contrast, spatial prediction is to evaluate the degree of the possibility of disaster occurrence in a specific location within the area, as compared to those in other locations. It does not address the question of predicting when a disaster occurs.

As viewed from the purpose of use, temporal prediction represents the technology required for local and short-term decision making such as operation control, whereas the spatial prediction represents the technology required for long-term and wide-area decision making such as planning of equipment reinforcement work and selection of a disaster sensor installation site. The following discusses typical the challenge to the research on temporal and spatial disaster prediction technology and its application.

2 Challenge to the research on temporal disaster prediction

(1) Operation control method based on new disaster hazard indicator

Correct evaluation of the degree of the hazard of external natural force caused by disaster and decision of adequate train operation based on this evaluation belong to the most important and basic disaster prevention technology using the temporal disaster prediction approach. Operation control in the event of a natural disaster caused by rainfall, strong wind or earthquake accounts for as high as about 40 percent of the total number of train service suspensions and delays. This is because a scientific and practical method for determining the hazard indicator or alarm threshold value for the natural external force has not yet been established. So even if facilities have been reinforced by disaster prevention work, the effect does not always reduce suspension or delay of train services resulting from operation control in the event of a natural disaster. This is one of the problems that can be mentioned.

We at the Safety Research Laboratory, have been engaged in the research of hazard indicators for accurate evaluation of the level of hazard caused by the disaster, the method of measuring, and a new operation control method in the event of disaster according to a scientific method for determining an alarm threshold value based on verification of its validity based on a large volume of statistical data and risk evaluation. The achievements of our research involves new indicators for the level of disaster hazard resulting from rainfall, earthquake, strong wind and bridge pier scour.

(2) Use of high-level disaster prevention information

The natural external data providing the basis for determining the operation control in the event of disaster as discussed in the previous section has been measured conventionally by observation equipment unique to railways. In recent years, however, more open and higher-level meteorological and seismic information provided by the Internet is coming to be used for railway disaster prevention. For example, The seismic data (see Fig. 1) provided by the very strong earthquake observation network (K-NET, KIK-net) of the Disaster Prevention Science Research Laboratory have played a crucial role in our study about the relationship between seismic motion index values and damages in railway structures.

Further, the Safety Research Laboratory is studying ways of using the precipitation analyzed by radar AMeDAS (Automated Meteorological Data Acquisition System) on a complementary or alternative basis with respect to the railway rain gauge in such a way as to determine the more accurate operation control in the event of rainfall.

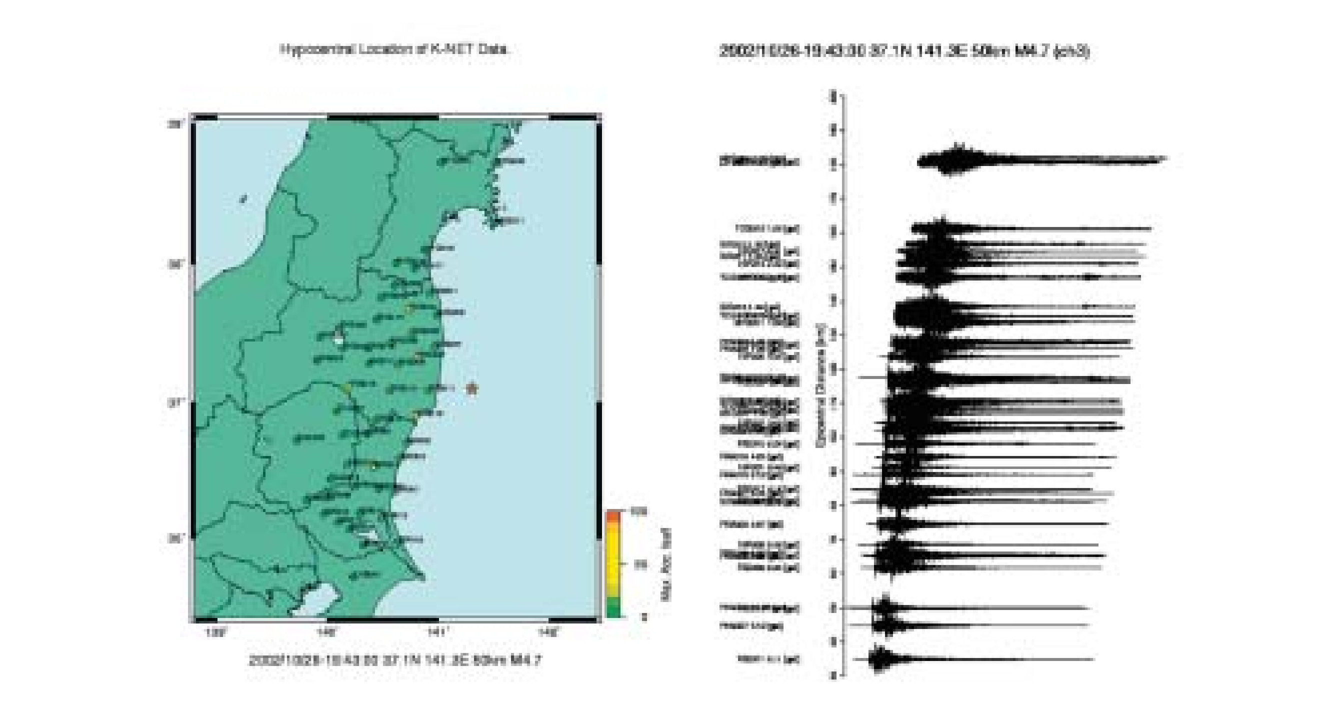

Fig. 1: An example of seismic wave provided by K-NET

(3) Clarification and evaluation of behavior of ground water

Collapse of a slope due to rainfall is the most crucial railway disaster in terms of frequency and impact. The relationship between rainfall and collapse of a slope has been studied on a macroscopic scale based on statistical analysis in order to achieve the target of working out the scientific operation control method, where the main object of the study has been the section with a distance of several kilometers through tens of kilometers. This method, however, is limited for precision evaluation of the resistance of each slope to rainfall, for example, when we want to know the effect of slope face protection works in advance.

To solve this problem, we are now studying a technique for evaluating the stability of the slope based on the measurement of the behavior of ground water of the rain having fallen on the slope. In the future, if the behavior of ground water can be correctly estimated based on the rainfall pattern and slope type, then it will be possible to ensure operation control during rainfall in conformity to the scientific hazard indicator.

3 Challenge to the study of spatial disaster prediction

Many railway disasters occur when the railway track is affected by the motion of earth and sand caused in the process of forming the topographic features. In the case of one type of the topographic features, the same topographic feature forming process has been repeated. It is highly probable that this process will recur in the future. This is a matter of common knowledge in topography. Accordingly, it is essential to have a sufficient knowledge about the topographic type of each point for spatial disaster prediction.

In the past, there was a trend to suppose that the best approach for spatial disaster prediction in the business of railway disaster prevention was to depend on the experience and intuition of engineers experienced in disaster. Today, however, it is extremely difficult to find such experienced engineers. Disaster prediction methods based on objective and scientific ground including academic research and analysis have come to be desired more acutely than ever before.

Further, a high degree of accountability (responsibility for explanation of an action) has come to be required from public disaster prevention business. As a result, designation and publicity (creation of a hazard map) of a hazardous position has come to be provided according to the quantitative standard. (See Fig. 2).

In conformity with such a trend, we are engaged in the study of an overall slope management system by combining the method for evaluating the level of disaster hazard and geographical information system, multilevel slope information management by geographical information system, and decision making support function. Here the method for evaluating the level of disaster hazard is based on measurement of a slope by remote sensing and methanalysis (comprehensive retrieval of the primary information gained from individual research results and combining them according to the statistical technique, thereby gaining overall findings and experience of a higher order) of the existing studies on spatial disaster prediction. By the commercialization of this slope management system, it is expected that a series of slope management procedures comprising inspection of a slope according to remote sensing data, identification of a latent disaster, evaluation of the level of hazard for each type of disaster, prediction of the effect of measures, comparison with other alternatives, and selection of survey items for future inspection can be reconfigured in a feasible form according to reusable data and an objective standard.

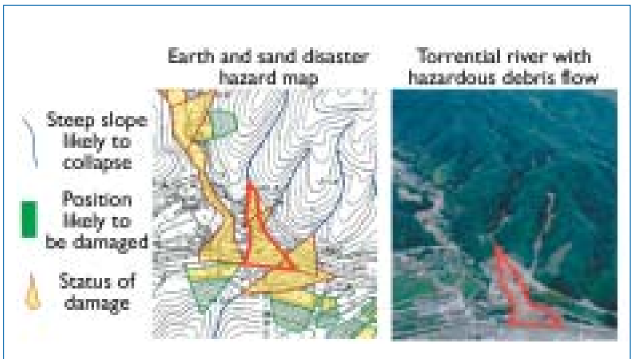

Fig. 2: Example of hazard map representing possible disaster on the slope

4 Disaster risk and management on an advanced level

In addition to the areas of studies discussed above, we are engaged in the development of risk evaluation according to disaster prediction and risk management in order to integrate them according to one basic concept and to improve the overall level. To put it more specifically, we are developing a seismic impact evaluation system to determine the optimum seismic risk reducing plan for a train running at a high speed.

5 Conclusion

Disaster prediction constitutes an important study subject not only for the railway business but also for the society at large. At the same time, it covers a great variety of fields involving understanding of natural phenomena, test and measurement technology, risk evaluation and decision making. Accordingly, interdisciplinary commitment is essential for its progress. Thus, we will make further efforts for establishment of a scientific and practical disaster prediction technology by making effective use of the achievements of the studies in the related fields characterized by startling evolution through tie-ups with related research and development organizations.