Research on Key Technologies for Earthquake Warning System in Rail Transit of Harbin

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ABSTRACT: This article takes the rail transit system of Harbin city as the research object and researches the layout of structure array, warning parameters and warning technical system of the rail transit system of Harbin city, which provides a strong technical support for practicality of the earthquake warning system in rail transit of Harbin city.

KEYWORDS: Harbin; Earthquake warning system in rail transit; Key technologies; Research

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Rail transit has existed for a long time as the public transportation in the city and it plays a more and more important role. Urban rail transit (metro and light rail) system is an effective way to improve the urban public traffic. Although the rate of earthquake is little, it is still a natural disaster to the safety of rail running. Especially when the speed of the train is more than 200 km/h, even earthquake with the smaller magnitude can lead to serious accident. The attack to subgrade, railway and bridge and so on will endanger the safety of the passengers life Harbin city urban rail transit system is China's first alpine subway system. At present, the development of Harbin city underground rail transit project is very fast, research is of great significance on the key technology of rail transit earthquake alarm system in Harbin.

1 DEVELOPMENT STATUS OF FOREIGN COUNTRIES’RAILWAY EARTHQUAKE DISASTER WARNING AND EMERGENCY SYSTEM

Japan, Germany, France and other countries have prepared detailed contingency plans against earthquake disasters, developed the earthquake pre-alarm system, prevented or reduced the damage to railway transportation safety caused by earthquake disasters. Therefore, With the rapid development of railway in our country, it is necessary to understand the foreign railway earthquake disaster emergency plan and warning system in all kinds of advanced technology, it can provide reference for the construction of railway earthquake disaster warning and emergency system in our country.

1.1 Japan railway earthquake rapid alert system

Japan is a many earthquake country. About 20% earthquake with up level 6 occur in Japan. in the 1960s, When they began to build the tokaido Shinkansen, they had considered the railway earthquake monitoring system. Entering the 21st century, the East Sea Railroad Company has developed a set of new tokaido Shinkansen fast earthquake alarm system, it could effectively provide early earthquake warning, and put into use in August 30, 2005. Its main features include: (1) Shortening estimated time. (2) Improving the accuracy. (3) Information transmission faster, more reliable. In 2006, across the whole country, the Japan meteorological agency started deploying emergency earthquake early warning system. Using 1 000 earthquake monitoring network of the nationwide distribution people can timely predict earthquakes which together with the combination of national earthquake early warning system. In 2009, the scale of the earthquake early warning extended to other regions outside the capital. The early warning information mainly comes from two monitoring points: railways and the meteorological agency.
1.2 Earthquake monitoring system of France’s railway Mediterranean Line

Mediterranean line belongs to the earthquake monitoring system based on the French state-owned railway company communications network, it set up 24 seismic stations along the Mediterranean line. Digital seismic stations along the route are buried, unattended station, they set up a one in every 10 km monitoring station. Each monitoring station and marseille and control center are linked together, forming earthquake monitoring networks of the Mediterranean line. Monitoring station has two sets of communication network which ensured the reliable transmission of the seismic information, the system is also connected to the national earthquake authentication center. Marseille control center has juggling and alarm device of the double machine redundant, upon receiving the earthquake monitoring alarm information and confirming by the verification center and the national seismological bureau, according to the set alarm threshold, marseille and control center gives the corresponding train operation control command to the train control system. Figure 2 is the French Mediterranean earthquake monitoring system structure diagram.

1.3 German’s railway earthquake monitoring equipment

Germany scientists successfully developed a new generation of intelligent railway networks which suits to the vast majority of countries and regions, and it is equivalent to the world's largest seismic sensors. Intelligent track can improve accuracy and integrity of the earthquake situation analysis, as we have a neural network system of the self debug ability and learning ability. It can be applied to various countries and regions, from a lower risk of the Rhine river upstream to Indonesia, the Indonesian with frequently occurring earthquake.

In order to solve the problem of signal interference warning System, researchers have developed a kind of "Embedded Rail System", in Germany, Spain and the Netherlands, the System has been put into use. Streets nearby railway traffic, farm tractors, or the train itself from the vibration will cause certain interference to the sensor system, and ERS can clearly distinguish the seismic waves of 30 HZ and a few hundred Hz train vibration. In Japan, France, Germany, South Korea, the Railway is more developed. These countries have established the earthquake disaster emergency plan and early warning system for the railway transport safety, as much as possible to reduce the harm of rail safety caused by earthquake disasters.

2 DEVELOPMENT STATUS OF DOMESTIC RAILWAY EARTHQUAKE DISASTER WARNING SYSTEM

Earthquake in China is very serious, seismic activity of our country is high frequency and high intensity and its source is shallow and distribution is wide. In order to ensure the train operation safety, railway line in China earthquake disaster early warning and contingency disposal measures should be taken. About railway in our country, under the condition of earthquake safety early warning system has not yet been established, at present, in parts of the national earthquake monitoring network is configured on the state seismological bureau, the railway departments from seismological bureau to obtain information on earthquake risk and may form an emergency early warning information. The earthquake risk information once confirmed, the railway department will cooperate with the relevant department under the state council and the local authorities, according to the corresponding disaster grade of a response. Railway of our country already is equipped with earthquake prediction information, for preventing
the risks of railway train operation safety requirements, and makes the regional risk analysis according to the national earthquake prediction in China railway to build appropriate earthquake early warning system, in order to minimize injury caused by such risks. Facing to the national conditions with many and serious earthquake disasters, China pay more attention to railway emergency management jobs. The emergency management level increased day by day. Because of the disposal work effect of earthquake disaster early warning and emergency plans in the seismic events, the construction of the railway system of earthquake emergency preplan will be further deepened and expanded and improved. Railway earthquake disaster early warning and emergency system will certainly play a more scientific and effective guidance role in the flame catastrophe disposal of our country.

3 RESEARCH CONTENTS

When destructive earthquake takes place, warning is one of unsolved key technologies for safety issue in earthquake for urban rail transit. This project is established on the basis of No. 62 priority themes, “Monitoring and Prevention of Major Natural Disasters”, in the “Public Security” part of No. ten key field under the National Medium and Long Term Program for Science and Technology Development.

This project mainly focuses on rail transit system of Harbin city. Based on the disaster prevention technology in civil engineering structure and real-time digital signal processing and analysis technology, this project researches the key technologies, such as layout of structure array, selection of warning parameters, framework of earthquake warning system and signal anti-interference algorithm, and provides theoretical support for seismic performance and design of rail transit system, as well as the technical support for application of earthquake warning system in rail transit of Harbin city.

3.1 Layout of structure array of rail transit system of Harbin city and research on warning parameters

In terms of layout of seismic network, we collect both earthquake information and site information in history; in terms of layout of strong seismic instruments in public areas and tunnels in metro stations, we choose Line no. one or other lines of urban rail transit of Harbin to test environmental background noise and research the factors such as validity of earthquake warning, anti-interference capability of device, communication, power supply, security, etc.; in terms of warning parameters, the research gives the influence of parameters, such as PGA, CAV, PSA and SV, to security of rail transit in earthquake, which changes current status that only PGA is adopted in traditional warning system. Through above research, an alternative is given to structure layout and warning parameters of rail transit system of Harbin. One of the structure layout options is to lay strong seismic array, aiming at simply obtaining strong seismic PGA record in principle of serving engineering earthquake resistance. For this option, it requires comparatively less investment. For another option, it serves not only engineering earthquake resistance, but also strong seismic array laid for earthquake warning, which can directly reduce or even avoid casualties.

3.2 Research on earthquake warning technology system of rail transit of Harbin city

This project researches the framework of earthquake warning system of rail transit and software module, as well as their correlations. The research objectives of framework of earthquake warning system include: modularity, expandability, robustness and interconnectivity. Modularity has the advantages of robustness, maintainability, operating efficiency, security, and so on, and it is the principle that must be followed in complex system design. In software system, a shared memory is used to form a circular message queue for cache data and matched data to process various modules with different speeds. Since the warning system may be interfered by various kinds of vibrations, the research provides the methods to reduce the noise of observation signals in earthquake warning system of rail transit, including filtering method and signal separation method. Through research on the environmental vibration level in Line No. one of urban rail transit of Harbin, an algorithm for anti-false alarm triggering of warning system is given. On the basis of traditional STA/LTA method in earthquake event detection, it analyzes the characteristics of data in 3 seconds and tells whether current event is earthquake event or other interference event. These characteristics include: predominant frequency, growth rate, vibration duration, number of zero-crossing, etc. The research provides the simulated testing methods for warning system, including software stimulation and board stimulation.

4 KEY PROBLEMS TO BE SOLVED

4.1 Researches on layout of structure array and warning parameters of rail transit

When making layout in seismic network and laying strong seismic instruments in public areas and tunnels in metro stations, we will consider both structural anti-seismic and need of earthquake
warning. It is a key technology needed to be solved that how we economically and efficiently design structure array and choose appropriate warning parameters in rail transit system of Harbin. In terms of layout of seismic network, it is needed to consider geological structure and transmission speed and direction of seismic wave in history; in terms of layout of strong seismic instruments in public areas and tunnels in metro stations, it is needed to consider validity, environmental background noise, anti-interference capability of devices, communication, power supply, security of earthquake warning; in terms of warning parameter, it is needed to research the influence of parameters, such as PGA, CAV, PSA and SV, to the security of rail transit in earthquake, and change current status that only PGA is adopted in traditional warning system.

4.2 Research on earthquake warning technology system of rail transit

This project researches the framework of earthquake warning system of rail transit and software module, as well as their correlations; it also researches methods to reduce the noise of observation signals in earthquake warning system of rail transit, including filtering method and signal separation method; it also researches the algorithms for environmental vibration and anti-false triggering of warning system in urban rail transit of Harbin. On the basis of traditional STA/LTA method in earthquake event detection, it analyzes the characteristics of data in 3 seconds and tells whether the current event is earthquake event or other interference event. These characteristics include: predominant frequency, growth rate, vibration duration, number of zero-crossing, etc.; it also researches simulated testing methods for warning system, including software stimulation and board stimulation. Above researches are key technologies of earthquake warning technology system of rail transit.

5 INNOVATIONS IN THE RESEARCH

5.1 Researches on layout of structure array for seismic monitoring in rail transit and warning parameter options

For the first time in China and abroad, this research combines the needs of fluctuation measurement and environmental vibration measurement in all stations of rail transit, earthquake warning parameters selection, validity of earthquake warning and engineering earthquake resistance.

5.2 Application of seismic identification and anti-interference technologies in earthquake warning technology system of rail transit

This research adopts signal separation method to reduce the noise of observation signals in earthquake warning system of rail transit; on the basis of traditional STA/LTA method in earthquake event detection, it adopts anti-interference algorithm in warning system to analyze the characteristics of data in 3 seconds and tell whether the current event is earthquake event or other interference event. It is the first research in China and abroad.

6 MAIN ACHIEVEMENTS

6.1 Researches on method of layout of structure array for earthquake warning system in rail transit and warning parameters

The project measures the fluctuation and environmental vibrations in all stations of rail transit, analyses its environmental background noise, and provides data support for array layout of earthquake warning system in nuclear power station. It also gives the influence of parameters, such as PGA, CAV, PSA and SV, to the security of rail transit in earthquake.

6.2 Research on reducing noise of observation signals in earthquake warning system of rail transit

Comparing the strengths and weaknesses of various noise reduction methods, we have traditional filtering method and signal separation method. For filters, we can choose Butterworth filter, Chebyshev filter, elliptic filter, etc. Through signal separation method, we use several sensors which are placed closely to each other and separate seismic wave from other interference events by means of algorithm for blind signal separation. Through comparison and analysis, we finally determine a method applicable for rail transit for removing strong vibration signals.

In the research, a great amount of information about research on layout of structure array and earthquake warning in China and foreign countries is collected, the development status of related study in China and foreign countries is analyzed, and feasibility analysis of the research is made. On this basis, we research the layout of structure array in urban rail transit system of Harbin city, provide reasonable and practicable plan for array layout, and choose one line from Line one, Line two or Line three of urban rail transit system of Harbin city to conduct environmental vibration measurement. Based on the environmental vibration level in Line one of urban rail transit system of Harbin city, we research the noise reduction of observation signals.
in earthquake warning system of rail transit and the anti-interference algorithm, and give the algorithm for warning system and the MATLAB program for simulated test system. We also give the testing method for warning system by using records of environmental vibration events and strong seismic records of natural earthquake to test the algorithm of warning system so as to verify the validity of warning algorithm.

7 CONCLUSION

In our country, emergency management level dealing with the natural disaster has increased day by day. Earthquake disaster early warning and emergency plan play an important role in seismic events disposal work, the construction of the railway earthquake emergency plan system will be further deepened and expanded and improved. Railway earthquake disaster early warning and emergency system will play a more scientific and effective guidance in the disposal of big earthquake disaster.

REFERENCES


AUTHOR INFORMATION

Pan Rui (1969-), female, Harbin University, associate professor, mainly engaged in civil engineering teaching and research work.

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