What is the useful application of the earthquake early warning system?

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ABSTRACT :
The early warning information is requires not to cause the social confusion and mislead especially for the public people and the important facilities but in these days some earthquake shows that it is hard to say the governmental information is successful. From the viewpoint of the practical or useful earthquake early warning system, it is very important to issue the warning quickly as possible and also to support the facility recovery if possible. This paper describes the basic ideas and examples of practical use of the useful application of the earthquake early warning system as follows. One is the portable P wave detection system for the rescue team and it can keep the safety of the rescue staffs with the P wave alarm independently from the network even in the focal area. Next is the rational train operation with the combination system of the P wave detection system and high density acceleration collectors. This system can stop train operation immediately by P wave and support the reoperation rationally by specification of checking zone with gathering observed acceleration in real-time. The last is the result of comparison between the network information and on-site information. As an example of the observation, the on-site system can issue the information five seconds before the S wave arrival and it was four seconds earlier than that of EEW by JMA. It shows the advantage and necessity of the on-site system especially for the important facility.

KEYWORDS:
earthquake early warning system, on-site alarm, P wave detection

1. INTRODUCTION

Japan Meteorological Agency (JMA), one of the governmental agencies has started propagating the Earthquake Early Information since autumn 2007, and then this kind of information is very poplar in Japan. Originally the technique to detect P wave had been already established more than 20 years as UrEDAS, JMA advocates they establish the new technique. However it seems that some earthquakes exposed the technical limit of the JMA information as the late or false information.

The processed information for warning may be transmitted to network via fixed communication line, and therefore this kind of alarm system is called as network alarm system. However, after the severe earthquake damage, it is very important to save the disaster victims immediately. For example, the rescue staffs at the hazard area are also under the risk of aftershocks and need a local alarm not depending on the network. This kind of alarm can be called as on-site alarm. And because the network alarm has a possibility of the lack information, important facilities have to equip their own early warning system. This kind of the system is also called on-site system. However the JMA type early warning system is too complex to set on-site temporary, and even if possible to install, the alarm is too late to receive at the epicentral area. On the other hand the new generation earthquake early warning system FREQL, Fast Response Equipment against Quake Load, can issue the P wave alarm by minimum 0.2 seconds after P wave detection. And FREQL is characterized as the unique all-in-one seismometer with the power unit.

At the time of the 2004 Niigata-Ken-Chuetsu earthquake, a land slide attacked a car and a hyper rescue team of

Tokyo Fire Department pulled the survivor. Based on their experience, Tokyo Fire Department asked us to modify FREQL to the portable equipment. Then the Portable FREQL was developed as a handy carrying P wave detection system. When the hyper rescue team was sent as a task force for rescue work of the 2005 Pakistan earthquake, this portable FREQL was used as important on-site portable warning system and P wave alarms were actually issued by three times during five days of the rescue work. And also the portable FREQL works as equipment for keeping safety not only in Japan but also for the international rescue team for the 2008 China earthquake.

On the other hand, in July 2005, an earthquake of M6.0 attacked the Tokyo metropolitan area and caused a traffic disturbance widely in Tokyo metropolitan area. After the earthquake, we proposed a new system for early warning and quick response. Tokyo Metro Company accepted our proposal, and we replaced and built the new early warning/quick response system as followed. The unique system consists of two seismometer networks. One is FREQL network with 6 seismometers to control the train operation immediately after the earthquake occurrence. And the other is the small digital seismometer AcCo network distributing 33 seismometers to grasp more detailed seismic motion on their service area and to optimize the checking zone after earthquake.

2. BASIC IDEA AND THE STRATEGY

The EEW information provided to public widely by Japan Meteorological Agency (JMA) consists of a large number of seismometers in nation wide with the communication network and issues the warning via some organizations 5.4 seconds in average after the trigger. This information plays a roll to make the common people to understand what the earthquake information is. But unfortunately as the practical or useful system, it must be said that are some problems on the processing and/or transmitting time and on the false alarm based on its algorism and software. From a technical aspect, the EEW by JMA is pseudo real-time system because the system stores waveform of the first two seconds and calculates parameters as new procedure after the trigger. Then if the system can not convergent the result, the system calculate with three, five, seven and ten seconds repeatedly. It seems this procedure requires too long time to issue the early warning. And to call new process sometimes causes the system failure, so it seems not to be appropriate for the important system as the warning system.

From the viewpoint of the useful application of EEW, the information must be propagated in short time as possible for the needed area and that will be used not only for the evacuation but also recovery of the facility. For this purpose it is better for EEW of each facility to install its own on-site alarm system and the network information must be used as backup. And also for the wide area as local government, it is necessary to get the precise information of the earthquake parameters including aftershocks to make a plan to search and rescue the hazard area. This kind of the information must be released by the governmental agencies. On the other hand, the On-site alarm system aims to gather the precise situation caused by the event so it is important to distribute the sensors for each facility.

3. EXAMPLES IN PRACTICAL USE

3.1. As the practical Portable Equipment to Keep the Safety of the Rescue Staffs

At the time of the 2004 Niigata-ken-Chuetsu Earthquake, the hyper rescue team of Tokyo Fire Department (TFD) went to the serious damaged area and took of a survived infant from the land slide. At that time the ground condition was terribly serious and all the staff was exposed under the high risk of secondary hazards caused by aftershocks. So they asked us to modify FREQL as portable equipment. FREQL has been developed as a new generation of UrEDAS, the first practical P wave detection alarm system. FREQL can detect P wave only in single station and issue the alarm based on the dangerousness of the earthquake motion in minimum 0.2 seconds after P wave detection and the alarm based on the earthquake parameters in one second after P wave detection. The main unit with sensors and processors is set in 5 inches square metal cube so it is not only easy to carry but also resistant to weather and electrical noise.

Based on the requirement of TFD, the Portable FREQL was developed as a P wave detection warning system independent from the network. And the system consists of mainly three components, the main unit with sensors and processors, the power unit with backup battery and the signal unit with loud buzzer and rotary light. These components, the monitoring PC system and cables are packed in one hard carrying case. TFD and other fire departments in nation wide have adopted the portable FREQL as equipment to keep the safety against the risk of the second hazards caused by aftershocks during their rescue activity. Figure 1 shows the over view of the portable FREQL.

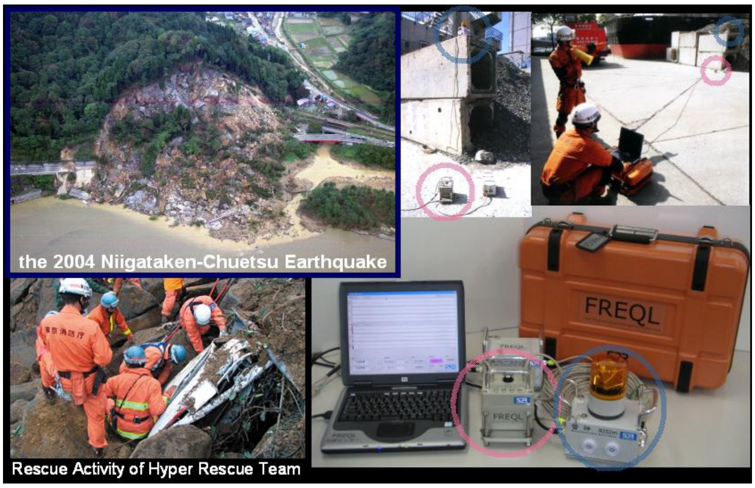

Figure 1 Overview of the Portable FREQL

After equipped the portable FREQL, not only this system keeps the safety of the rescue staff in Japan, but also the hyper rescue team took their FREQL to Pakistan and FREQL issued the P wave alarms three times during around five days to keep the safety of the staffs. Then after the China earthquake in 2008, some news reported FREQL was took there and used in same manner in 2005.

In these days, the portable FREQL is modified to be more usable with combining the main unit and the power unit and with four way buzzer. Figure 2 shows the appearance of the new portable FREQL, FREQL-Light.

Figure 2 New Portable FREQL (FREQL-Light)

3.2. Combination of the Early Warning System and Monitoring System for Proper Train Operation

Tokyo Metro, Subway Company in Tokyo metropolitan area, built the new earthquake early warning/quick response system. Tokyo Metro network is the core of the railway transportation system for the entire Tokyo metropolitan area as in Figure 3.

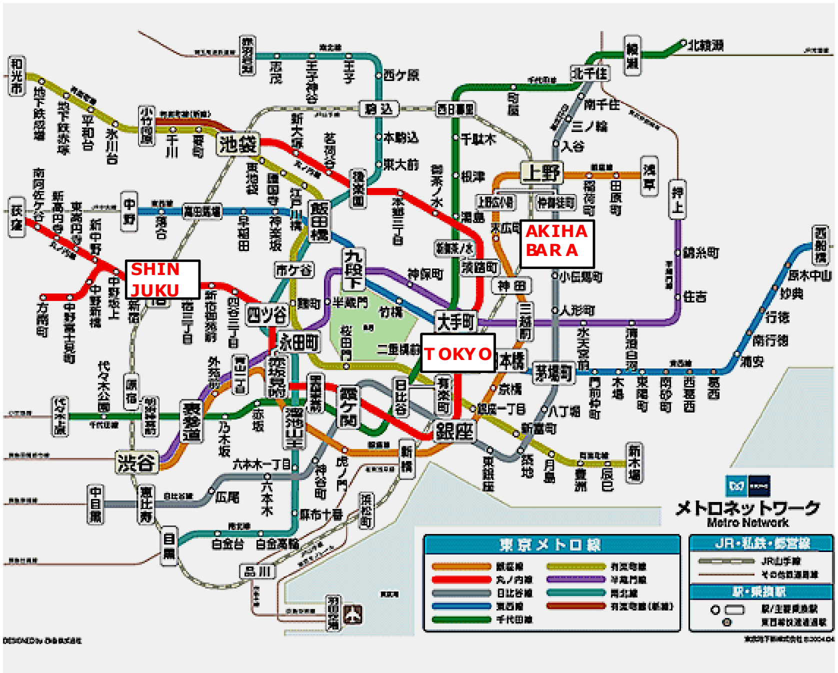

Figure 3 Subway Network of Tokyo Metro Company

In July 2005, a Mjma6.0 earthquake attacked the Tokyo metropolitan area as in Figure 4. This earthquake occurred at 35.5°N and 140.2°E with about 73km in depth, and the maximum JMA intensity was 5+ corresponding to MMI=VIII approximately. This earthquake occurred at north-west of Chiba prefecture and caused a traffic disturbance widely in Tokyo metropolitan area. All the train operation had been stopped for a long time after the earthquake occurrence, although a severe damage was not caused even in the area of high intensity. The longest down time for the train operation was more than seven hours. And that of Tokyo Metro was four hours. At that time Tokyo Metro had to check the entire track on foot, because the control reference value for train operation exceeded. The value of Tokyo Metro is 100Gal of 5HzPGA and this value varies by each railway Company. Here, 5HzPGA is the high cut filtered Peak Ground Acceleration at 5Hz and this acceleration shows good agreement with the damage level. To check the entire track on foot is the reason why all train operation had been stopped for a long time.

After the earthquake, we proposed a new system for the early warning and the quick response. This idea was that it is necessary for the train control against the earthquake to equip the system not only to issue the early warning but also to support the quick and rational recovery work after the earthquake. Tokyo Metro Company accepted our proposal, and replaced Compact UrEDAS and built the new early warning/quick response system as followings. Compact UrEDAS is also able to issue the P wave alarm one second after the P wave detection based on the dangerousness of the earthquake motion. At the time of the 2004 Niigata-ken Chuetsu Earthquake, Compact UrEDAS for Joetsu Shinkansen issued the P wave alarm three seconds before the S wave arrival to the derailed Shinkansen train and saved that train from the hazard.

This new network system consists of two seismometer networks as shown in Figure 5. One is the early warning system network consisting six sets of FREQL to control or stop the train operation immediately after the earthquake occurrence. And the other is the network of the portable digital seismometer consisting of 33 sets of AcCo in every about three kilometers mesh to grasp more detailed seismic motion on their service area. AcCo is small all-in-one seismometer and able to indicate the acceleration value and real-time intensity. Because of the compactness, it was easy to propagate a lot of seismometer to the offices.

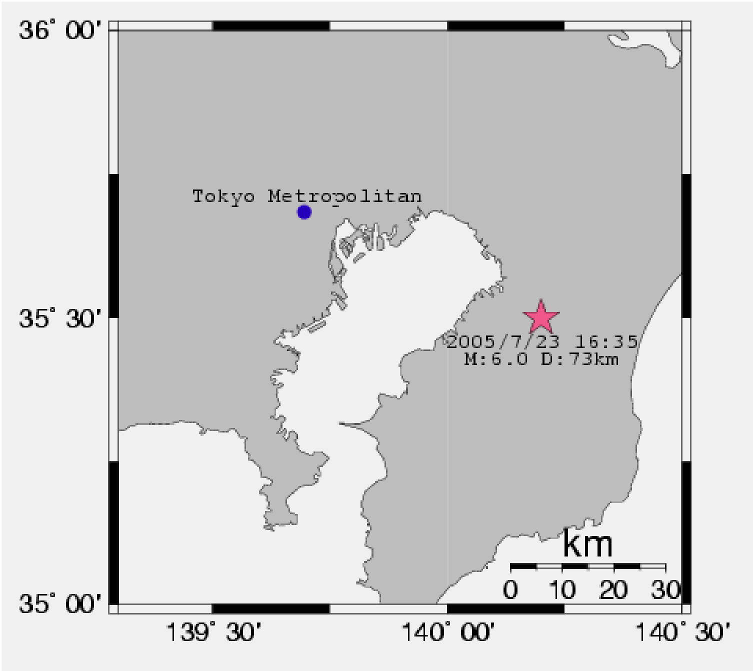

Figure 4 The 2005 Chiba North-West Earthquake

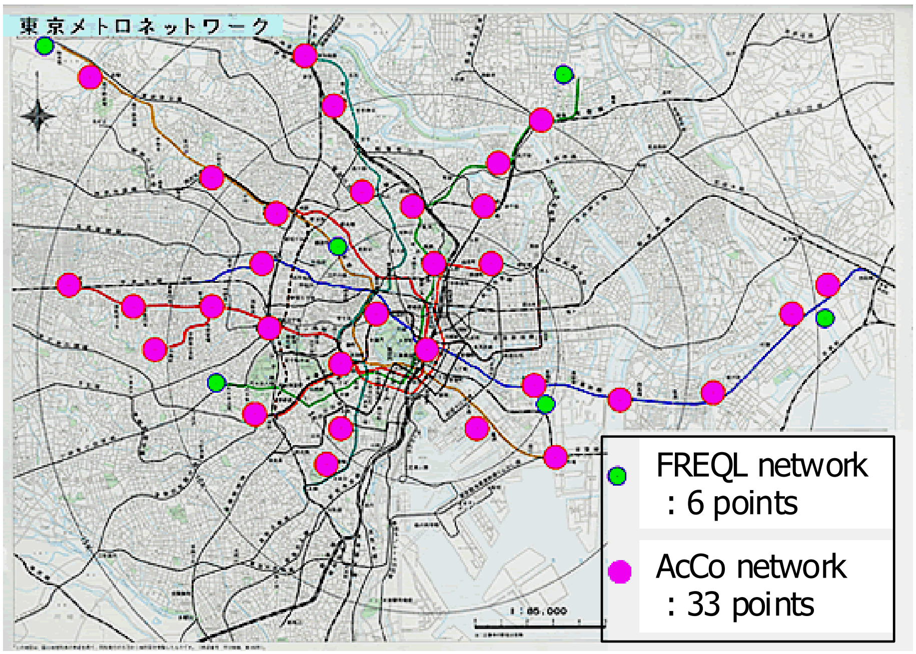

Figure 5 Network of FREQL and AcCo

The information from both FREQL network and AcCo network is gathered to the operation center and displayed on the individual monitoring system. The monitoring system for AcCo can indicate the integrated observed information from AcCo and FREQL and the regulated area and its level for each station on the subway network image. The AcCo monitoring system is also installed on the control table for each subway line.

At the time of the earthquake occurrence, the early warning system FREQL detects the P wave at first immediately and issues the warning automatically if necessary. And then the 33 local seismometers AcCo inform the actual earthquake motion of each site independently in real-time as in Figure 6. AcCo calculate the real-time intensity as a power of the earthquake motion in each sampling and the maximum value of the real-time intensity corresponds to the intensity of JMA. However because the intensity of JMA is derived from the entire waveform data one minute after the earthquake termination from its definition, the intensity of JMA can not calculate in real-time.

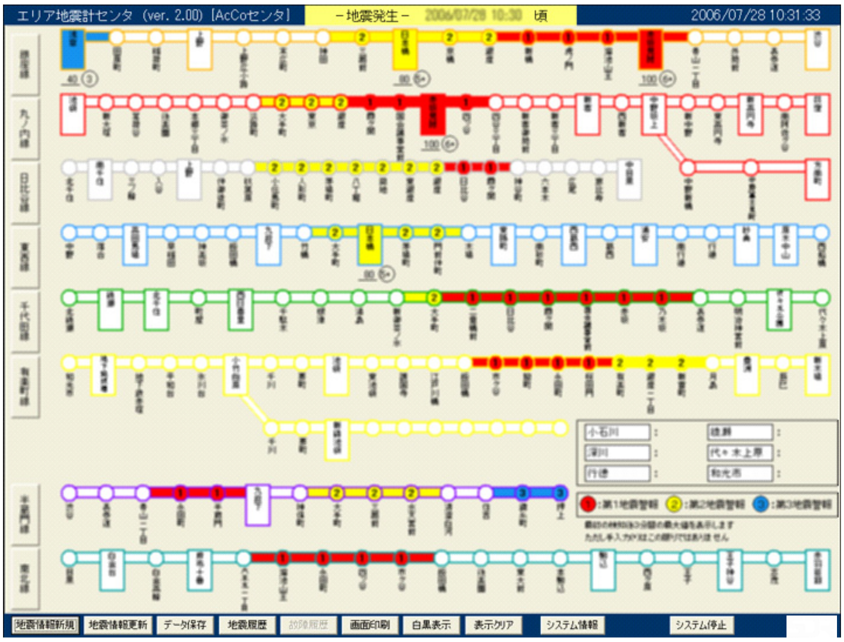

Figure 6 Display simulation of the earthquake occurrence

With the combination of early warning and detailed earthquake information, this system realized the quick response and the restart of the train operation because the early warning became faster and the checking zone after the earthquake was optimized. This updated system realizes the quicker warning from one second to minimum 0.2 seconds. And in case of Figure 5, the checking section is optimized and the number of the section is reduced to 20%.

For the large system as the train operation, it is necessary for the control against the earthquake to equip the system not only to issue the early warning but also to support the quick and rational recovery work after the earthquake.

3.3. Compare with Network Information and On-site Information at Important Facility

Miyagi prefecture locates northern part of the main land of Japan and repeatedly suffered severe damage by large earthquakes. And it is said that next large on is soon. In this area, one nuclear power plant starts a research activity to make clear the behavior of the earthquake early warning information systems especially against the possible large earthquake in this area. There are two kinds of earthquake early information system to compare the result of the network information and the on-site information. One of the system is from JMA as a network information and the other on is FREQL installed on the plant premise as the on-site P wave detection system. After installing the system, some earthquakes have already been observed.

As an example of the earthquake occurred at 74km for the sea side of the plant, the on-site information system FREQL could inform the occurrence of the event one second after the P wave detection and it corresponds five seconds before the S wave arrival. On the other hand the information from JMA was issued one second only before the S wave arrival. This result shows that the important facilities as nuclear power plant must equip their own on-site information system not relying on the information from the other organization.

4. CONCLUSION

This paper describes the basic ideas and examples of practical use of the useful application of the earthquake early warning system as follows.

One is the portable P wave detection system for the rescue team and it can keep the safety of the rescue staffs with the P wave alarm independently from the network even in the focal area. Next is the rational train operation with the combination system of the P wave detection system and high density acceleration collectors. This system can stop train operation immediately by P wave and support the reoperation rationally by specification of checking zone with gathering observed acceleration in real-time. The last is the result of comparison between the network information and on-site information. As an example of the observation, the on-site system can issue the information five seconds before the S wave arrival and it was four seconds earlier than that of EEW by JMA. It shows the advantage and necessity of the on-site system especially for the important facility.

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