Examples of Actual and Simulated EEW for Damaged Earthquakes

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On EEW, Earthquake Early Warning



From past experience, we can understand EEW as follows;

EEW can get only short time margin. It is important for EEW to avoid Overestimation.

It is extremely necessary and important for people receiving EEW to prepare and exercise in advance.

In any case, only the immediate warning can be useful.



Concept of Earthquake Early Warning



are two kinds of the There earthquake alarm. One is "On-site Alarm" which is the alarm based on the observation at the side of the objects to be warned. The other is "Front Alarm" or "Network Alarm" which is the alarm based on the observation near the epicenter to warn for the possible damaged area. Both alarm types described can make use of two different triggers. One is so-called "S-wave Alarm" or "Triggered Alarm". And the other is "P-wave Alarm".

With combining the function of each alarms, we have developed FREQL based on UrEDAS which is the first actual EEW system.



Change of Processing Time for EEW



This year is 35th anniversary of UrEDAS, the world's first practical P wave alarm system.

While JMA system performs every one second for the alarm processing intermittently with stored data, UrEDAS and FREQL perform the procedure continuously in every sampling time, 0.01 second.



FREQL

(Fast Response Equipment against Quake Load)



- FREQL is developed for the earthquake warning system based on the experiences of development and operation of the world first P wave alarm system UrEDAS.
- FREQL function is combined the functions of UrEDAS, Compact UrEDAS and AcCo.
 - P wave alarm is available 0.1 seconds in minimum after P wave detection (after 2009).
- Earthquake parameters are estimated with one second after the P wave detection.
 - S wave alarm is also available based on acceleration and real-time seismic intensity, RI, same as AcCo.



FREQL is Toward to the New Field, as for the Hyper Rescue Team in the Risk of Aftershocks

the 2008 Sichuan Earthquake Mw 7.9

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 (夕刊)

 4版
 2008年(平成20年)5月17日



the 2004 Niigataken -Chuetsu Earthquake Mw 6.6



Rescue Activity of Hyper Rescue Team

Hyper rescue team acts in a risk of large aftershocks.

After the Niigataken Chuetsu Earthquake, the hyper rescue team approached us to adopt FREQL as a support system for the rescue activity.

Tokyo fire department and other 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, not only in Japan but also in the world.





On M- Δ Relationship



UrEDAS Alarm based on M-∆ Diagram after Bitoh, Nakamura and Tomita (1985)





UrEDAS FREQL can and issue an alarm based on the distribution Of the past earthquake damage on magnitude to epicentral distance plane. This alarm is referred to as an M- Δ Alarm.

Moreover this relation could support restarting operation.



On RI, Realtime Seismic Intensity

"Realtime Seismic Intensity" was first named by myself for my newly technology but there are some groups in Japan using the same name "Realtime Seismic Intensity" with another definition. I am afraid of confusion caused by using the same. Also RI of my definition corresponds to the supplying ability of seismic energy.



Definition of DI, Destructive Intensity, and Realtime Seismic Intensity RI which maximum value corresponding to Instrumental JMA Intensity and MMI



Nakamura (1998)

Nakamura (2003)

Compact UrEDAS estimates the destructiveness of the earthquake immediately from the earthquake motion directly, not from the earthquake parameters as UrEDAS, and then issues the alarm if needed. To estimate destructiveness of the earthquake motion, I defined DI, Destructive Intensity, as shown in this slide. Based on the DI, a new seismic intensity, realtime seismic intensity RI is defined.



The Change of RI for Earthquake Motion



When Ρ wave arrives, RI increases drastically. After initial P wave, RI gradually increases until the S wave arrival. After the arrival of S wave, it reaches its maximum value. This value can relate damage to and Instrumental Seismic Intensity of JMA or other scales like MMI.

Instrumental JMA Intensity scale is defined calculated to be artificially only after the earthquake termination. On the other hand, RI can be calculated realtime with physical in background. This be can concluded with the as. continuous observation of RI, earthquake alarm can be issued efficiently and damage can be estimated precisely.





An Example ← Acc. of EW ← Acc. of NS ← 5HzPGA ← RI: Realtime Seismic Intensity

This figure compares the actual behavior of the realtime seismic intensity with the response of cats at a cat café.

It is expected that the alarm based on the RI is faster than the sensing capability of quiet cats against earthquakes.



The 2017 Puebla-Morelos Earthquake (Mexico)

2017/9/19, 13:14 (local time) M7.1, h51km



The 2017 Puebla-Morelos Earthquake

Xalapa Enríquez

Mexico City

UNN

Possible damage area based on Japan's experience Log R = 0.71M - 3.2 Epicenter of the 2017 Puebla-Morelos earthquake M7.1, 51km depth, by USGS

Acapulco

Acapulco

Google Earth

Based on the earthquake information, the degree of damage seems to be minor than usual but the affected area becomes wider because the depth is deep as 51 km. From the experience in Japan, the affected area is estimated within 70km radius. But the serious damage was actually caused for buildings in Mexico City distant more than 120 km.



Zihuatanejo

www.webcamsdemexico.com



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This movie shows how people do or the collapse situation of buildings during the earthquake motion. Please notice sound of a siren, announce and the difference of the building situation, immediate collapse (building A) or delayed collapse (building B).



Seismic Waveforms at UNM Observatory and Results of Frequency Analysis



Strong motion records at UNM are opened to public, so here considers the time of issuing onsite alarm or the situation of a building A collapsed immediately and another building B collapsed much later. According to a frequency analysis, the strong motion of the Puebla earthquake at UNM as a hard ground predominates 0.6Hz or 1.6 seconds.





After the P wave arrival, the RI increased drastically till around RI 1, and then kept increasing during about 6 seconds. After keeping the RI 2.5 for 8 seconds before the S wave arrival, it increased for the RI 4. It finally decreased gradually after keeping the RI 4 for more than 10 seconds. Next considers the time of issuing alarm with enlarging the area of pink frame.





Realtime Seismic Intensity RI and Timing of Warning and etc.

Although the current alarm issued by CIRES is network alarm, it was issued 6 s after the P wave arrival and was too late. But, CIRES says the time of issuing alarm can be accelerated as 5 s before the P wave arrival applying the new developing method. As a result of the simulation of issuing onsite FREQL alarm using the record at UNM, the alarm is issued 1.8 s after the P wave detection and the lead time of this alarm is expected as 15 s before the S wave arrival and over 20 s before reaching preset alarm level of intensity RI 4 or MMI 6.8.





The result of response analysis agrees with actual damage situation of both the buildings A and B. So the reason of the collapse is the resonance between the input earthquake motion and buildings and the too low stiffness of the buildings. Especially in case of the building B, if the natural period was 1.3 seconds, the building might not be collapsed. Slight difference of the stiffness seems to lead to tragedy. This is an example to recognize anew the importance of strengthening from the view point of the earthquake disaster mitigation.



The 2018 Northern Osaka Earthquake

2018/6/18, 07:58 (local time) M6.1, h13km

From the magnitude 6.1, it must be minor damage if caused. But, although the damaged area was almost within estimated area, the extent of damage was larger than can be estimated. And because the occurrence was during morning commute at metropolitan area, the earthquake made the operation of mass transit stop and then caused great confusion as a lot of stranded person.

Here considers the reason why the damage was larger than can be estimated, with the behavior of the realtime seismic intensity RI or the issued timing of EEW. And the video of TV news will be introduced on the situation of subway.





White circle indicates the outer edge of possible damage area. Actual damage was almost concentrated at the area of small ellipse, and it corresponds to the area with large seismic intensity.









For example, if FREQL were installed at Takatsuki, the FREQL issued P wave alarm at the moment when detected the earthquake, and the RI reached 4 within 1 second. After keeping the level more than 1 second, the S wave arrived and then reached the RI 5.7 less than 1 second after S wave detection. The RI gradually became small afterward. EEW by JMA was issued at the damaged area eventually after reaching the RImax, so it had no meaning as an alarm.



Strong Motion Recording Sites and Estimated Source Locations



It is easy to confirm the time arriving the earthquake motion from the change of the RI, and using this time the exact hypocenter with 13 km depth can be determined within 2 seconds after first detection. Similarly, it is also easy to confirm the time appearing the RImax and this time makes possible to estimate Max-source with 6 km depth in the south southwest of epicenter. It shows the fault rupture progressed toward to the ground surface. Because of it, unexpected damage might be caused at the western area against epicenter. Information of hypocenter and Max-source are extremely important to determine the points suffered damage and lead quick rescue activity.



TV NEWS on the earthquake by NHK Osaka



This is a NHK TV news video movie on confusion of transit.

It is necessary for quick response just after the earthquake to grasp exactly the damage. For the priority of the investigation, the earthquake motion along the train lines must be exactly confirmed based not on estimation but on observation. On this purpose, Tokyo metro or Osaka metro subway networks have constructed a system to observe along the train lines in high density and realized the proper reoperation quickly after the earthquake occurrence.



The 2019 Ridgecrest Earthquakes Main shock: 2019/07/05, 20:19 (local time), M7.1, h8km





The Change of RI at the Largest Three Sites and the Timing of Warning



Starting point of fault rupture, so called epicenter, and Max-source are estimated by least-square method using the detection time of this earthquake and the appearance time of the maximum Realtime Seismic Intensity RI at first nine sites.





Epicenter, Maxsource, RI (MMI), Permanent Displacement Vectors derived from 9 Strong Motion Observation Sites and GNSS

Estimated epicenter is almost similar to that by USGS. So with this estimation, the exact location of the epicenter is expected to be determined within 5 seconds after first earthquake detection. The Max-source locates finally at a point about 20 km northwest from the epicenter. The Max-source is expected to be fixed within about 30 seconds after the first earthquake detection. Determining the epicenter and Max-source makes possible to estimate the center of the large motion or direction of the fault rupture, so it is expected to help grasping the damage situation.



Conclusions

- 1. EEW is effective and necessary for the moving facilities, as railways or elevators.
- 2. But EEW issued after the strong motion at sustain damage area like JMA's is meaningless. Even before the strong motion, EEW itself will not be effective for people. To utilize the EEW for people, it is necessary to awake and educate. To awake means to grasp the risk of environment surrounding them. And to educate means to train effective actions to keep safety. For well awaken and educated people, EEW is not necessarily because many people can feel something unusual against P wave motion when destructive earthquakes.
- 3. Quick response requires exact information based on observation, as the location of the epicenter, Max-source, distribution of seismic intensity and so on.
- 4. The basic countermeasure is strengthening the facilities. It is quite important to know the current risk of surrounding environment.



END

Thank you for your kind attention!

Deeply thanks to UNAM, CESMID, NIED and JMA for strong motion data

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