Introduction of Earthquake Early Warning at Schools

Masato MOTOSAKA
Self-introduction
~Recent activities

- Invited lecture regarding development of EEW/SHM system
  - USC, California, 2009
- AGU conference, SF, USA
- 10 years memorial conference of Kocaeli Turkey earthquake, Turkey
  - Riverside City, California, 2013

Kahoku Shinpou-2009/11/1

- Disaster Prevention Education at Schools
- Special lecture for pupils and students
Contents

- What is EEW? and Utilization in Japan
- First successful example of EEW during the 2008 Iwate-Miyagi Nairiku earthquake
- EEW during the 2011 Tohoku Earthquake
  - Good practice at schools
  - Lessons EEW learned from the huge earthquake
- Future recommendation and EEW application in foreign countries
What is Earthquake Early Warning System?

**EEW is notification of seismic ground motion before its arrival, and is a good tool for mitigation of damage caused by seismic strong ground motion if taking appropriate actions.**
Outline of EEW in Japan

- An EEW in Japan is defined as a warning/forecast on seismic strong motion provided before its arrival.

- Japan Meteorological Agency (JMA) has commenced a nation wide service in Japan of EEW provision to general public since October 2007.

- A legal system has been also established so that private sectors may calculate and/or provide an estimated arrival time of a strong ground motion and its intensity as ground motion forecasts under the technical supports and endorsement by JMA.
Method to know earthquake generation before shaking

Electric signal speed is faster than seismic wave!
Principle of EEW (I)
~P-wave and S-wave

**P-wave**
- fast (6～8km/s)
- Earthquake Information

**S-wave**
- slow (3～4km/s)
- Energy
When seismometers near the source catch P-wave, JMA determine the source location and magnitude.

The source information is sent to a receiver at the evaluation point, EEW is sent to a receiver at a evaluation point and then seismic intensity and available time to S-wave arrival are estimated.
Various application fields

- Controlling trains
- Controlling factory lines
  --> To mitigate damage
- Controlling elevators
  --> To prevent people from being trapped
- Suspending work in progress
  --> To avoid mistakes
- Workers performing hazardous tasks
  --> To secure safety
- To prevent traffic accidents
- At home
  --> To enable personal protection
- Alerting schools and assembly halls
  --> To guide evacuation
Response during afforded time

- Human reaction
  * In school, preserve safety of pupil and teacher
  * In office, preserve safety of employee

- Mechanical reaction
  * Shinkansen
  * Automatic elevator’s stop at certain floor
  * Automatic shut down of LPG
  * Stop of product line in manufacture factory
Application of EEWS in schools

Earthquake is coming

From teacher to pupil
*Training/Evacuation

Effectiveness

① Realization of social basis of EEWS
② Ensure safety of teachers and pupils
If an earthquake occurs during class?

from disaster prevention education DVD by supervised by M.Motosaka and Y.Toda
Effectiveness of the early warning

After NHK English News

Pupils can duck under desks within 5s

Psychological Surplus in evacuation

Effectiveness in evacuation induction
It is Important to use the Disaster Prevention Technology Together with Training & Education for Earthquake Damage Reduction
3 major functions of the system

① Evacuation mode
This mode secures the safety of pupils and teachers and persuades the evacuation when the expected intensity becomes more than a specified intensity e.g. JMA IV, issuing a warning via speakers and showing a warning image on the screen.

② Training mode
This mode supplies the function for evacuation drills, issuing early warnings for earthquakes with JMA intensity less than III or a manually set intensity. In both cases, the drill is mainly based on voice broadcast in order to secure the pupils’ safety when a teacher is not present.

③ Education mode.
This mode provides “Static Screen” and “Dynamic Screen” modes, which show pictures of earthquake damage and animation of human and structural behavior during earthquakes respectively.
First successful example of EEW during the actual eq.

June 14, 2008
Iwate–Miyagi Inland earthquake (M7.2)

Available time and the estimated seismic JMA intensity at 5 schools for the 3rd issued source information from JMA
The EEW 21s before S-wave arrival

About 100 students could actually do the drilled evacuation actions

Effectiveness of broadcasting was realized
## EEW during the 2011 Tohoku earthquake

<table>
<thead>
<tr>
<th>提供時刻等</th>
<th>地震波検知時刻</th>
<th>地震波検知から の経過時間(秒)</th>
<th>北緯</th>
<th>東経</th>
<th>深さ</th>
<th>マグニチュード</th>
<th>震源要素等</th>
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<td>5.4</td>
<td>38.2</td>
<td>142.7</td>
<td>10km</td>
<td>4.3</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>14時46分46.7秒</td>
<td>6.5</td>
<td>38.2</td>
<td>142.7</td>
<td>10km</td>
<td>5.9</td>
<td>—</td>
</tr>
<tr>
<td>4</td>
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<td>142.7</td>
<td>10km</td>
<td>6.8</td>
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<tr>
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<tr>
<td>6</td>
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<td>9.6</td>
<td>38.2</td>
<td>142.7</td>
<td>10km</td>
<td>6.3</td>
<td>—</td>
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<td>7.2</td>
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<td>142.9</td>
<td>10km</td>
<td>8.1</td>
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Public warning was issued y 4th issue, Information after 10 sec from P-wave arrival is limited to M7 level even after 100 sec, about M8.
2011 Tohoku earthquake and Earthquake Early Warning in Schools

Nagamachi E.S.
14s before S-wave arrival
Tsurugaya E.S. (15s before)
Furukara 3rd E.S. (21s before)
Shiroishi J.H.S. (21s before)

Efficiently used for evacuation

Escaped from the toppled objects, shoe cupboard, heavy safe boxes!

By way of School WAN (Miyagi-SWAN): Sendai West H.S. (15s before)
Effect of EEW in Nagamachi Elementary School, in Sendai

- A second grader is cleaning the shoe cupboard circumference. A shoe cupboard of the central part that does not make a wall a back turned over. Pupils could be away from it thanks to earthquake breaking news.

- Three large-sized safes of the staff room neighboring press room turned over, and escaped from being crushed thanks to EEW.

"After the experience of Tohoku earthquake (Main shock), pupils can take evacuation action by themselves when EEW is announced for many after shocks."
Movement of MEXT for promotion of EEW in schools

- EEW has advantages to lead evacuation action before severe shaking. Successful example has been reported during the 2011 Tohoku earthquake. (Nagamachi elementary School in Sendai)

*Discussion with MEXT related persons and education committee of local government

*Invited paper for Japan Society of Safety Education

- Ministry of MEXT announced on September 27, 2011 the budget making for EEW in 1,000 schools as 3 years plan (1st year: ¥750 million)
- In fiscal year 2012, precedent installation in 1,000 schools
1. Personal safety

Sendai schools and universities

I've confirmed that EEW worked well Nagamachi Elementary School in Sendai City: *The earthquake warning was announced about 10 sec before shaking and all pupils sank under their desks. Gradually shaking became larger. One minute later a blackout occurred and after another two minutes severe shaking continued*.

The EEW at Shiroishi Junior High School, Shiroishi City was issued and staff and pupils were evacuated.

Sendai-West High School's EEW using Miyagi-SWAN (School WAN) also worked. Teachers were in a meeting and sank under desks following the EEW. Athletics club students in the gymnasium were also evacuated.

Tohoku University's EEW using the university LAN worked and issued the EEW to the broadcast systems at 5 campuses.

— report from Masato Motosaka
Lessons learnt from the Tohoku Earthquake for promotion of EEWS

- Source parameter determination for a huge earthquake
- Problem of false alarm and its countermeasures
- EEW receiver connected to automatic broadcasting
  * Setting of threshold value for broadcasting
  * Setting by judge of only the 1st issue didn’t lead to EEW announcement
- Performance of broadcasting system
- Necessity of redundancy for change of source information
- Enhancement of accuracy of ground motion prediction

Successive use of observed data not only on-site but also Local/Regional and JMA
Future recommendation and EEW application in foreign countries

1) EEW enables to reduce human damage by information for human reaction and also mechanical reaction. Through the experience of the Tohoku earthquake, successful utilization at schools is important to enhance the social understanding basis for EEW. The EEWS would be installed all schools in future.

2) Evacuation drill using EEWS’ drill function and daily maintenance of EEWS are needed for evacuation during real earthquake. Degree of the maintenance divided black and white for the EEW utilization.

3) To develop EEW in foreign countries, the real-time earthquake observation network is crucially needed. For developing countries, the financial support would be needed to install the observation network for EEW system.
Thank you for your attention

From Masato Motosaka photo collections
Previous method for ground motion prediction

① Determination of source parameters

‘Point’ source

② Ground motion prediction using waveform at front obs. pt.
For advancement of EEW, utilization of front-site waveform data

1. Ground motion prediction

Direct prediction using data set of obs.data for past earthquakes

* On-site + Local/Regional
* Application to Structural Control
Development of Next Generation EEW/SHM System

IRIDeS Tohoku University

Real-time earthquake information receiver/analysis system

Earthquake obs. and SHM system

Composition of EEW/SHM System

Obs. point distribution in Miyagi prefectural area

Real-time waveform display software

Extension to foreign countries (Mongolia)

Synergic combination

Earthquake Early Warning
Telecommunication tech., earthquake obs. tech

Structural Health Monitoring System ID tech. Structural Analysis tech
Ancient China: Think about ancestor of seismometer by Zhang Heng

- Origin of seismometer
- Chang Heng (AD. 78~139) invented it in AD.132
- Identify the direction of earthquake (8 directions)
- Collect data from the indicated direction

☑ At that time, messenger transport the disaster information

☑ Now, front site waveform information should be collected by telecommunication technology