EARLY ESTIMATION SYSTEM FOR EARTHQUAKE DISASTERS

by

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ABSTRACT

Out of the lessons learned from the Hanshin - Awaji Earthquake, the National Land Agency is developing a Disaster Information System (DIS) that can categorize and analyze information on earthquake disasters using a Geographic Information System (GIS). As one of the subsystems of this DIS is Early Estimation System (EES), which estimates the amount of damage immediately following an earthquake, in a short period of time. One such subsystem has been running since 1996. This paper gives an overview of the EES and explains how estimates are made.

Keywords: Damage Estimation,
Early Estimation
Estimate Method
Operation Record

1. OVERVIEW OF THE DISASTER INFORMATION SYSTEM

The Hanshin - Awaji Earthquake of January 17, 1995, taught us the importance of prompt emergency actions taken by disaster prevention organizations after an earthquake and especially the importance of finding out the state of damage suffered at as early a point as possible.

Based on the Hanshin - Awaji Earthquake experience, the National Land Agency started developing a Disaster Information System (DIS) that can categorize and analyze information on earthquake disasters using a Geographic Information System (GIS), with the objective of providing support to governments in making an initial response and taking emergency actions in the event of an earthquake. Subsystems of the DIS include an Early Estimation System (EES) which quickly provides a rough estimate of the scale of damage immediately after an earthquake has occurred, and an Emergency Measures Support System (EMS) that displays disaster and damage information on a digital map to support authorities in planning emergency actions.

The National Land Agency began development on the DIS in 1995 and the EES has been in operation since 1996. As for the EMS, development is currently underway for a scheduled start of partial operation in 1999.

2. OVERVIEW OF THE EARLY ESTIMATION SYSTEM

In a short amount of time after an earthquake, when information is scarce and limited, the EES gives a rough estimate of the scale of damage. EES aims at providing authorities with the information needed to make swift, correct decisions on establishment of a disaster countermeasure headquarters, emergency actions to be taken, etc.

A flowchart of how estimates are made with the EES is shown in Fig. 1. The system starts up automatically when the Meteorological Agency reports an earthquake of seismic intensity 4 or

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higher on-line. In the next 30 minutes, it estimates seismic intensity distribution with meshes (approx. 1 square kilo meter) and estimates structural damage (number of collapsed buildings) within each cell and the number of casualties (deaths, injured, etc.) likely to arise as a result. From this information, the scale of damage is roughly understood. The information is transmitted to agencies concerned and used towards helping governments study initial responses.

Since started operation in April 1996, EES has been used for 103 earthquakes of seismic intensity 4 or higher up until March 1999. This includes 4 earthquakes of seismic intensity 5+ and 2 earthquakes of seismic intensity 6- (M6.2 recorded on May 13, 1997 in the Satsuma area of Kagoshima Pref. and M6.1 recorded on September 3, 1998 in the northern part of inland Iwate Pref.).

3. EES ESTIMATE METHOD

Having been through many large-scale earthquakes, Japan has extensive records on past earthquakes and damage caused by them, enabling us to draw a relationship between the size of earthquake and damage, for each different area of the country. Using this know-how and analytical techniques developed in recent years, the EES estimates a seismic intensity distribution and estimates structural damage and potential casualties to arise as a result. Estimate method for each item is explained as follows.

(1) Seismic Intensity Distribution

The seismic intensity distribution is estimated from information gathered around the country after an earthquake occurs and transmitted on-line by the Meteorological Agency. It is estimated per mesh (approx. 1 square kilometer).

The process to estimate the seismic intensity distribution is shown in Fig. 2.

1) Area to be estimated is determined.

Data from all areas measuring a seismic intensity 3 or higher are sampled, and the area formed by these points and the surrounding area within an approximate 40 km radius is taken as the target area for estimate. To keep the estimate procedure as short as possible, area estimated is limited to the range in which damage can occur.

2) Seismic intensity is converted into velocity.

The seismic intensity measured in each measuring point is converted to velocity, as the velocity can be obtained on the surface and is basically constant when constructing a distribution of the earthquake motion. Though the relationship between seismic intensity and velocity has yet to be established, a conversion formula was created from data on the five most recent earthquakes including the Earthquake in south area of Hyogo Pref.

3) Velocity on the bedrock is estimated.

Using the surface velocity obtained at the measuring points and the surface amplitude, the velocity on the bedrock is estimated. By estimating the earthquake motion on the bedrock, it is possible to estimate a distribution of earthquake motion that is not affected by the type of surface. The surface amplitude was obtained for 13 types of terrain, using the Midorikawa-Matsuoka equation.[1] The terrain types of each measuring points were taken from digital national land data.

4) Distribution of bedrock velocity is estimated.

From the bedrock velocity obtained at each measuring point, contours (of velocity) are created and a mesh topographical distribution of the bedrock speed is estimated.

5) Velocity on surface is estimated.

The surface velocity is estimated per mesh using the bedrock velocity in the opposite way of step 3).

6) Velocity is converted into seismic intensity.
The seismic intensity is estimated per mesh using the surface velocity in the opposite way of step 2).

As described above, a topographical seismic intensity distribution is estimated per mesh, from the seismic intensity measured at each measuring point.

(2) Structural Damage

Structural damage is estimated as the number of collapsed buildings based on the estimated seismic intensity distribution (unit = mesh). Though an estimate is made for every mesh, results are tabulated and expressed for each municipality. An estimate is made separately for wood buildings and non-wood buildings.

The process to estimate structural damage is shown in Fig. 3.

1) Number of buildings is estimated.
The number of wood and non-wood buildings in each municipality is taken from the fixed asset ledger of the Ministry of Home Affairs. Age-wise, the buildings are divided into new and old as described later on. Then, the number of wood and non-wood buildings in each mesh is estimated based on the population ratio for each mesh.

2) Number of collapsed wood buildings is estimated.
For each mesh, the number of collapsed wood buildings is estimated by multiplying the collapse factor by the number of wood buildings. The collapse factor is determined based on 4 conditions - the previously estimated seismic intensity, predominant period, building age and area.

From the past experience we know that, if two wood buildings are subjected to the same seismic force, a building built on soft ground will suffer more damage than a building built on hard ground. Therefore, 2 categories have been set for predominant period based on ground hardness. Building age is categorized into new and old, using the 1960 revisions to the Building Standards Law as a dividing line. Area is categorized into Hokkaido, cold regions (Tohoku, Hokushinetsu and San-in) and ordinary areas, in consideration of the fact that buildings in snowy places are more rigid than in other places.

3) Data is tabulated for each municipality.
The number of collapsed wood buildings estimated in each mesh is tabulated on each municipality.

4) Number of non-wood collapsed buildings is estimated.
For every mesh, the number of collapsed non-wood buildings is estimated by multiplying the collapse factor by the number of non-wood buildings. The collapse factor is determined based on 2 conditions - the previously estimated seismic intensity and building age. Building age is categorized into new and old, using the 1981 revisions to the Building Standards Law as a dividing line.

5) Data is tabulated for each municipality.
The number of collapsed non-wood buildings estimated in each mesh is tabulated for each municipality.

(3) Casualties Resulted from Collapsed Buildings

The potential casualties are estimated as the number of deaths per municipality, based on the number of collapsed buildings in the respective municipality. The death toll estimated here is based entirely on the number of collapsed buildings and does not account for deaths from traffic accidents, fire and other causes. These factors have been left out of the estimate because there are too many undefined elements.

The process to estimate the number of deaths due to building collapse is given in Fig. 4.

1) Population is estimated.

Population is estimated by the time of day and behavior, from the daytime and nighttime populations for each municipality and data derived from surveys on people's move. Here, the time of day is divided into 24 hours, whereas behavior is categorized as staying at home, staying indoors somewhere else than at home and moving. Because sufficient data on people's move is not available, the difference in behavior patterns between different areas is not taken into account.

2) Number of persons staying in wood homes is estimated.

The number of persons staying in wood homes when the earthquake hit is estimated by multiplying the percentage of wood homes for the respective prefecture by the number of persons categorized as staying at home at the time of the earthquake occurrence. The percentage of wood homes is obtained from housing statistics.

3) Number of deaths resulted from wood home collapse is estimated.

The number of deaths resulted from wood home collapse is estimated by multiplying the death factor for wood homes by the number of persons staying at wood homes when the earthquake hit. The death factor for wood homes was determined in association with the number of collapsed wood buildings, that was taken from data on five comparatively recent earthquakes in which 300 or more persons died.

4) Number of persons in non-wood buildings is estimated.

The number of persons in non-wood buildings is estimated by subtracting the number of persons in wood homes from the number of persons categorized as being at home when the earthquake hit, and adding that to the number of persons categorized as being indoors somewhere else than at home.

5) Number of deaths resulted from non-wood building collapse is estimated.

The number of deaths resulted from non-wood building collapse is estimated by multiplying the death factor for non-wood buildings by the number of persons in non-wood buildings. The death factor for non-wood buildings was set in association with the number of collapsed non-wood buildings, which was taken from data on the Hanshin - Awaji Earthquake and other earthquakes.

6) Total death toll

The death toll is calculated for each municipality, by adding the total number of deaths resulted from wood building collapse and non-wood building collapse.

Although the explanation is omitted herein, the EES can estimate the number of heavily injured persons and critically injured persons for each municipality using the number of deaths.

4. EES OPERATION RECORD

As was mentioned earlier, the EES has been used on 103 occasions so far and it has been confirmed fairly adequate in estimating seismic intensity distribution (See Fig. 5). Its ability to estimate damage has yet to be verified because - fortunately - large-scale earthquakes, which can cause severe damage, have not occurred since the start of EES operation. In any case, however, in regard to the two seismic intensity 6- earthquakes that were recorded, results were close enough to indicate the scales, though they can be considered slightly overestimated as shown in Table 1.

As the system is used more and more, we plan to review the estimate methods as needed and improve the system performance.

5. ADDITIONAL TSUNAMI ESTIMATE CAPABILITIES

Japan is surrounded by ocean on all sides and has suffered from much damage caused by tsunami that accompanied earthquakes. Thus, protection against tsunami is a serious issue in coastal areas. However, before taking any sort of countermeasures, it is necessary to make a tsunami hazard map that indicates potential flood areas in the event of tsunami. Here, it would also be necessary to presume the type of tsunami that could occur in each specific area and the damage it could cause.

In setting the presumed tsunami, past experience with tsunami has been used. However, this yields an issue that past experience alone is not always enough to prepare for infrequent tsunami. Therefore, the National Land Agency teamed up with the Meteorological Agency and Fire-Defense Agency to compile techniques for making tsunami hazard maps into a "Tsunami Disaster Forecast Manual." These techniques utilize earthquake fault models and tsunami behavior simulations made possible from recent research findings and new computer technology.

Currently, the National Land Agency is using this Tsunami Disaster Forecast Manual to create tsunami hazard maps (See Fig. 6) for all coastal areas in Japan and to build a database of the map, with the ultimate goal of forecasting the potential damage of tsunami. The Meteorological Agency will announce a new tsunami forecast system in 1999, and National Land Agency will give the EES additional capabilities to make an early damage assessment under flooding caused by tsunami. The system will make it possible to know the state of flooding soon after a tsunami occurs, by searching the database for the tsunami hazard map that contains the area and wave height incorporated in the tsunami forecast.

With the EES capable of estimating tsunami, we expect that the system will be utilized by governments to rationalize their initial response to tsunami occurrence.

Reference

1) Masahiro Matsuoka & Saburo Midorikawa, Wide-Area Seismic Intensity Distribution Prediction Using Digital National Land Data, Structural Systems Papers for The Japan Architects Association, No. 447, pg. 51 - 56, 1994.

Table 1 Comparison of EES estimate against actual results

	Satsuma, Kagoshima Pref.		Northern Iwate Pref.	
	Number of collapsed buildings	Number of deaths	Number of collapsed buildings	Number of deaths
Estimate	Approx. 800	Less than 100 (15)	Less than 100 (11)	0
Actual results	77 (Completely or partially destroyed)	0	0	0

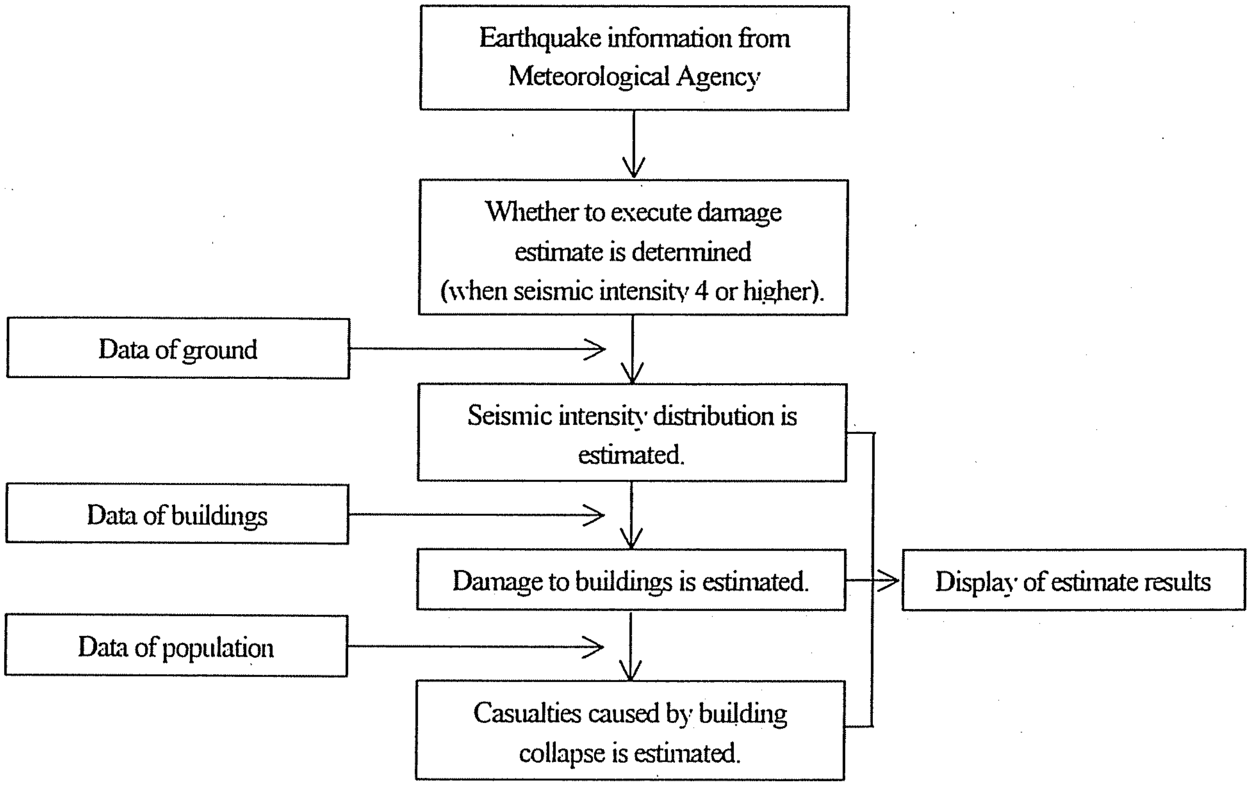

Fig. 1 Flow chart for earthquake damage estimate

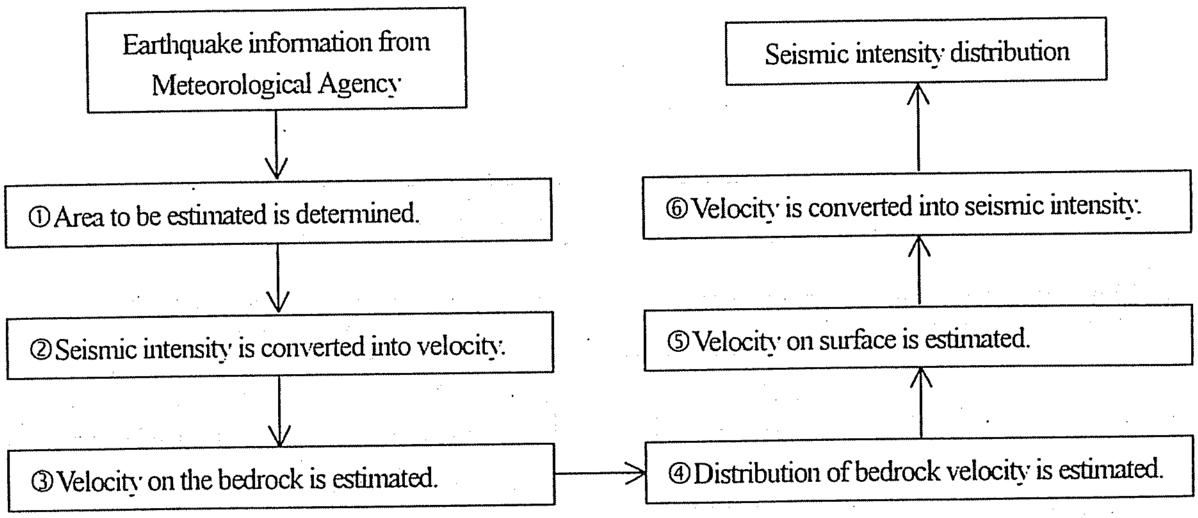

Fig. 2 Process for estimating seismic intensity distribution

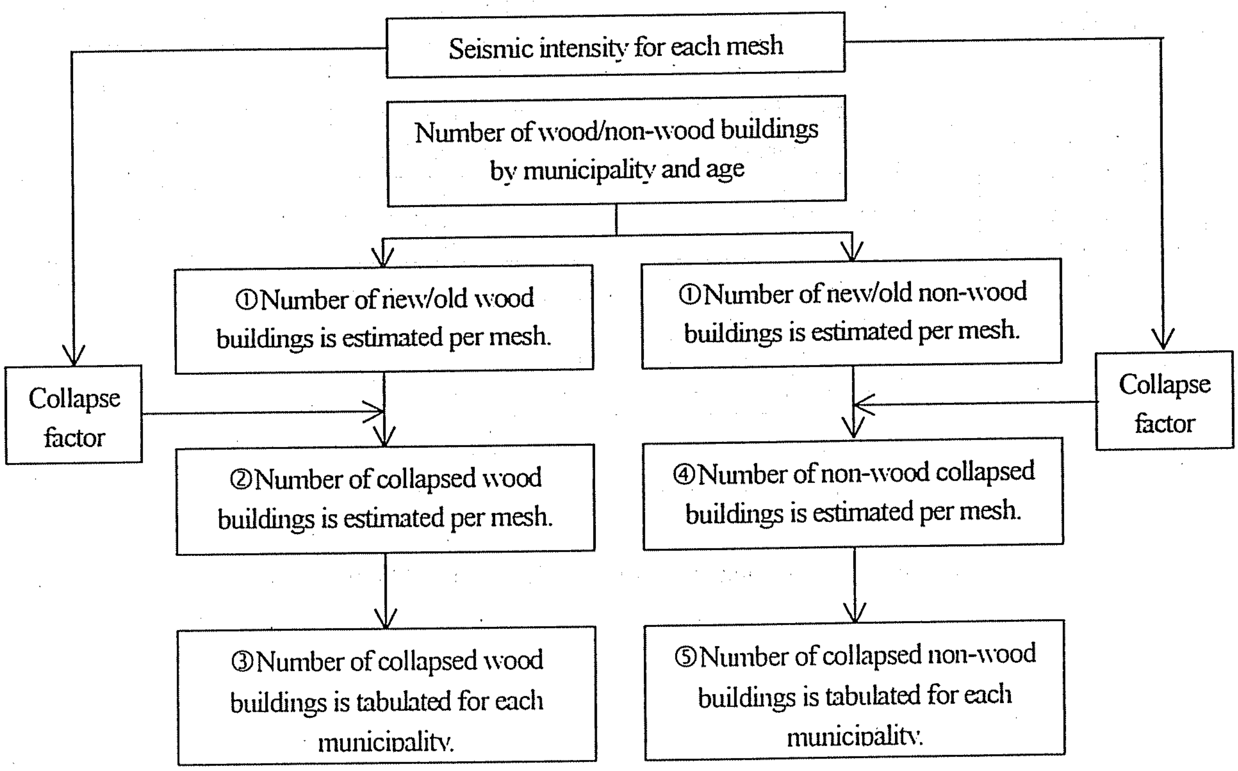

Fig. 3 Process for estimating structural damage

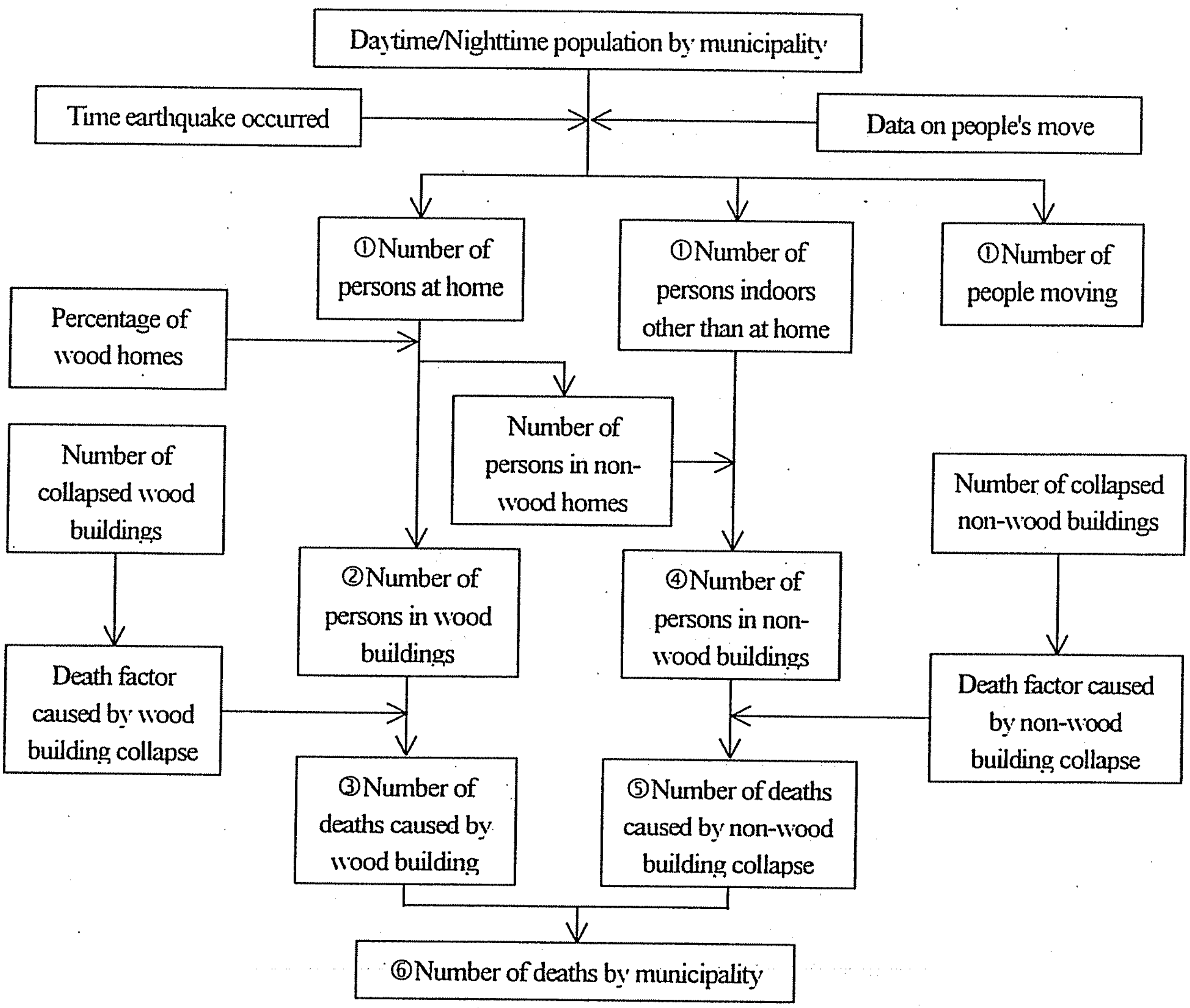

Fig. 4 Process for estimating the number of deaths caused by building collapse

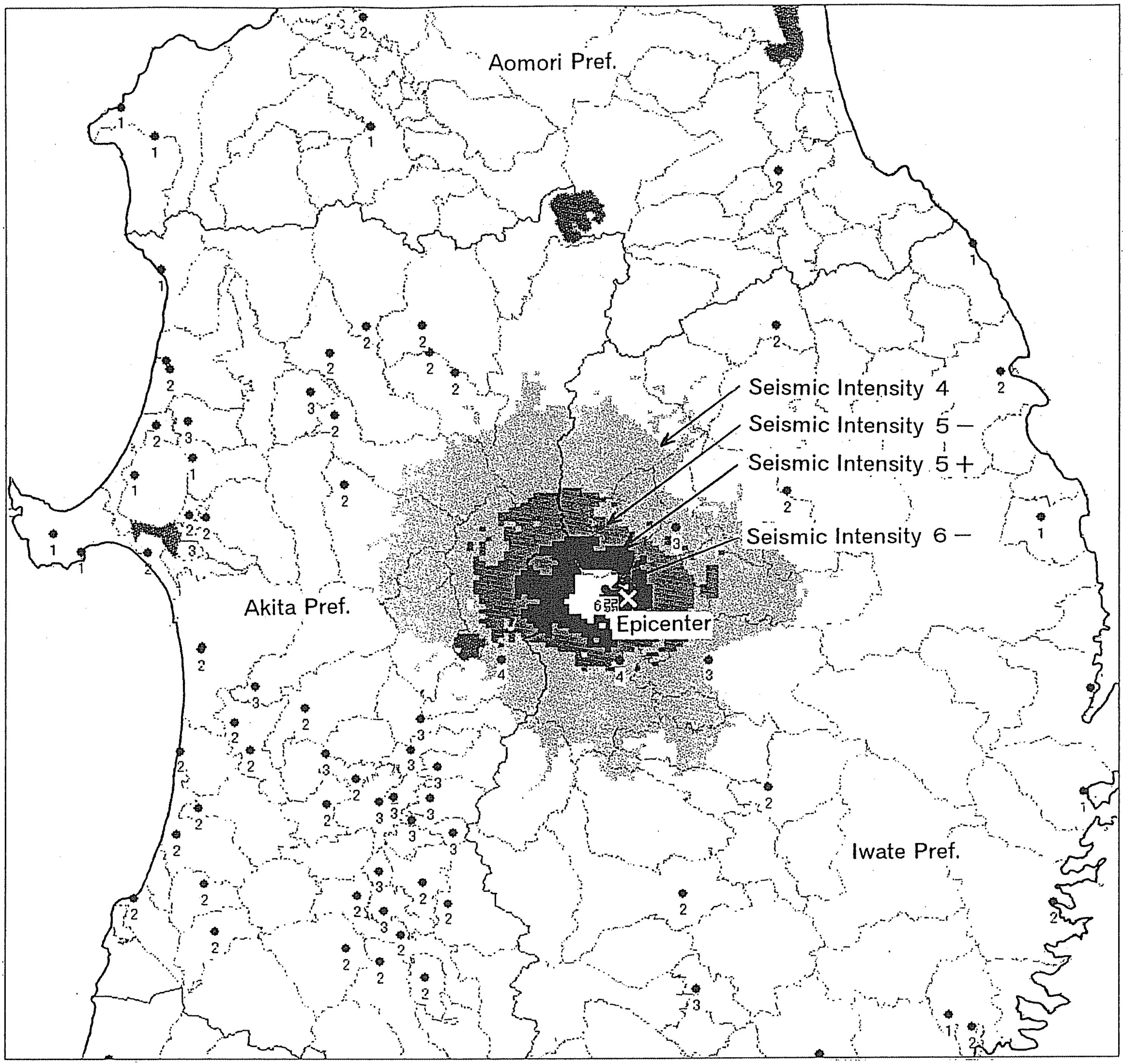

Fig. 5 Seismic intensity distribution
(Earthquake in the northern part of inland Iwate Pref.)
● measuring point
seismic intensity

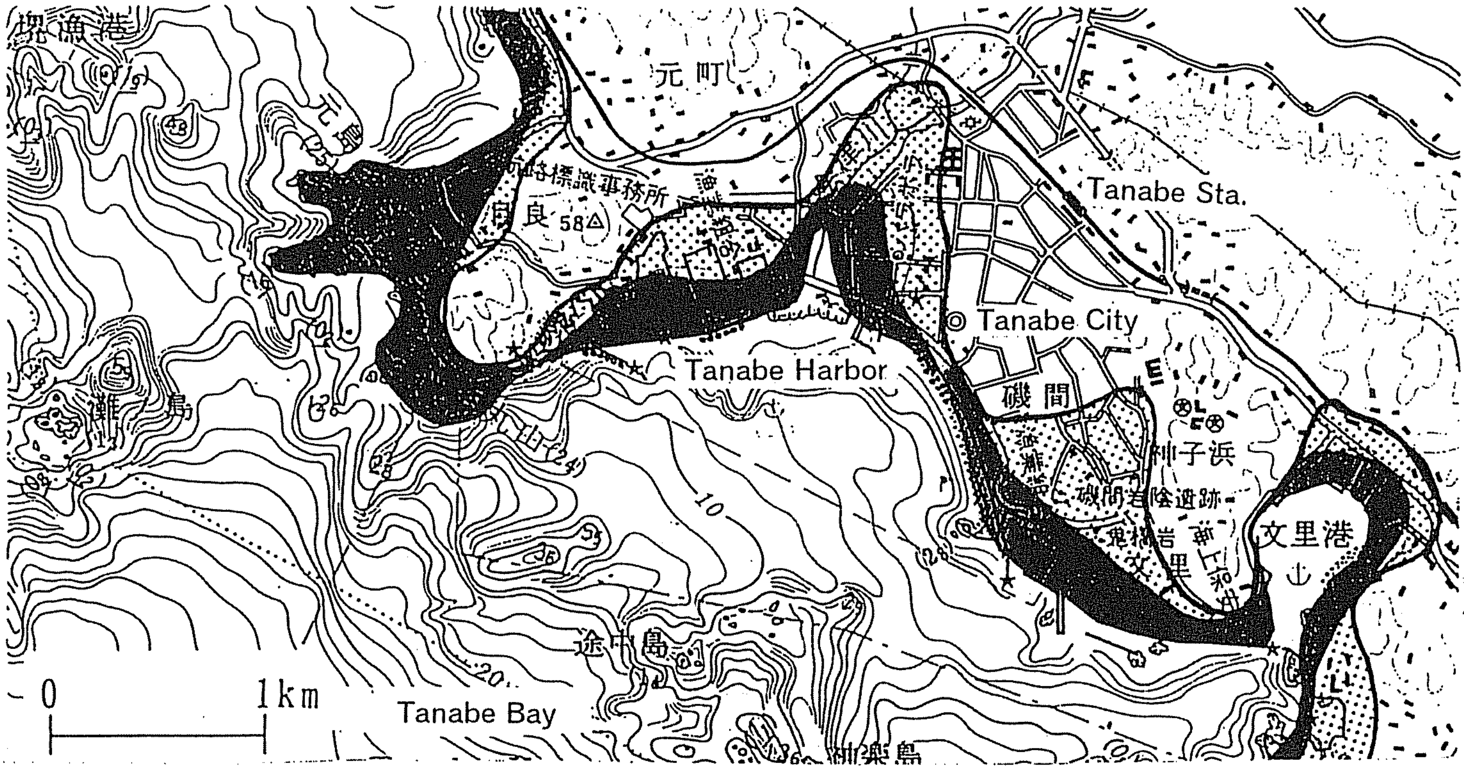

Fig. 6 Tsunami hazard map (example)
(Assume 4 meter tsunami hit the coast of Tanabe, Wakayama Pref.)
Dark area: 2 meter or more under water
Shaded area: 0 - 2 meter under water