

SEISMIC MICROZONATION OF COASTAL HILLSIDE CITY - A CASE STUDY IN OTARU, HOKKAIDO, JAPAN -

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ABSTRACT

Purpose of this study is understanding the problems of seismic zonation of coastal hillside city. The areas where are studied on seismic microzonation incline toward metropolitan area, however earthquakes hit not only them but also small cities. In this paper we chose Otaru, small coastal hillside city, as test field. In order to understand the problems, we collected and review many information, such as geological, geographical and social. By solving these problems in Otaru, for example relations between distribution of slopes and difficulty of evacuation, we can apply to other coastal hillside cities.

KEYWORDS

coastal hillside city; seismic intensity; geographical undulations; historical building.

INTRODUCTION

Japan is an island country, so we have many cities that is surrounded by a mountainous landscape which follows the coastline. There have been many studies on seismic microzonation, however, the most of them are of metropolitan areas which are wide sedimentary plain. However we have many earthquake damages not only in such metropolitan areas but also in coastal cities. In order to develop a method for seismic zonation of such coastal hillside cities, in this paper, we chose Otaru, city in Hokkaido, as a test field.

There are mountains back of the city, because of the port has been used as an excellent natural port for a long time. However flat residential area is limited and has been spreading to steep hill side area based on various geological formations. There are many historical old buildings which are exposed in vulnerable conditions and are utilizing as touristic resources. Therefore it is necessary to consider these situations to disaster prevention problems.

THE CITY OF OTARU AND ITS ENVIRONMENT

Otaru is located near the boundary between the Eurasian plate and the North American plate and many earthquakes have occurred as shown in Fig. 1. Both the Off Shikotan Peninsula earthquake of 1940 and the 1993 Hokkaido Nansei-oki earthquake are the Interplate-type earthquakes, and the Ishikari Bay earthquake of 1834 is Intraplate earthquake. In Otaru, these two types of earthquakes must be considered in the way of disaster

prevention.

The city is formed on three steps marine terrace, therefore it is noted for its many slopes. The topographical map is shown in Fig. 2 with railway and highway systems.

It has been developed as historical port city, along with growth of shipment of coal in Hokkaido. However, the output of coal has decrease in 1970s, the population is decreasing to about 170 thousands. Moreover 17.5% of population is 65 and over years aged people, this is the highest among major cities in Hokkaido. Residences became very old, and the percentage of houses which built before 1960 is 23.7%, it is also highest among major cities.

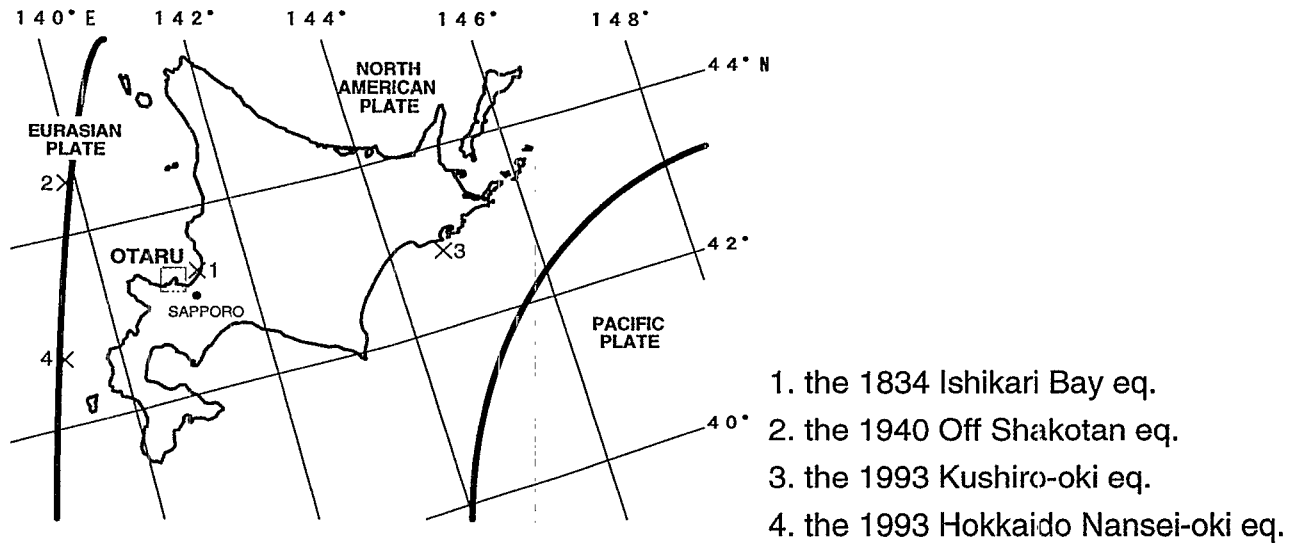


Fig. 1 Location map of Otaru and earthquakes used in this study.

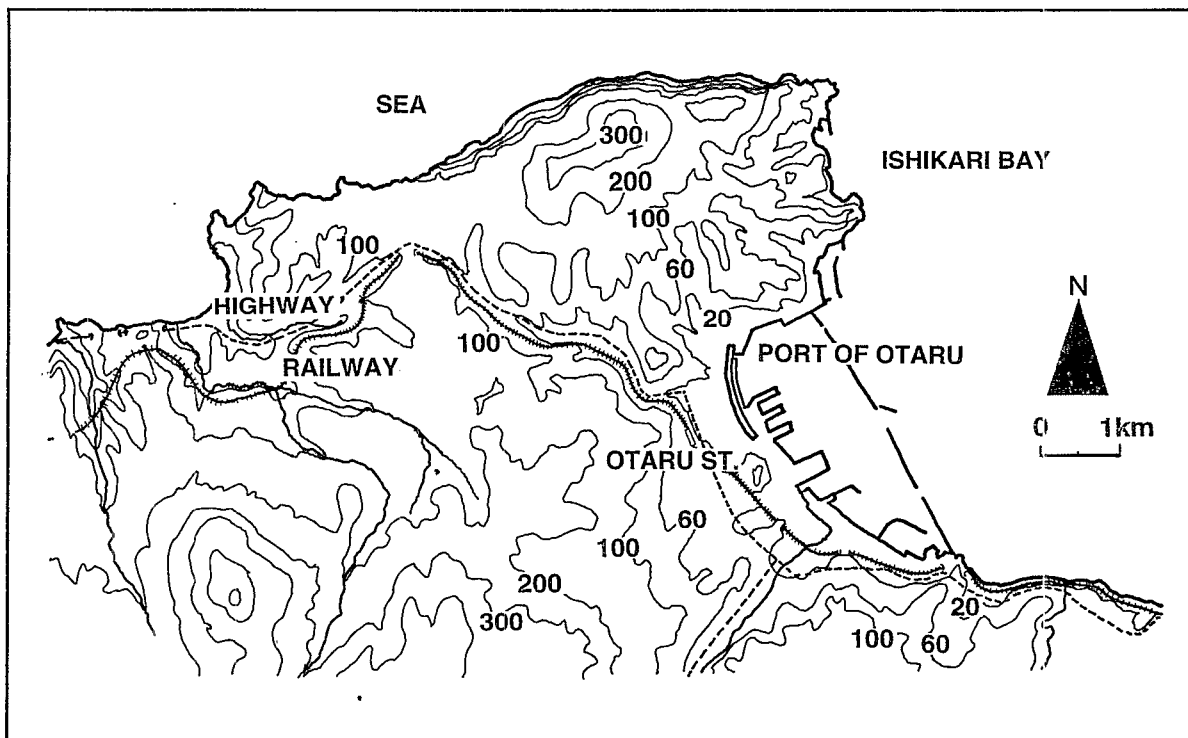


Fig. 2 Topographical map of Otaru with railway and highway systems.
Contour lines are indicated in meter.

REPRESENTATION OF VARIOUS MICROZONATION MAPS

Various information in Otaru, such as geological, social,, are collected and shown on a personal computer with GIS technique. The city area is divided into 500 meters square segments. For an example Fig. 3 shows the geological map. In Otaru, not many deposits are distributed, and some bed rocks are exposed. Majority of distribution of surface soil are volcanic ashes or rocks.

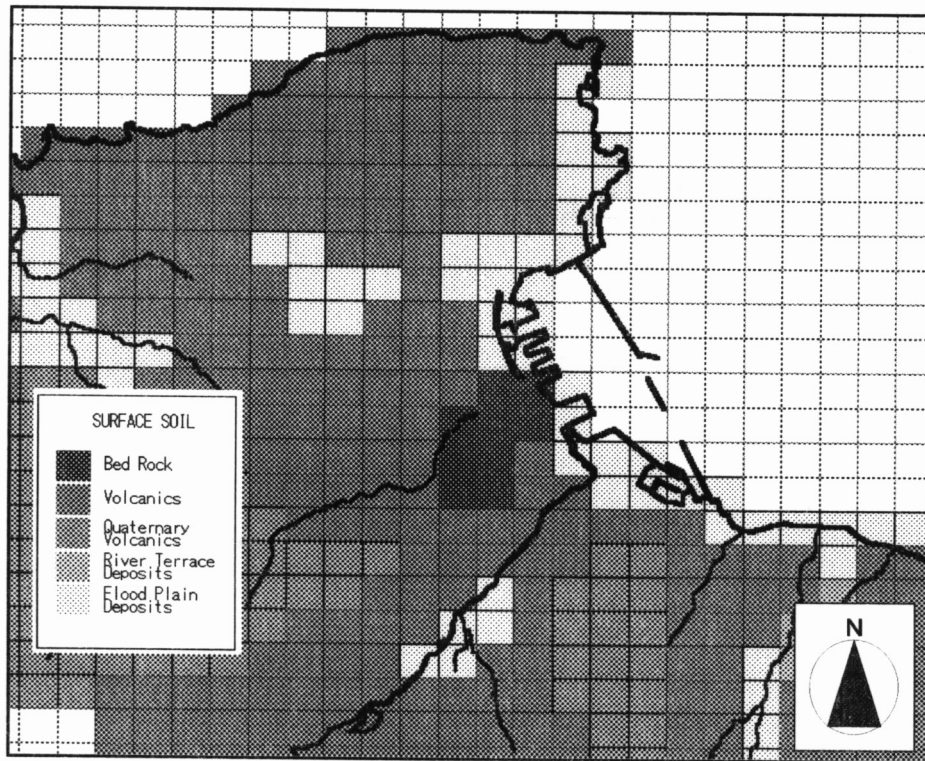


Fig. 3 Surface soil condition of Otaru by 500 meters square segments segments.

From damage distributions of past earthquakes

In the Off Shakotan Peninsula earthquake of 1940 and the 1993 Hokkaido Nansei-oki earthquake, slight damages occurred. The location of these are picked up from newspapers of those days and plotted on Fig. 4. Damage concentration on around Nishiki town is found, where soft deposits soil distribute.

From seismic intensity surveys

In the 1993 Kushiro-oki earthquake and the 1993 Hokkaido Nansei-oki earthquake, Otaru was shaken in intensity 4 and 5 in JMA(Japan Meteorological Agency) scale. Intensity surveys are conducted after these two earthquakes using the questionnaire method(Ohta, 1978) in order to estimate intensity in details. Average of intensities resulted from the surveys are 3.2 and 3.9, and they are lower than intensities announced by JMA. Fig. 5 shows intensity distribution in the Hokkaido Nansei-oki earthquakes of 1993. Influence of surface soil conditions on intensity are not so clear in these data. At the times of these two earthquakes the higher altitude become, the smaller intensity become(Fig. 6). This tendency must be affected by the depth of deposits.

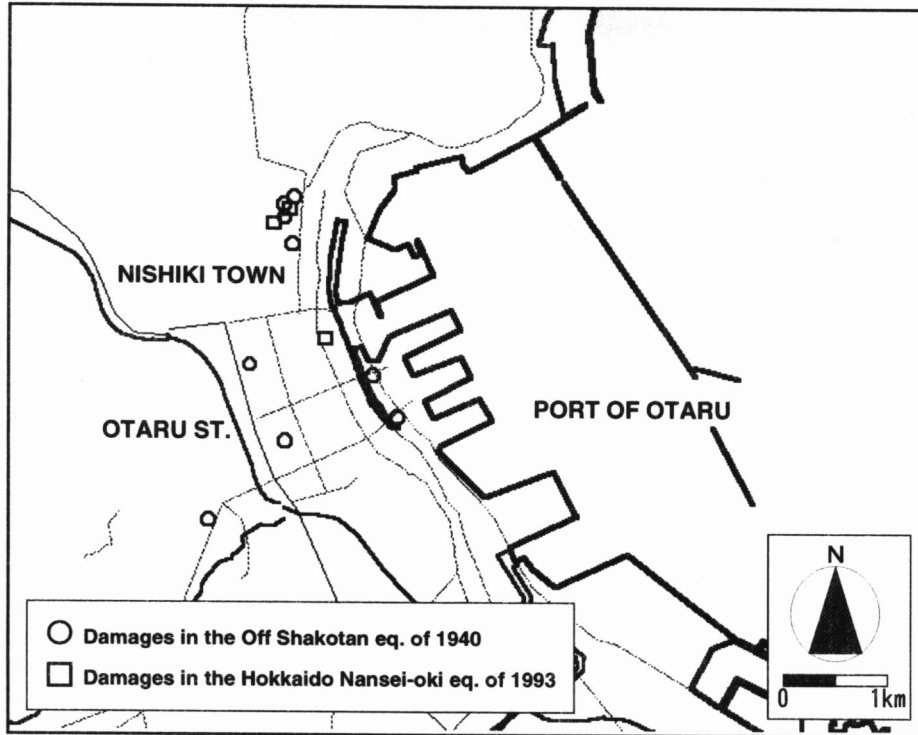


Fig. 4. The distribution map of earthquake damages.

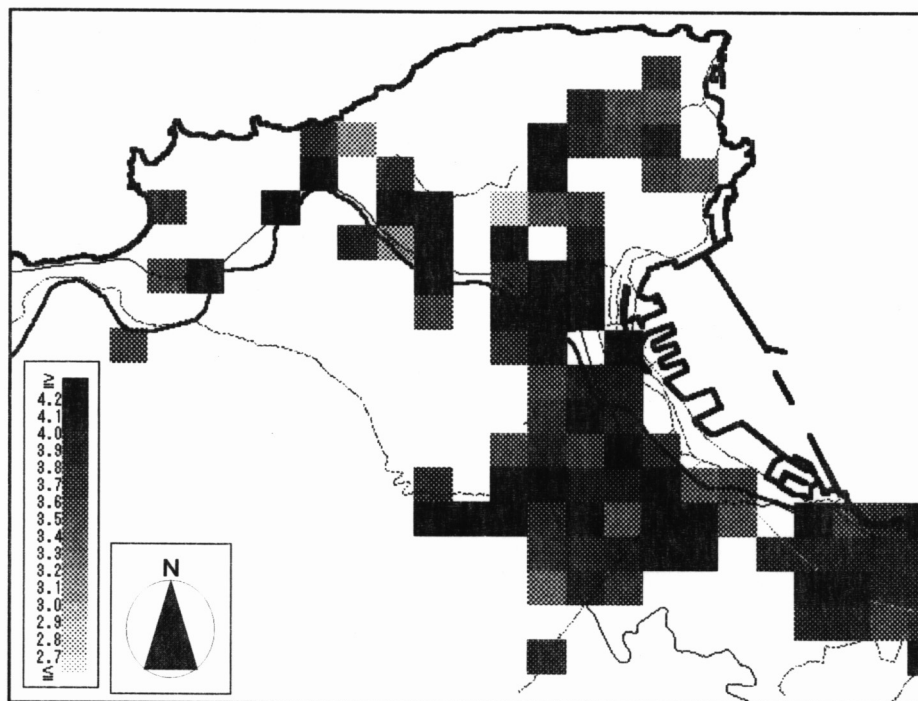


Fig. 5. The distribution map of seismic intensities estimated from questionnaire survey by 500 meters square segments. -in the 1993 Hokkaido nansei-oki earthquakes.-

Rounding to the nearest whole number, thus estimated intensity values correspond to that of JMA.

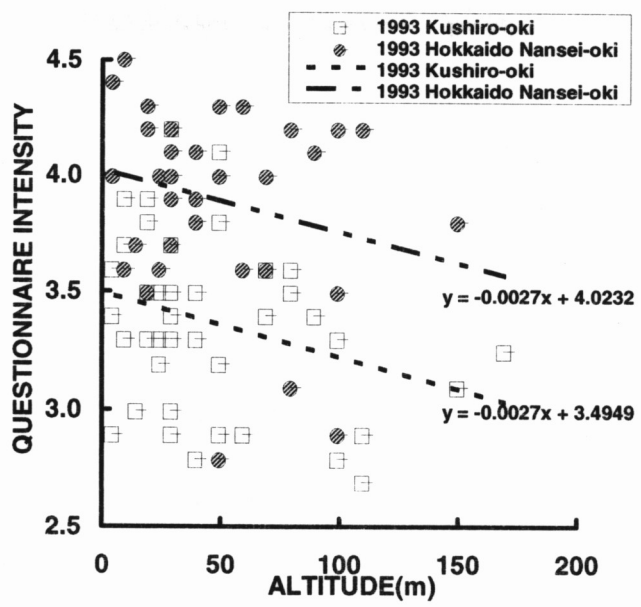


Fig. 6. Relations between altitude and seismic intensity. This tendency must be affected by the depth of deposits

From geographical and geological data

To understand the distribution of slopes, undulations map are made(Fig. 7). This map shows that a lot of undulations are distributed in residential areas. As shown in Fig. 8, we made Landslide risk map combining the undulation data with the surface soil conditions data. In Fig. 8, one point of past landslide is shown. At this point, Temiya town, 12 houses were lost in 1912. This point is indicated as vulnerable in this map too.

Microtremor measurements were carried out along with 4 observation lines to understand the characteristics of ground motion. Natural periods of the ground recorded in these measurements are approximate to the natural periods calculated from S-wave velocity and depth of the deposits with boring data, as shown in Fig. 9.

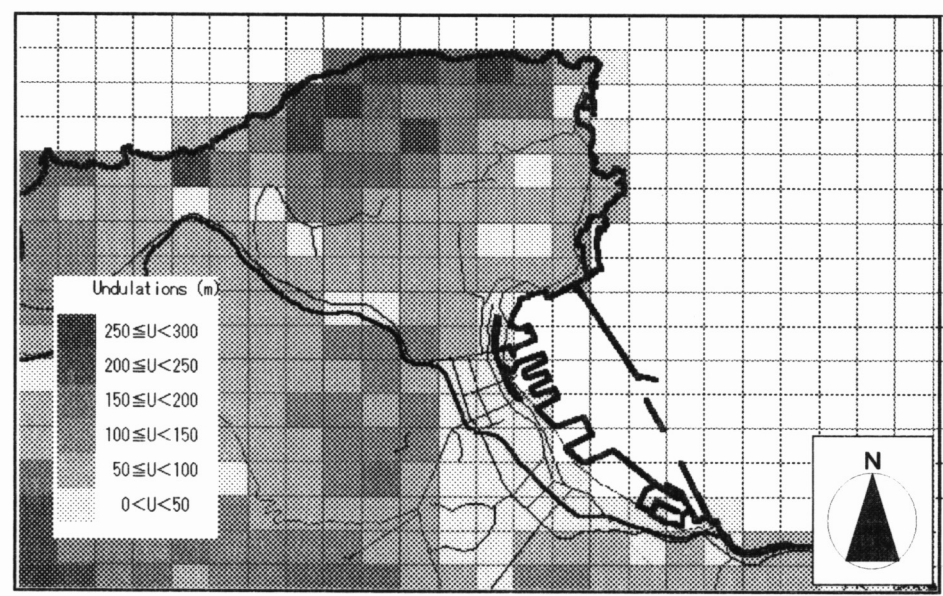


Fig. 7. Undulations map of Otaru by 500 meters square segments.

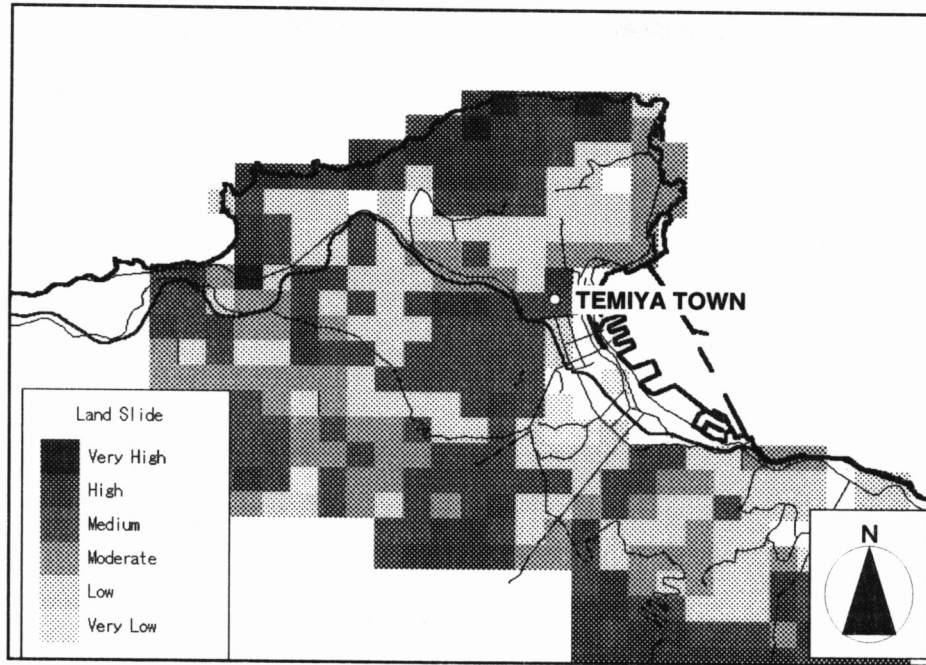


Fig. 8. Landslide risk map of Otaru (by 500 meters square segments).

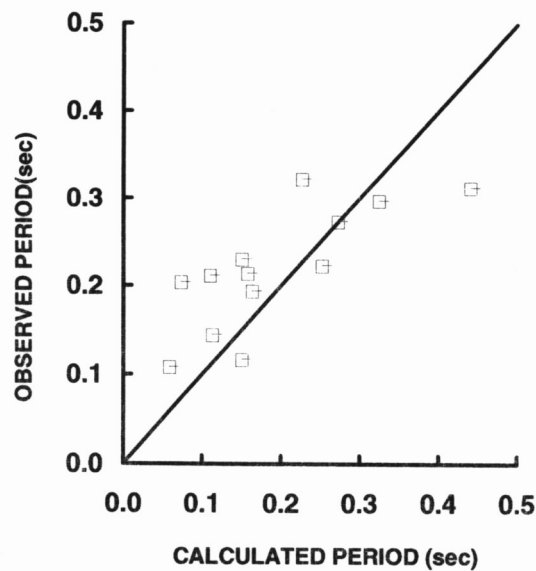


Fig. 9. Relations between observed period and calculated period.

From existing building data

The city of Otaru is active in utilizing and preserving historical buildings, however old buildings is vulnerable in earthquakes. Historical buildings are divided into 4 groups in terms of structures, based on the data of Historical Buildings in Otaru city (Architectural institute of Japan Hokkaido office. 1994), and these distributions are shown in Fig. 10. This distribution map shows that a lot of timber frame masonry buildings are located near Ironai street which is a tourist attraction. Timber frame masonry buildings are built to protect products in storage from many fires, their main structure is wooden frame and, it is covered with fire-resistant bricks. Their fire-resistant bricks are prospected to fall down easily, this will cause more death and injuries. Therefore, these buildings must be utilized and conserved with the usage of advanced technology. Old houses are easy to collapsed. These are crucial problems Otaru has.

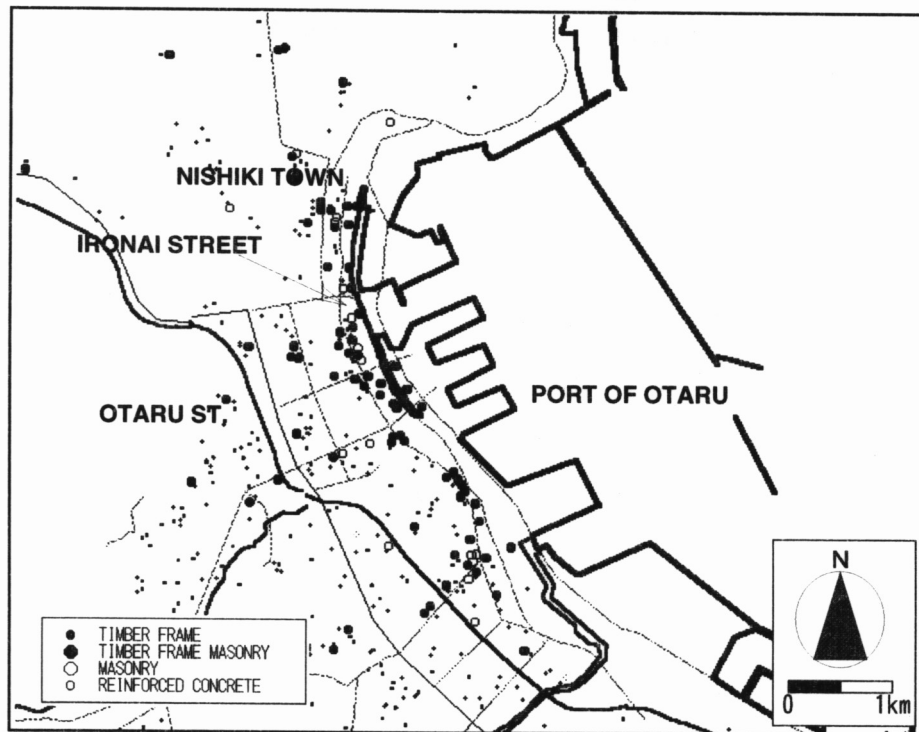


Fig. 10. Distribution of historical buildings.

CONCLUDING REMARKS

In this paper, some microzoning maps which was related with disaster prevention were presented. In such cities, difficulty of evacuation and fire fighting must be checked with data of undulations. There are many aged people, which means that there might be many people who are vulnerable to disasters, so that we must give careful consideration to its estimation.

It became clear that there were high correlation between the data of microtremor measurements and boring data. In addition to this, through comparison with the data of intensity, surface soil, topography and strong motion records, the characteristics of ground motion must be clarified.

Moreover in regions with heavy snowfalls such as Otaru, seismic zonation can't be thought without snowfalls. In January 1996, heavy snow was felt and the city of Otaru was isolated from surrounding areas. This problem must influence evacuation and rescue activity.

This paper pointed out some problems of the seismic zonation of Otaru. In particular high percentage of aged person is pointed out in other hillside coastal cities. By solving these problems in the city of Otaru, we will make model which can be applied to many hillside coastal cities. The seismic zonation map must be made immediately so that it can be applied to the community and urban planning of coastal hillside cities.

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