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VERSATILE APPLICATION OF DENSE AND PRECISION SEISMIC INTENSITY DATA BY AN ADVANCED QUESTIONNAIRE SURVEY

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SUMMARY

Motivated by a belief that qualified seismic intensity data should have wider application capability in engineering seismology and earthquake engineering, we have been continuing a systematic determination of intensity based upon a questionnaire method advanced in both of survey scheme and subsequent data processing. In this paper, we discussed in relation with seismic intensities, some of topics domain in engineering seismology and its neighboring fields from source and near-field characteristics, regional and local microzoning characteristics to seceding impacts upon social bodies.

INTRODUCTION

The officially announced seismic intensities by JMA (Japan Meteolological Agency) have serious demerits as to be the basic data for succeeding studies, since its determination is made in a small number of sites and in rather low accuracy due to the strong necessity of quick reporting. In 1972 we first introduced an alternative questionnaire method to estimate seismic intensities more densely and precisely (Ref.1), and we have surveyed for more than 30 modelate-to-large earthquakes in Japan as well as for a few earthquake in foreign countries where the MM or MSK intensity scale is popular.

In this paper, the results obtained through these surveys were summarized on versatile applications to engineering seismology and earthquake engineering problems, demonstrating the significance of dense and qualified seismic data.

QUESTIONNAIRE SURVEY

Prepared questionnaire for evaluating seismic intensity at a site contains 34 items of questions. All of the items in the questionnaire are made in reference with the texts in JMA intensity scale. Special attention paid are to prepare duplicate questions in a certain range of intensity so as to improve the accuracy of respondents. The collected questionnaires are analyzed so as to get raw intensities first, in the manner as one intensity by one questionnaire, and then by use of several tens of raw intensity data in a unit area, statistically processed so as to improve its accuracy with two significant figures.

Many examples cited in this paper are obtained through the following surveys to three recent damaging earthquakes in Japan.

1978 OFF MIYAGI EARTHQUAKE On June 12, 1987 a large earthquake of M=7.4 occurred off Miyagi prefecture, northern Japan and serious damage was dominant in and around Sendai city. The questionnaire survey was conducted at five cities, including Sendai, where intensity were reported as V by JMA and an investigation of human behavior during a shaking was also aimed with additional 18 questions. Total number of distributed and collected were 4,300 and 3,586 respectively.

1982 OFF URAKAWA EARTHQUAKE On March 21, 1982 a large earthquake with M=7.1 occurred off Urakawa, Hokkaido district in northern most Japan. Although the maximum intensity by the JMA was VI at Urakawa, no continuation to V was reported at any affected areas. For the purpose to overcome such contradiction, and to draw precise isoseismal maps including epicentral region, a survey was carried out distributing 6,325 questionnaires to 212 municipalities in Hokkaido. We also performed dense questionnaire surveys with special objectives of getting precise isoseismal map, of elucidating intensity distribution along the coastal line passing through epicentral area, and of characterizing microzoning of Sapporo city.

1983 CENTRAL JAPAN SEA EARTHQUAKE A great earthquake occurred on May 26, 1983 and brought serious damages to northern districts in mainland Japan. Because of its large magnitude of 7.7, the affected areas were so wide covering Hokkaido, Tohoku and Kanto districts. For this earthquake a dense survey was performed similarly to the 1982 Off-Urakawa earthquake, including 435 municipalities. The total number of questionnaires delivered exceeds well 10,000, by which almost all the areas with intensity of III and higher were investigated.

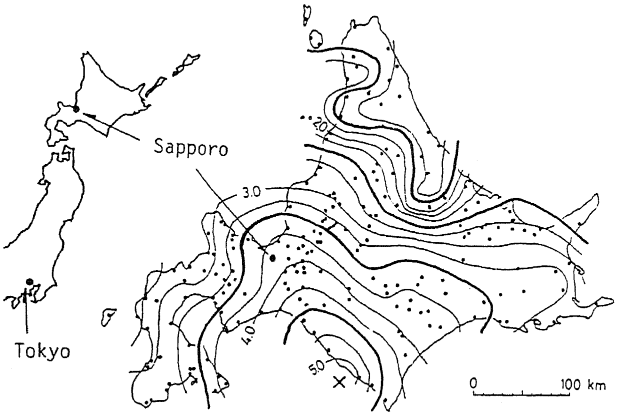

Fig.1 Obtained isoseismal map of 1982 Off Urakawa earthquake.

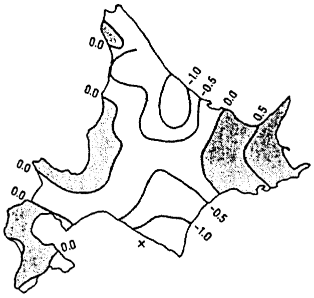

Fig.2 Intensity anomaly map of 1982 Off Urakawa earthquake.

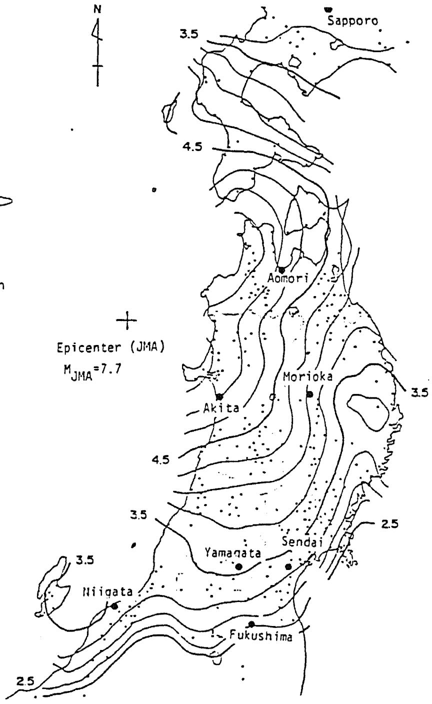

Fig.3 Obtained isoseismal map of 1983 Central Japan Sea earthquake.

PRECISE ISOSEISMALS COVERING ALL THE AFFECTED AREA

In case of 1982 Off Urakawa earthquake, a precise isoseismal was obtained as shown in Fig.1, which is 0.25 increment-isoseismal maps drawn by use of obtained intensities by municipalities. The actual drawing was made automatically by Ohta and Kagami's technique (Ref.2). Contour lines seem extended in E-W direction , but contracted in N-S direction. This is a common character of isoseismals due to earthquakes in Hokkaido district. To know more detail about this peculiarity, the deviation from the standard intensity attenuation with distances was deduced and its anomaly map was drawn as is shown in Fig.2. As is seen in this figure intensity anomaly is positive deep seated soft soils deposit widely and in its negative region geologically old or volcanic rocks distribute. This clearly shows that the obtained isoseismal map anomalies reflects well regionality in seismic wave propagation.

For the 1983 Central Japan Sea earthquake, the isoseismal map drawn with 0.25 increment is illustrated in Fig.3. From this we find several significant features. One is that the area with intensity V and higher spreads widely in NS direction than in EW direction. This seems due to configurational characteristics of the earthquake fault. The other contours have also the similar tendency of extending NS direction. And this tendency is rather common to most isoseismal maps for shallow earthquakes occurred in northern part of Japan. This isoseismal seems to contains many informations and an extractions are expected.

DETECTION OF SOURCE AND PASS EFFECT

The N-S directionally extended isoseismal contours in Fig.3 can not be explained by a simple attenuation equation assuming a point source and seems to reflect well the finiteness of seismic source. We have already proposed an empirical equation for calculating the intensity distribution considering the finiteness of focal plain (Ref.3). Using this, we perform the following examinations. That is, through numerical comparison of calculated and observed intensities in near-distances we try to find out the optimum configurational solutions in terms of fault length and strike direction. The ranges we examined are for fault length L from 40 to 200km and for strike direction from N30W to N30E, assuming that fault width is known as W=40km and dip angle as 30E. Actual calculation was done so as to evaluate the correlation between observed and calculated intensities in ranges higher than III. Fig.4 illustrates contours of thus obtained correlation coefficient. From this we know that the optimum values are L=120km and N20E. These values are in quite agreement with those derived from instrumental data. This clearly tells that the obtained isoseismals reflect well the source finiteness and configurational characteristics.

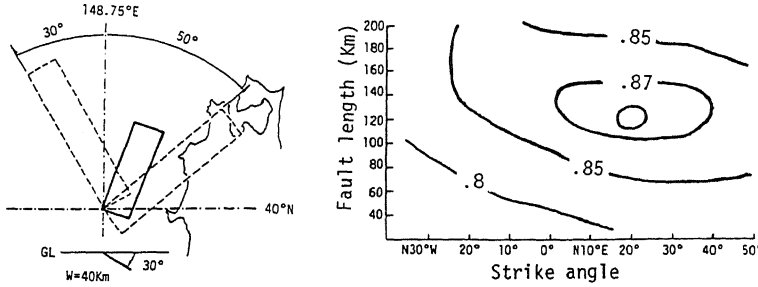

Fig.4 Estimation of fault length and strike direction (1983 Central Japan Sea eq.).

MICROZONING BY DENSE INTENSITY DATA

During the 1982 Off Urakawa earthquake, a dense questionnaire survey was performed in several towns locating Pacific coastal line in epicentral region. Fig.5 summarizes observed and calculated intensity distributions, together with the other physical data. The upper most curve shows relative ground deformation between this earthquake. The second one is PGA (peak ground acceleration) distribution curve. The lowest ones are our calculation and observation. The calculated intensities are based upon the empirical equation proposed by us (Ref.3). All the distributions cited here are in remarkable agreement. A comparison of the ground deformation curve with that of observed intensity tells that the occurrence of dominant ground failures is limited within the region where the intensity is equal to or higher than the lower bound of VI.

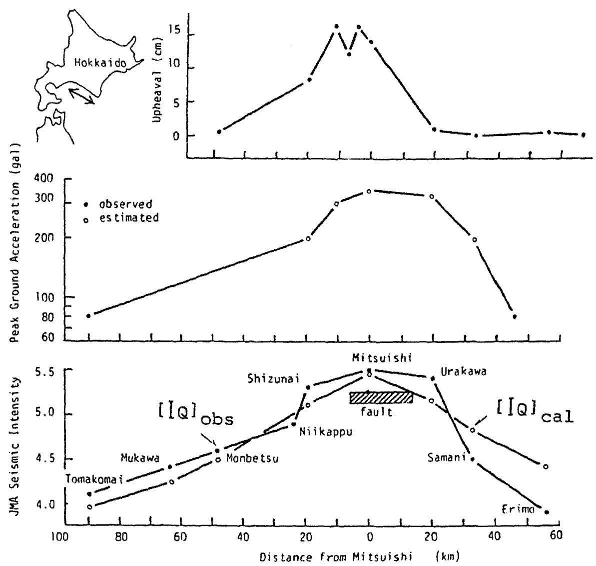

Fig.5 Comparison of intensity with other physical data (1982 Off Urakawa eq.).
upper : ground deformation
center: peak ground acceleration
lower : observed and calculated intensities

Similar but more dense survey was performed in Sapporo city distributing 10,000 questionnaires so as to cover whole the residential area, and got 83 % answers. Areal distribution of intensities are shown in Fig.6 together with site plots where considerable damages occurred. Thus obtained microzoning characteristic reflects well the seismic severity distribution due to this earthquake. Next, we examined a physical reason of such microzoning characteristics. Fig. 7 illustrates a line-up of histograms of intensity deviation from the average value by surface soil types. The right side 4 histograms are for alluvial soils, which indicates rather large intensities, and the remainder ones are mostly for older soils and rock sites. Based on the data we developed an empirical equation to estimate seismic intensities in terms of earthquake magnitude, epicentral distance, soil type and its thickness.

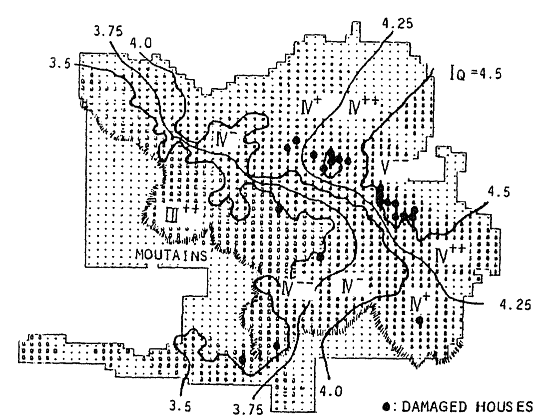

Fig.6 Intensity microzonig map in Sapporo city (1982 Off Urakawa eq.).

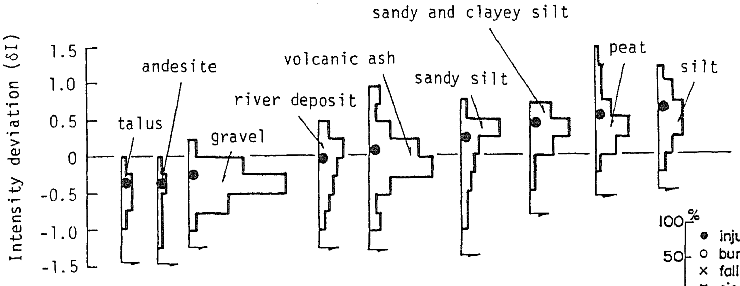

Fig.7 Histograms of intensity deviation by soil types (1982 Off Urakawa eq.).

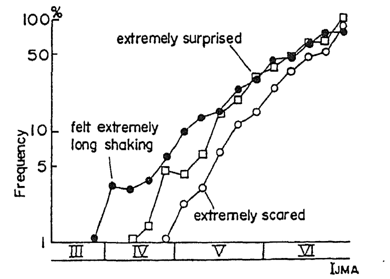

Fig.8 Relation of psychological responses to seismic intensity (1978 Off Miyagi eq.).

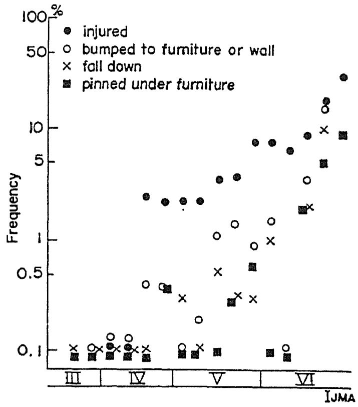

Fig.9 Relation of human behavior to seismic intensity (1978 Off Miyagi eq.).

AS AN INDEX TO INTERPRET VARIOUS ASPECTS OF SEISMIC DISASTERS

From an idea that the precise seismic intensity data can be an effective index to interpret various aspects of seismic disasters, we have been carrying out an explanation of suffered events in relation with the intensities.

HUMAN RESPONSE Basic knowledge on human behaviors under the circumstances of a large earthquake is of great importance to find out a better way of mitigating earthquake disasters, especially such serious calamity as loss of human lives and injuries. For this purpose field survey has been performed in recent decade. In the process of analyzing, the seismic intensity was recognized as an important index. From the data of 1978 Off Miyagi earthquake, a remarkable correlation of human responses to seismic intensities was pointed out. Psychological responses such as fearfulness become sever (Fig.8) and passive or unautomatic behavior increase in number (Fig.9) corresponding to the increasing of intensity.

ASPECTS IN HOUSEHOLD UNIT During the 1983 Central Japan Sea earthquake, in a town locating along the coastal line with a population of 10,000, a whole survey for all the families was performed and compared with damage and other data. Fig.10 illustrates the observed intensities by 18 sub-areas in comparison with structural damage rate and periods necessary for recovery of daily life and for restoration of dwelling. We understand that all of them in sub-areal distribution are in dominant correlation and therefore the seismic severity measured in terms of seismic intensity is the most fundamental factor on direct and indirect disasters.

ASPECTS IN LOCAL GOVERNMENTAL UNIT In a study on earthquake disasters by local governmental unit, seismic intensity is also good index to explain various aspects of disasters from direct to indirect, immediate countermesures and subsequent restoration. From the data obtained by the questionnaire survey

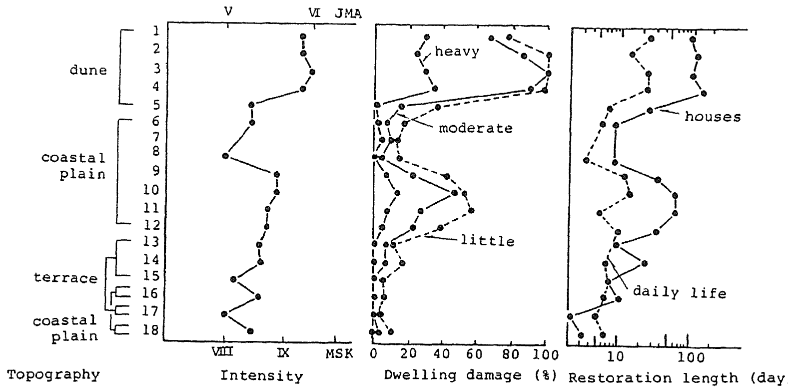

Fig.10 Comparison of intensity with damage and aftermath

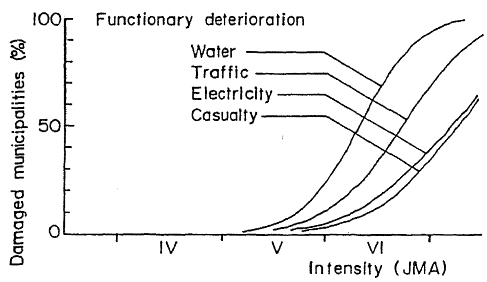

Fig.11 Damaged municipality as a function of seismic intensity (1983 Central Japan Sea eq.).

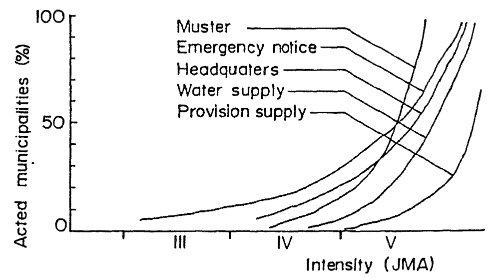

Fig.12 Frequency of municipality taking countermeasures (1983 Central Japan Sea eq.).

carried out for all the municipalities of city, town and village in Hokkaido and Tohoku district, many aspects were interpreted with the seismic intensity. For examples, not only physical damage but also functional deterioration are strongly affected by the seismic intensity as shown in Fig.11. As for the post-countermeasure of municipality, the seismic intensity is also good index as shown in Fig.12.

CONCLUDING REMARKS

Through this series of studies for developing seismic intensity survey by means of questionnaire method we found that dense and qualified intensities are rather easily obtained and such intensity data are well applied for advanced analysis on seismic source and path characteristics and for comparative study with damage and other data. In conclusion we would like to say that, since this questionnaire method is simple and systematic enough to be performed with no much special technique, it should have wider application capability to any other countries than Japan.

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