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ASSESSMENT OF POTENTIAL DAMAGE TO URBAN BUILDING GROUPS BASED ON REGIONAL SEISMIC ACTIVITY

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SUMMARY

This paper presents a practical method for the evaluation of damage to RC and wooden building groups considering the regional seismic activity, the local ground condition and the randomness of earthquake force as well as resistance capacity of buildings. Local distributions of ground motion intensity and prediction of building damages for future earthquakes are studied for Sendai city.

INTRODUCTION

Earthquake damage ratio of urban building groups is one of the most fundamental measures for expressing the damage level of urban spaces against severe earthquakes. It is also used as basic data for estimation and prediction of various indirect damages including fire risk and casualties.

The authors formerly presented a method for estimating the damage ratio of urban building groups due to the maximum ground motion in a given period of time by use of reliability theory (Ref. 1). In this paper, RC and wooden constructions are taken up as two representative building groups organizing large cities. The results on the prediction of damage ratio of building groups in Sendai city due to severe earthquake are shown in the form of mesh maps.

PREDICTION OF EARTHQUAKE GROUND MOTION

The expected intensity of earthquake ground motion in Sendai city within a specified period of time is predicted based on the regional seismic environment and the property of surface soil layers. The method for evaluation of the maximum ground motion used in this analysis is as follows (Ref. 2).

(1) Fig. 1 shows the plots of epicenters of earthquakes with magnitude greater than 5.0 around Sendai area during the period from 1926 to 1981. Three interplate (ocean) earthquake source areas (H,J,I in Fig. 1) and two intraplate (inland) earthquake source areas (Q,R in Fig. 1) are assumed. The probability distribution of magnitude in each area is modeled by the modified Gutenberg-Richter formula by Utsu considering the upper bound magnitude. Assuming the process of earthquake occurrence to be a Poisson process, the probability distribution of maximum magnitude in specified period of time is estimated.

(2) Earthquake source areas are modeled by the assembly of small square

areas with 0.25°x0.25° (about 28kmx23km), each having independent earthquake activity. The probability distribution of maximum base rock motion in Sendai area is determined by the method of Cornell.

(3) Based on the ground motions and damage data for the 1978 Miyagi-ken-oki earthquake and the 1962 Northern Miyagi earthquake, two attenuation models for evaluation of base rock acceleration corresponding to ocean and inland earthquakes are developed (Ref. 3).

(4) Using surface soil layer model for each 500mx500m (1kmx1km for mountain area) mesh determined by Miyagi prefectural government (Ref. 3), the soil layer amplification is calculated by equivalent linearization method and earthquake motion intensities at ground surface are evaluated.

The 500m mesh map of the expected maximum ground acceleration A_{max} in Sendai area for 75 year period is shown in Fig. 2. The values of A_{max} for 75 years are considered to be equivalent to those of the 1978 Miyagi-ken-oki earthquake.

ESTIMATION OF EARTHQUAKE DAMAGE TO A GROUP OF BUILDINGS

The seismic resistance capacity of building groups and the earthquake force exerted on buildings are assumed to be modeled by the random variables, R and S, having the probability density functions, $f_R(r)$ and $f_S(s)$. It is assumed that R and S are independent each other. The earthquake damage ratio of building groups Pf is then expressed as follows (Fig. 3).

$$Pf=P[R\leq\alpha S]=\int_0^\infty f_S(s)\int_0^{\alpha s} f_R(r)dsdr \qquad \text{-------(1)}$$

where α is a parameter expressing the level of damage. Using the energy conservation rule for the inelastic earthquake response, the value of α can be expressed as follows (Fig. 4).

$$\alpha=1/\sqrt{2d-1} \qquad \text{-------(2)}$$

where d = ductility factor related to level of damage. The lognormal distribution is assumed both for R and S.

In case that the building resistance R and the earthquake force S in a certain area are divided into some different groups, R_i and S_j, the earthquake damage ratio Pf of whole area is given as follows.

$$Pf=E[P_{ij}]=\sum_i\sum_j q_{ij}p_{ij} \qquad (\sum_i\sum_j q_{ij}=1) \qquad \text{-------(3)}$$

where q_{ij} = occurrence probability for combination of R_i and S_j.
p_{ij} = damage ratio evaluated from R_i and S_j.

PROBABILITY DISTRIBUTION OF RESISTANCE CAPACITY

For the prediction of earthquake damage ratio, it is very important to evaluate the probability distribution of the seismic resistance capacity of actual building groups. However, there have been few studies on this problem due to the lack of suitable data. In this paper, the probability distribution of resistance capacity of RC and wooden building groups are assumed as follows.

<u>RC building groups</u> As an index for the resistance capacity of low-rise RC building groups, the ultimate base shear coefficient C_Y was proposed by Shiga, which is defined by column and wall areas in the first story (Ref. 4). The probability distribution model of C_Y expressed by lognormal distribution proposed

by Onose (Ref. 5) is used. Fig. 5 shows the probability density functions of C_Y with the different mean values for the number of stories and the constant coefficient of variation of 0.45. In the calculation, the distribution of the number of stories in a certain area is modeled as lognormal distribution with the mean value of 2.0 for suburbs and 3.0 for central areas and the coefficient of variation of 0.3, based on the research of RC buildings in Sendai city.

Wooden building groups The probability distribution of resistance capacity of wooden building groups proposed by authors based on the damage data in the 1978 Miyagi-ken-oki earthquake is used (Ref. 6). Fig. 6 shows the relation between the data of observed damage ratio (partial damage and above) and the mean value of A_{max} for 75 year period for each primary school zone in Sendai. The smooth curve in Fig. 6 is the lognormal distribution model for the cumulative distribution function of the data. It is assumed that the damage to wooden building occurs in case that the earthquake force exerted on buildings is larger than the resistance capacity and that the earthquake force is given by the intensity of the ground motion multiplied by 2.0. Then the probability distribution of resistance capacity of wooden building groups is modeled as lognormal distribution with mean value of 0.68 and coefficient of variation of 0.24 (Fig. 7).

PREDICTION OF DAMAGE RATIO OF RC AND WOODEN BUILDING GROUPS IN SENDAI CITY

It is necessary for the prediction of damage ratio considering damage level to define the appropriate value of ductility factor d of Eq. (2) corresponding to the damage condition. Based on Refs. 5 and 6, the relation between ductility factor d and the damage level is given in Table 1.

Fig. 8 shows the examples of the results of damage ratio prediction for the central part of Sendai city for 75 year period. The random variables S expressing the earthquake force is assumed as lognormal distribution with the mean value equal to the maximum ground acceleration for 75 year period multiplied by 2.0 and the coefficient of variation of 0.40.

The comparison of predicted values for 75 year period with the actual percentage of damage is made for several areas in Sendai city. It is assumed that the percentage of damage of the rural areas in which there are obviously no or few buildings is zero.

The predicted values of RC building groups for the level of medium damage and above are 6.9 % in Kamisugi area, 13.7 % in Naga-machi area, 21.3 % in Oroshi-machi area, whereas the actual damage ratios observed in the 1978 Miyagi-ken-oki earthquake are 2.6 %, 10.3 %, 8.9 % respectively.

The predicted values of wooden building groups for the medium damage and above are 6.6% in Kamisugi-yama area, 14.8 % in Naga-machi area, 25.6 % in Rokugou area, whereas the actual values are 0.4 %, 8.5 %, 14.7 % respectively.

CONCLUSIONS

Using a method for the probabilistic assessment of potential damage to urban building groups considering the variation of both the resistance capacity and the earthquake force, the damage ratios for RC and wooden building groups in Sendai city are predicted and compared with the observed values.

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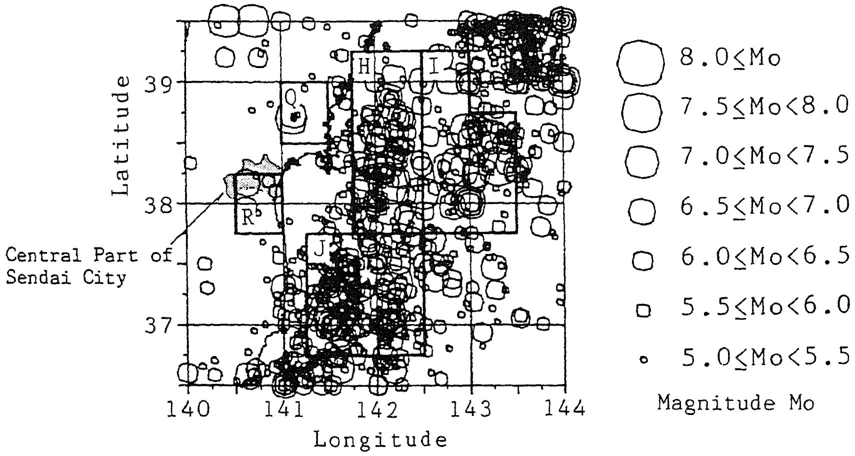


Fig.1 Epicenters of Earthquakes around Sendai

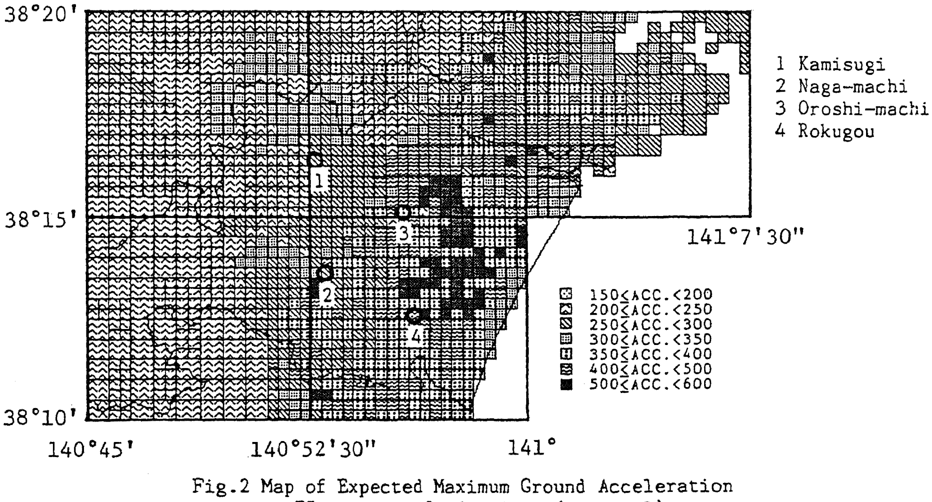


Fig.2 Map of Expected Maximum Ground Acceleration in 75 years in Sendai Area (unit gal)

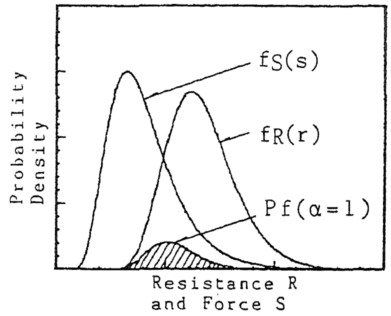


Fig.3 Damage Ratio Pf and Probability Distribution of Resistance R and Force S

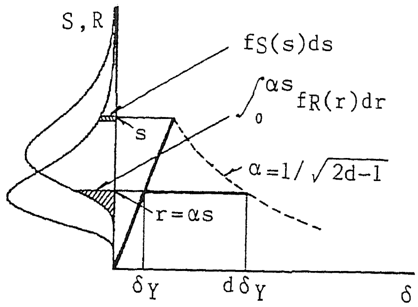


Fig.4 Parameter α and Energy Conservation Rule

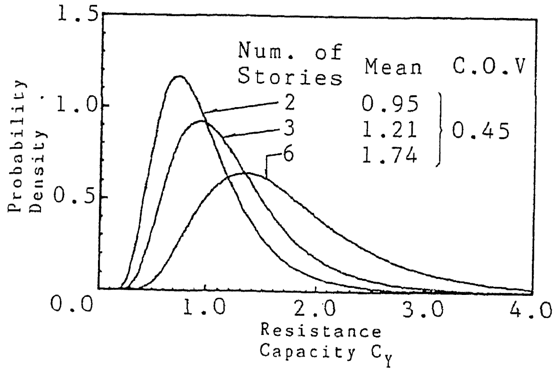


Fig.5 Probability Density Function of Resistance Capacity of RC Buildings

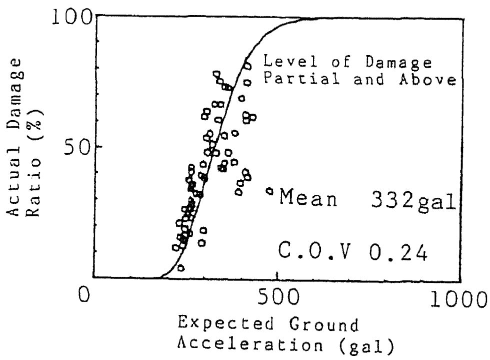


Fig.6 Relation between Actual Damage Ratio and Maximum Ground Acceleration

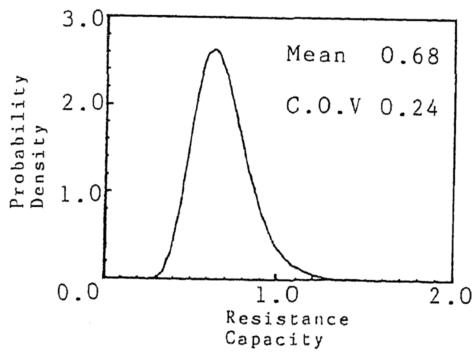


Fig.7 Probability Density Function of Resistance Capacity of Wooden Buildings

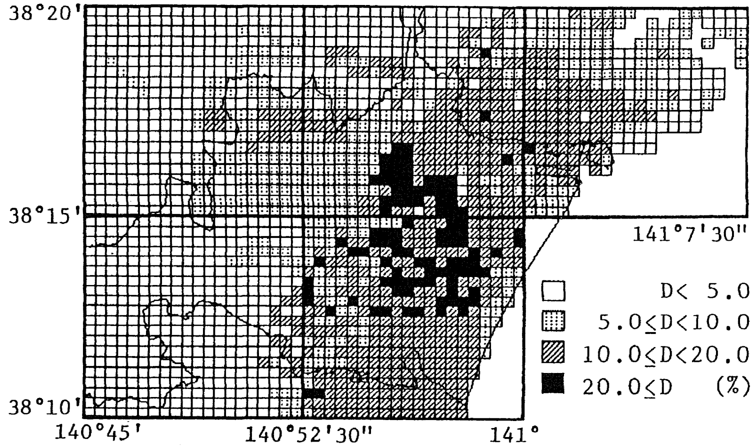
Table 1 The Values of Ductility Factor Corresponding to Level of Damage

(a) RC Buildings

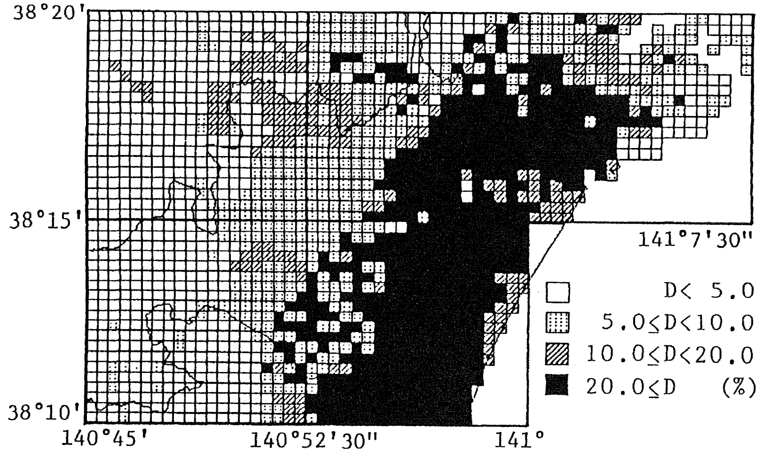
Level of Damage	Slight and above	Medium and above	Heavy and above	Collapse
Ductility Factor d	0.75	1.00	1.25	1.75

(b) Wooden Buildings

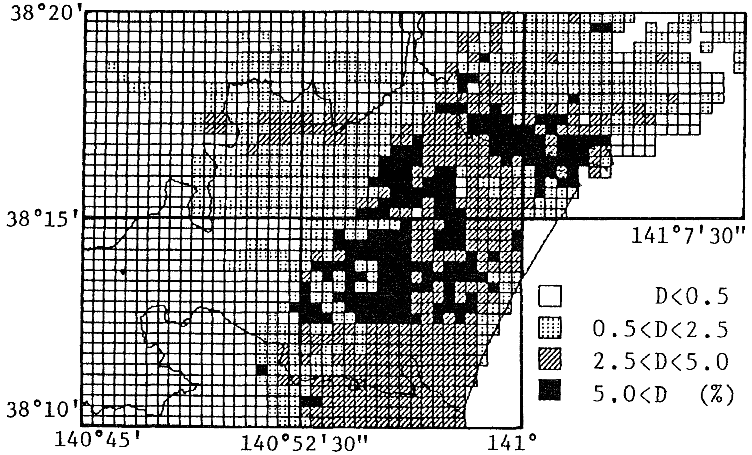
Level of Damage	Partial and above	Medium and above	Collapse
Ductility Factor d	1.00	1.74	2.36



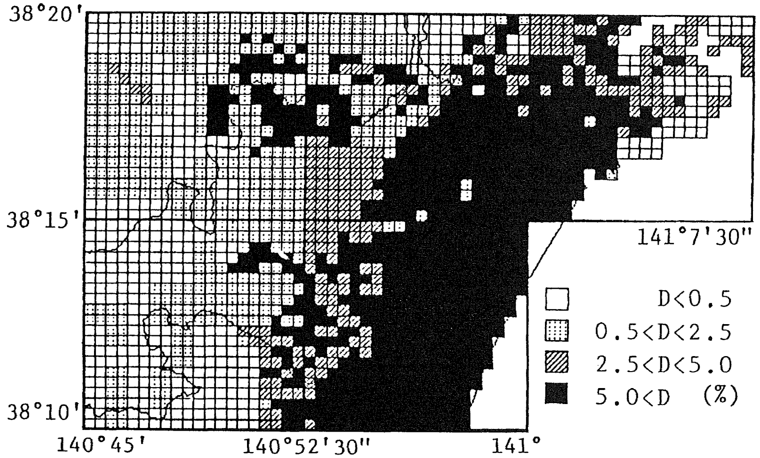
(a) RC Buildings (Medium Damage and Above)



(c) Wooden Buildings (Medium Damage and Above)



(b) RC Buildings (Collapse)



(d) Wooden Buildings (Collapse)

Fig.8 Maps of Expected Percentage of Damage in 75 years