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Method for estimating areal seismic risk potential

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ABSTRACT: A method for estimation of areal seismic risk potential in the region of Kochi Prefecture, Japan, is given. Visible outcomes are obtained through analyses of the paper, the classification map of ground condition, distribution map of seismic intensity, liquefaction potential map, tsunami risk map, slope collapse potential map and damage distribution map of wooden buildings. Based on these results, the distribution of various risk potentials can be grasped and overall estimation of regional seismic hazard can be carried out.

1 INTRODUCTION

Many administrative organizations in Japan have carried out damage estimations on future earthquakes in each area with support from researchers. In these attempts, how to evaluate many types of damages as a series of operations and how to synthesize the results of these analytical works are very important. This paper presents a method for estimation of areal seismic risk potential in the region of Kochi Prefecture, Japan. The items and flow of investigation are shown in Figure 1.

The most basic subject for damage estimation on regional scale is the survey of ground conditions which include classification of landforms and deposits and subsoil analysis. In this survey, topographical and geological maps are used for the grouping of surface layer ground, and also frequency response analysis due to many boring logs are conducted. Expected earthquake was based on a consideration of seismicity and actual damage from past earthquakes. Seismic intensity is calculated by using the relationship between intensity and distance from the fault plane of expected earthquake to each area based on the past events. The result of seismic intensity evaluation affects seriously not only the estimation of damage to buildings but also the slope collapse analysis and soil liquefaction analysis. Otherwise, tsunami risk is determined by the relationships in wave heights calculated from tsunami propagation simulation, amplification ratio based on the topographic condition of the seashore and the coastal anti-disaster facilities.

The results of the above mentioned analyses and the earthquake response analysis are gathered to estimate the damage to wooden buildings. In Japan, becase of the universal distribution of wooden houses, the estimated result of wooden building damage is essential index for seismic hazard analysis on regional scale.

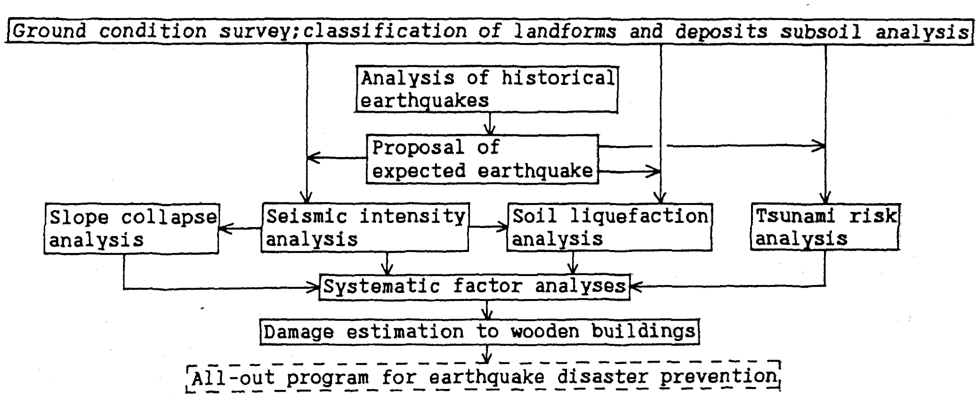

Figure 1. Total frame of comprehensive damage esitimation

2 GROUND CONDITION SURVEY AND SEISMIC INTENSITY

Kochi Prefecture suffered severe damage due to the 1946 Nankai Earthquake. Many earthquakes occured repeatedly in this area. In this paper, we supposed as same type earthquake as the 1946 Nankai Earthquake. Figure 2 shows the location of Kochi Prefecture and adopted earthquake model proposed by Ando (1982). Also, the same distant lines are shown in Figure 2, which indicates the minimum distance from fault plane to each site. We have certified appropriateness of the distance measured in above mentioned way (Miyano 1982).

Ground condition survey was conducted in two stages. First, using topographical and geological maps and 1150 boring logs, the classification map of ground condition was obtained. According to these datum, 30 ground types were identified as shown Figure 3. Next, we carried out the frequency response analysis due to the SH-wave multiple reflection theory of stratum by using 30 ground type models. This is one way of dynamic analysis of ground condition for zoning.

As a result of this analysis, reclassification of ground condition was conducted by means of the value(Rmax) and the period(fp) of the maximum response magnification factor. 30 ground types were arranged into 6 ones(A~F) as follows.

Ground type A: $1<fp\leq 2$(Hz) and $10\leq Rmax<15$
Ground model No.6,14,20,29

Ground type B: $1<fp\leq 2$(Hz) and $5\leq Rmax<10$
Ground model No.15,17,24,25,26,27

Ground type C: $2<fp\leq 4$(Hz) and $10\leq Rmax$, $4<fp$ and $15\leq Rmax$
Ground model No.1,3,5,8,9,11,30

Ground type D: $2<fp\leq 4$ and $5\leq Rmax<10$ (inclding the case that second peak(R2) is $10\leq R2<15$), $4<fp$ and $5<Rmax$
Ground model No.2,4,7,10,12,13,19,23,28

Ground type E: $4<fp$ and $5\leq Rmax<10$
Ground model No.16,18,21,22

Ground type F: Mountainland

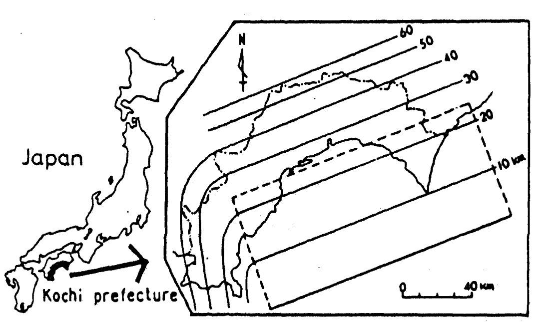

Figure 2. Site location, fault model and distance from fault plane

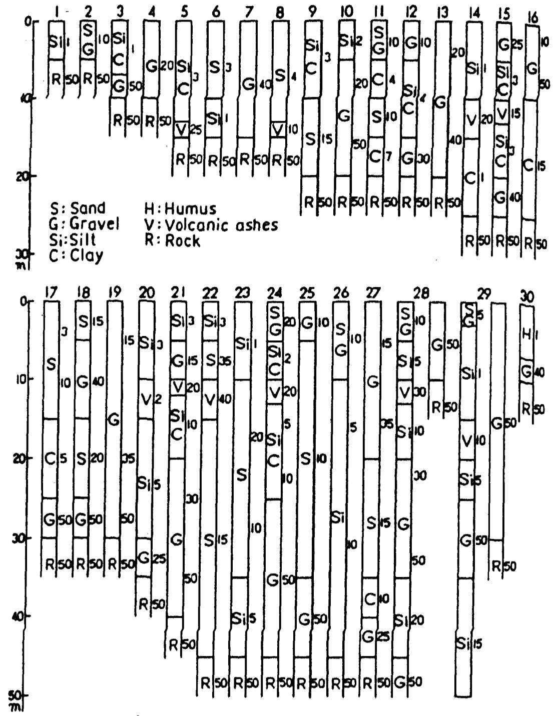

Figure 3. Ground types

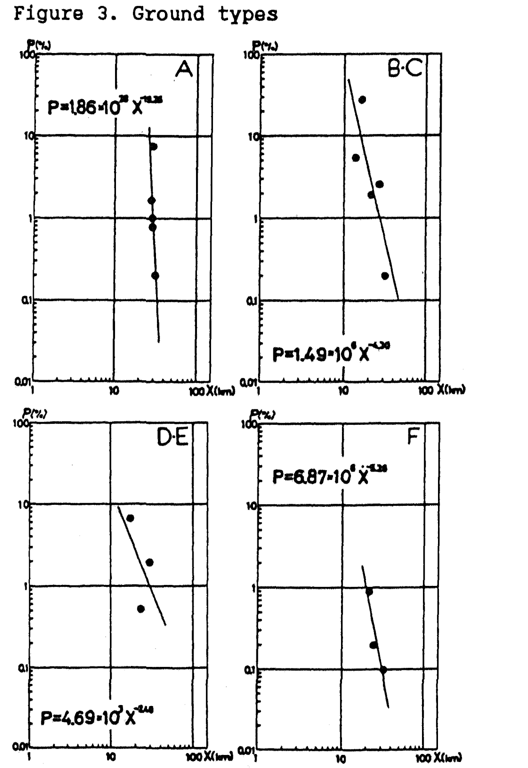

Figure 4. Relationship between wooden houses total collapse ratio(P) and distance from fault plane(X)

On the other hand, the relationship between wooden houses total collapse ratio(P) due to 1946 Nankai Earthquake and distance(X) from fault plane are obtained on each ground type as Figure 4. Also, we showed the relationship between wooden houses total collapse ratio(P) and seismic intensity(K) estimated from the overturning of tombstones at the Great Kanto Earthquake as Figure 5 (Miyano 1982). K value can be changed to acceleration(Acc) by multiplying 980 gal.

According to these results, the P-X relation on each ground type is converted to the Acc-X relation, and we can get the distribution of ground surface acceleration values as shown in Figure 6.

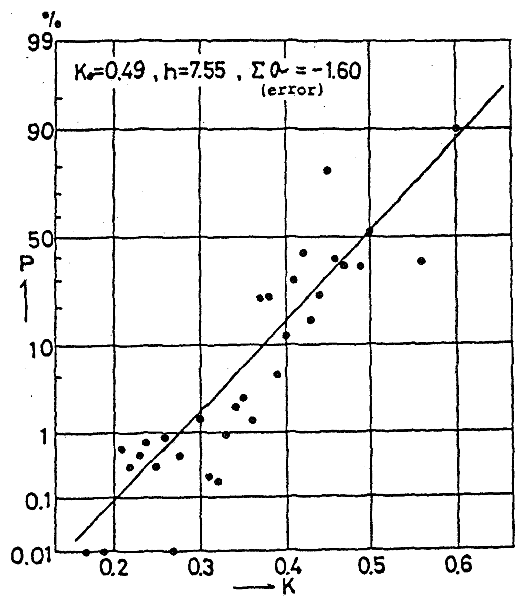

Figure 5. Relationship between wooden houses total collapsed ratio(P) and seismic intensity(K)

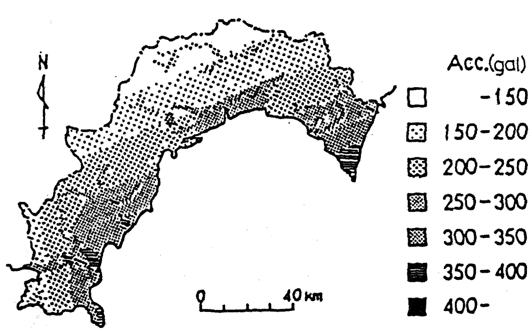

Figure 6. Estimated distribution of ground surface acceleration

3 SLOPE COLLAPSE ANALYSIS

Slope collapse is divided into three classes by its scale;total amount of collapse 10^7 ~ 10^9 m^3 is called huge collapse, 10^4~10^6 m^3 is called land slide collpse and 10^0~10^3 m^3 is called ground surface slide collapse. We treated, in this paper, the last one because of the actual condition in Kochi Prefecture. In the past study (Yamaguchi & Kawabe 1982), it was pointed out that slope collapse occured in the area where acceleration was over 200 gal at some earthquakes. Therefore, the estimated acceleration value is one of the most important factors in the slope collapse analysis.

Otherwise, the gradient of slope has much influence on the slope collapse (Sorimachi 1978). After these considerations, we conducted the relationship between acceleration and number of slope collapse places (Table 1)(Matsuda 1990). The distribution of estimated slope collapse places number is shown as Figure 7.

Table 1. Number of slope collapse places per 1 km^2

Acceleration	Number of slope collapse
Over 400 gal	8
350~400 gal	6
300~350 gal	4
250~300 gal	2
200~250 gal	1
Under 200 gal	0.2

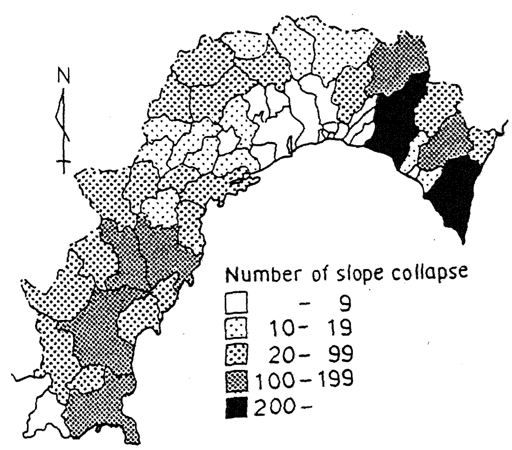

Figure 7. Distribution of slope collapse

4 TSUNAMI RISK ANALYSIS

We carried out numerical experiments based on the finite difference method (Lopez & Maki 1972) to calculate tsunami wave height at the seashore of Kochi Prefecture. Observed tsunami wave height at 1946 Nankai Earthquake was refferred to on this occasion. Calculated arrival time of the wave fitted in that of 1946 event (Figure 8). According to the calculated value, the topographical amplify effect and the coastal anti-disaster facilities, we investigated the housing damage by tsunami. Consequently, it was estimated that total collapsed or washed away houses number was 2018 at high tide in the whole area of Kochi Prefecture, and 245 at low tide.

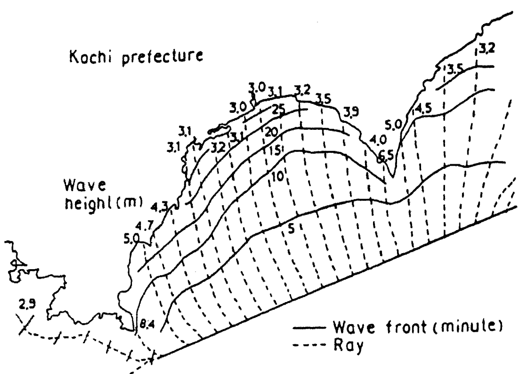

Figure 8. Calculated result of tsunami wave propagation

5 DAMAGE ESTIMATION TO WOODEN BUILDINGS

In Japan, many houses are built of wood and they are distributed universally. Therefore, damage estimation to wooden buildings is essential index for seismic hazard analysis on regional scale. We conducted the seismic response analysis of ground-building models. The procedures are showed as follows.

1. Nonlinear seismic response analysis on 30 ground types. We got input earthquake waves for building models.
2. Examinations of building models.
3. Elasto-plastic seismic response analysis of wooden building models. We calculated the maximum displacement response.
4. Judgment of vibration damage due to maximum displacement.

Next, we studied about soil liquefaction analysis. The liquefiable areas were determined by the FL value (TMG 1987). Total collapse ratio of wooden building in the liquefied areas was estimated 10.5 % due to the investigation result of 1946 Niigata Earthquake (Mochizuki & Miyano 1977) and 1983 Nihonkai-chubu Earthquake (Mochizuki, Enomoto & Matsuda 1983).

6 CONCLUSIONS

The method for estimating areal seismic risk potential in Kochi Prefecture was presented. Some visible outcomes were obtained through analyses of this paper, distribution map of

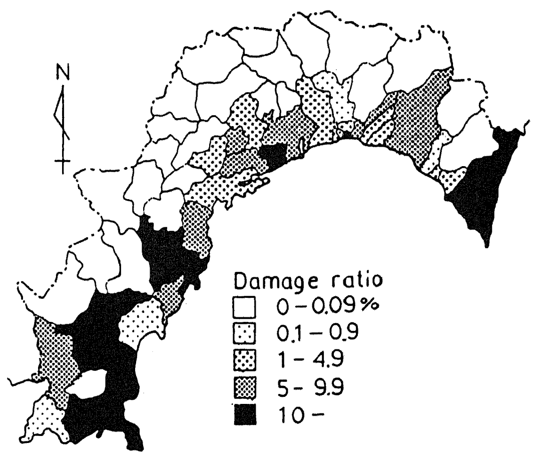

Figure 9. Damage distribution of wooden buildings

seismic intensity, tsunami risk map, slope collapse potential map and damage distribution map of wooden buildings (Figure 9). In figure 9, damage of wooden buildings according to ground motion, soil liquefaction and tsunami wave were synthesized.

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