AN ATTEMPT OF MICROZONATION IN AND AROUND SENDAI CITY

by

Yoshihiro SUGIMURA[I]

SUMMARY

Process of evaluating dynamic characteristics of ground and making microzoning maps is shown and some results derived from this process are discussed. Discussion materials are originating from the research work on damage by 1978 Off-Miyagi Prefecture earthquake on 12 June and ground survey data in and around Sendai City, Japan. A mesh method based on latitude and longitude is used for preparing microzoning maps. Predominant period of ground, empirical classification of geographical and geotechnical condition and damage ratio of wooden houses caused by collapse of retaining wall and vibration effects are plotted on such maps and compared to each other.

INTRODUCTION

The aspects of geotechnical and structural damage in and around Sendai City during Off-Miyagi Prefecture earthquake on 12 June in 1978 (M=7.4) show the regional difference due to the effect of each site condition. This fact suggests the significance and necessity of microzonation of this area, espetially for relation between dynamic characteristics of surface soil layers and earthquake damage. In this paper, therefore, geotechnical materials such as about nine hundred past boring records with standard penetration test results are collected and used as original data to evaluate dynamic characteristics of ground. On the other hand, the distribution of damaged wooden houses caused by collapse of artificial fill ground and vibrational effects is selected as the representative damage type by the earthquake which shows directly the effect of each site condition.

ARRANGEMENT OF BORING DATA AND OUTLINE OF GROUND OF SENDAI CITY

A mesh with thirty seconds in latitude and longitude, respectively, is used as a fundamental unit in arrangement of boring data. Fig. 1 shows the meshed map of Sendai City with location of each boring survey. Partitioning length per mesh is approximately regarded as 740m in east-west direction and 940m in south-west direction within this area, although the length on longitude is changing with latitude. Contour lines in Fig. 1 show the distribution of depth of tertiary bedrock, and in geotechnical sense, this map may be divided broadly into two areas, west side area and east side area which locate from the boundary line so-called Nagamachi-Rifu fault (not active) laying from south-west part to north-east part. West side area consists of mainly hills and terraces which are generally regarded as stable hard ground from viewpoint of earthquake-proof performance. There scatter at places, however, areas such as steep slopes and artificial fill ground, which are regarded as not always good concerning earthquake-proof performance. East side area consists of flood plain, marine soil deposits, back marsh, peat, sand dune and so on, which are regarded as mainly alluvial soft ground.

I Head of Geotechnical Engineering Division, Structural Department, Building Research Institute, Ministry of Construction, Japan

SIMPLIFICATION OF BORING DATA AND DYNAMIC ANALYSIS OF GROUND

In order to clarify the dynamic characteristics of soil deposits at each site, it is convenient to simplify the original boring data at the site. Y. Ohsaki and O. Sakaguchi (1973) showed the simplification method by using the concept of soil type factor and N-values in standard penetration tests. The extended method of Ohsaki's method is uded in this paper, i.e., the new soil type factors are added to gravel-sand, sand-gravel, gravel and rock, respectively, as shown in Table 1. Corresponding to this change, thresholds for making boundaries by soil type are changed from the original value 0.666 to 0.45 and 0.25 for the ranges of soil type factors zero to 1 and 1 to 2, respectively. Table 2 shows adjacent sublayers regarded as a single layer to object layer, arranged in the way mentioned above. Simplification by N-value is used by the same process of the original method. Finally, boundaries are made in view of both simplification by soil type and by N-value. Simplified soil type factor is determined by taking average value weighted thickness of each layer included in a new simplified layer, and it's soil type is determined by taking account of boundary values shown in Table 1. Simplified N-value is determined by taking geometric average of original values included in the new layer in the range from 1 to 99.

Table 1 Soil type factor

Soil Type	Symbol	Representative Values	Boundary Values	Simplified Soil Type
Clay	CC	0	1/6	CC
Sandy Clay	SC	1/3	1/2	SC
Clayey Sand	CS	2/3	5/6	CS
Sand	SS	1		SS
Gravel Sand	GS	7/6	5/4	SS
Sand Gravel	SG	4/3	17/12	SG
Gravel	GG	3/2	7/4	GG
Rock	RR	2		RR

Table 2 Soil type regarded as single layer

Objective Layer	Adjacent Sublayers
CC	SC
SC	CC, CS
CS	SC, SS
SS	CS, GS
GS	SS, SG
SG	GS, GG
GG	SG
RR	--

Unit weight of simplified layer is interpolated by using new soil type factor and the straight line relation - 1.5 t/m^3 for pure clay (STF=0.0) and 2.2 t/m^3 for rock (STF=2.0). Initial shear modulus in tons/qs. of simplified layer is estimated regardless of soil type and on the average by the expression, $G=1200N^{0.8}$, which is proposed in the original method. Initial damping ratio is assumed at 2% for every layer. Based on these data, response function between ground surface and tertiary bedrock at each boring point is computed by one-dimensional nonlinear amplification theory of soil deposits. Only predominant period of ground, however, is used in this paper as the first element of dynamic characteristics of soil deposits.

MICROZONING MAPS BY VARIOUS METHOD

MICROZONING BY GEOGRAPHICAL AND GEOLOGICAL CONDITION Empirical classification is used as a microzoning method for geographical and geological condition of surface layer in it's nature state. From the viewpoint of earthquake-proof performance, the four graded groups are arranged in turn from good condition to poor condition as follows: (1) 1st group - hills, (2) 2nd group - terrace, gravel flood plain, (2) 3rd group - sand flood plain, natural levee, beach ridge, sand dune, (4) 4th group - reclamined land, back marsh, old river bed, peat, marine soil deposits. Fig. 2 shows the result of the judgement by the ratio of area occupancy of each group in every mesh. Half length divided meshes are used concerning the meshes in which the judgement is extremely difficult. It can be seen from this figure that the two areas (group 1, 2) and (group 3, 4) are divided on the whole at the boundary of Nagamachi-Rifu fault, which is already mentioned before.

MICROZONING BY PREDOMINANT PERIOD OF GROUND Predominant periods of ground are selected from computing results of response functions at all boring points and classified into four groups as follows: (1) 1st group - rock and $T \leq 0.15$ (sec), (2) 2nd group - $0.15 < T \leq 0.35$ (sec), (3) 3rd group - $0.35 < T \leq 0.65$ (sec) and (4) 4th group - $0.65 < T$ (sec). Result of this classification is shown in Fig. 3. Half length divided meshes are used at need for the area which includes plural groups of predominant periods. As for the meshes without boring data, classification judgement is made by taking account of the depth of tertiary rock at the site and condition of circumference. Fig. 3 leads to the followings: (1) shorter period ground (group 1 and 2) and longer period ground (group 3 and 4) are clearly divided along Nagamachi-Rifu fault, (2) the tendency of growing longer of period by effect of artificial filling is recognized at some places in northern and southern hills, (3) there are two distinct areas of very long period ground (group 4) corresponding to the basins of the river Nanakitada in northern part and the river Natori in southern part, respectively. This fact is closely connected with the depth of tertiary bedrock.

MICROZONING BY DAMAGE RATIO OF WOODEN HOUSES Based on research work on the distribution of earthquake damage, the damaged wooden houses are selected as the most available data for microzonation and divided into two groups caused mainly (1) by damage of artificial fill ground such as collapse of retaining wall and (2) by vibrational effects. The ratio of numbers of damaged houses to the total ones is calculated in each mesh as shown in Fig. 4 and Fig. 5. As for the cause of damage of artificial fill ground, there exist clearly two areas, northern hill and southern hill which have been rapidly developed in these two decades. On the other hand, the high damage ratios by the cause of vibrational effects concentrate to the eastern part from the Nagamachi-Rifu fault, though the tendency of scattering of damaged areas to some extent is recognized in the western part.

CONCLUSION

The followings are clarified through discussions above: (1) The predominant period of ground is corresponding to the geographical and/or geological condition empirically judged, i.e., the longer is the former, the worse is the latter. (2) Heavily damaged areas caused by vibrational effects are generally corresponding to those of comparatively long period ground. (3) Heavily damaged areas caused by collapse of retaining walls are concentrated on the areas of worse geographical and/or geological condition even if the predominant period of which is judged and classified into the group of good condition.

REFERENCE

Ohsaki, Y. and Sakaguchi, O. (1973), Major types of soil deposits in urban areas in Japan, Soils and Foundations, Vol. 13, No. 2, pp. 49-65

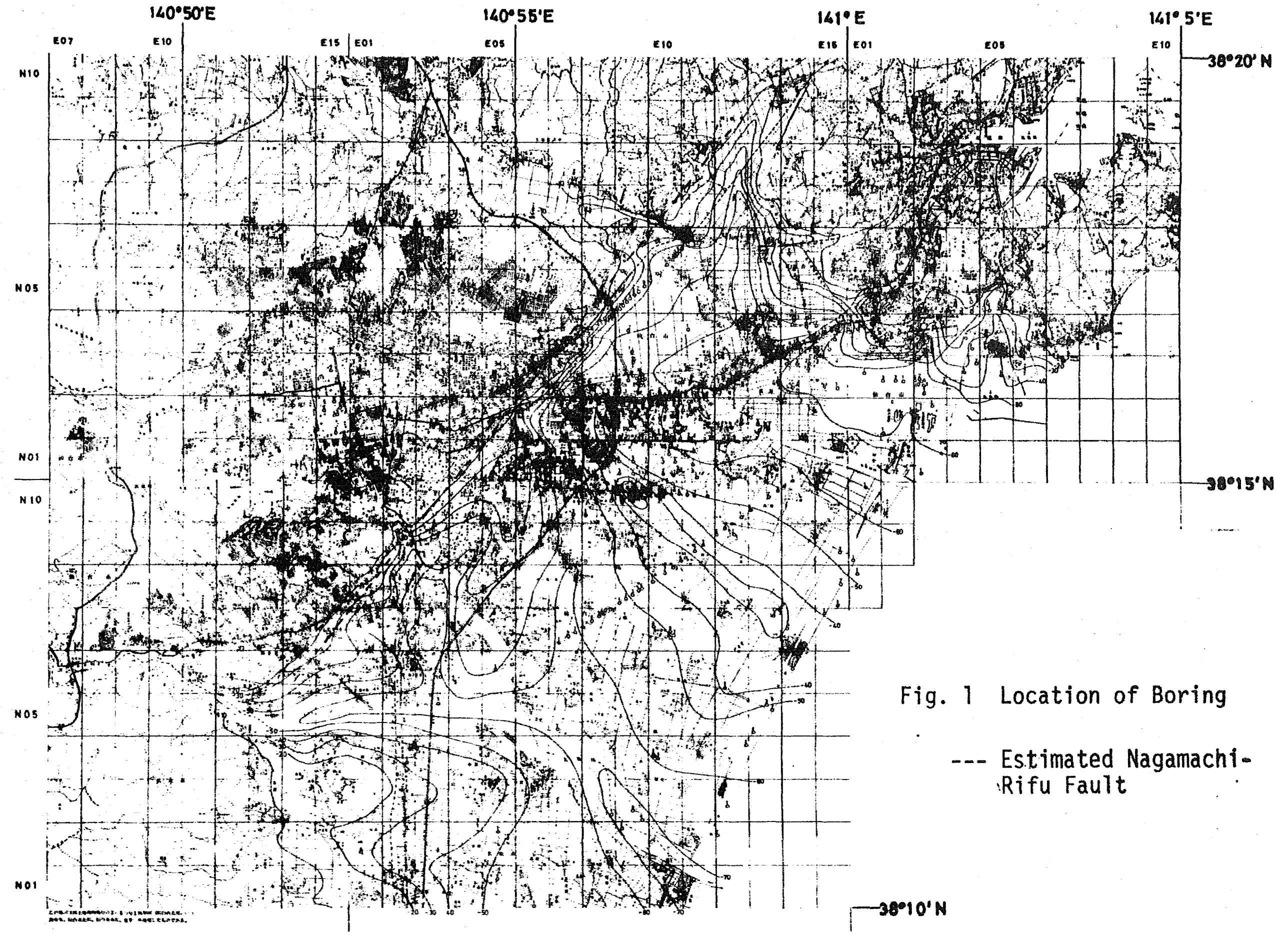

Fig. 1 Location of Boring

--- Estimated Nagamachi-Rifu Fault

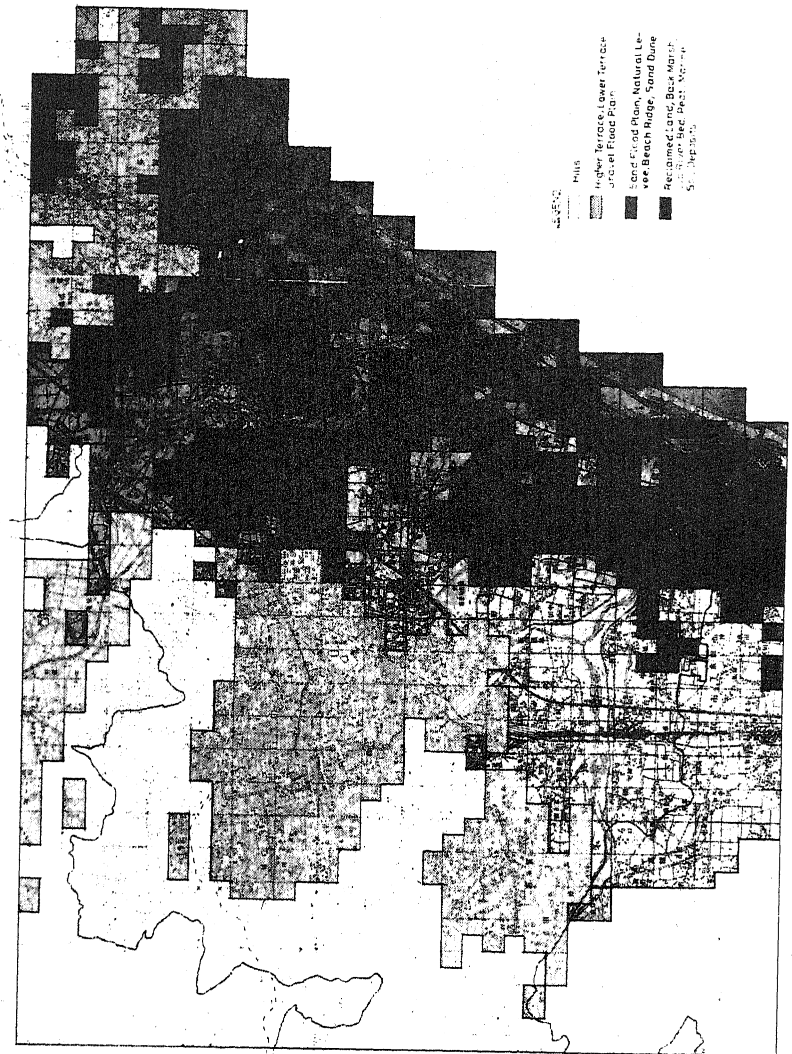

Fig. 2 Microzoning by Subsurface Soil Condition

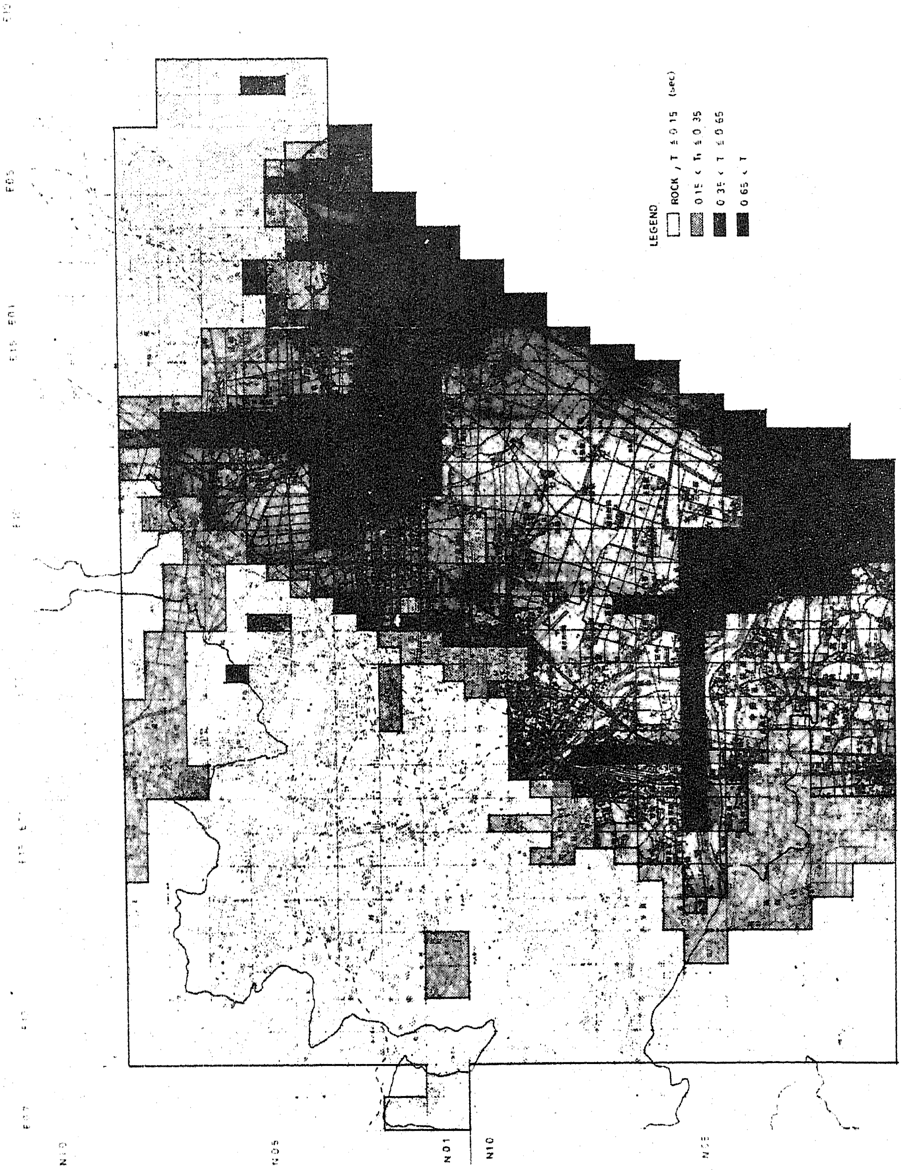

Fig. 3 Microzoning by Predominant Period of Ground

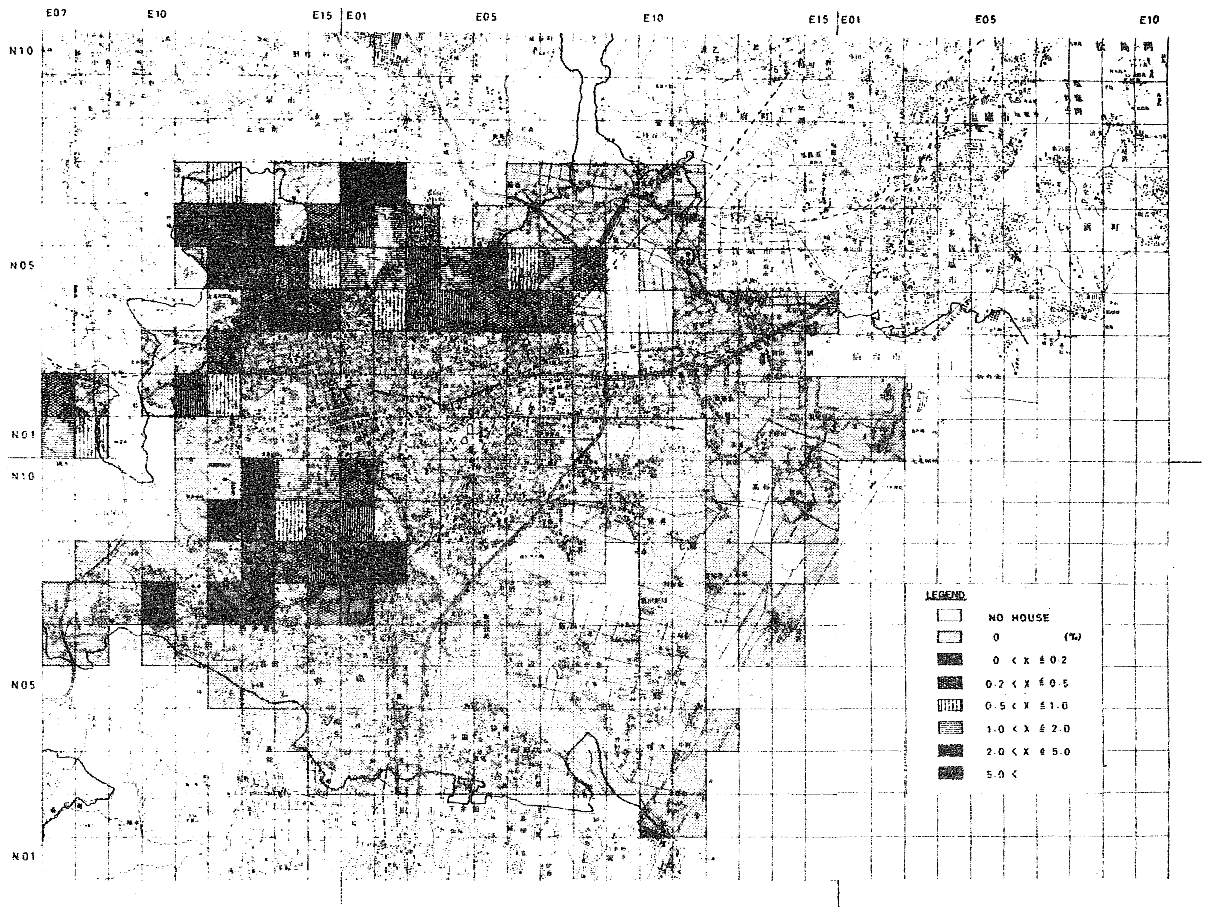

Fig. 4 Microzoning by Damage Ratio of Wooden Houses Caused by Damage of Artificial Fill

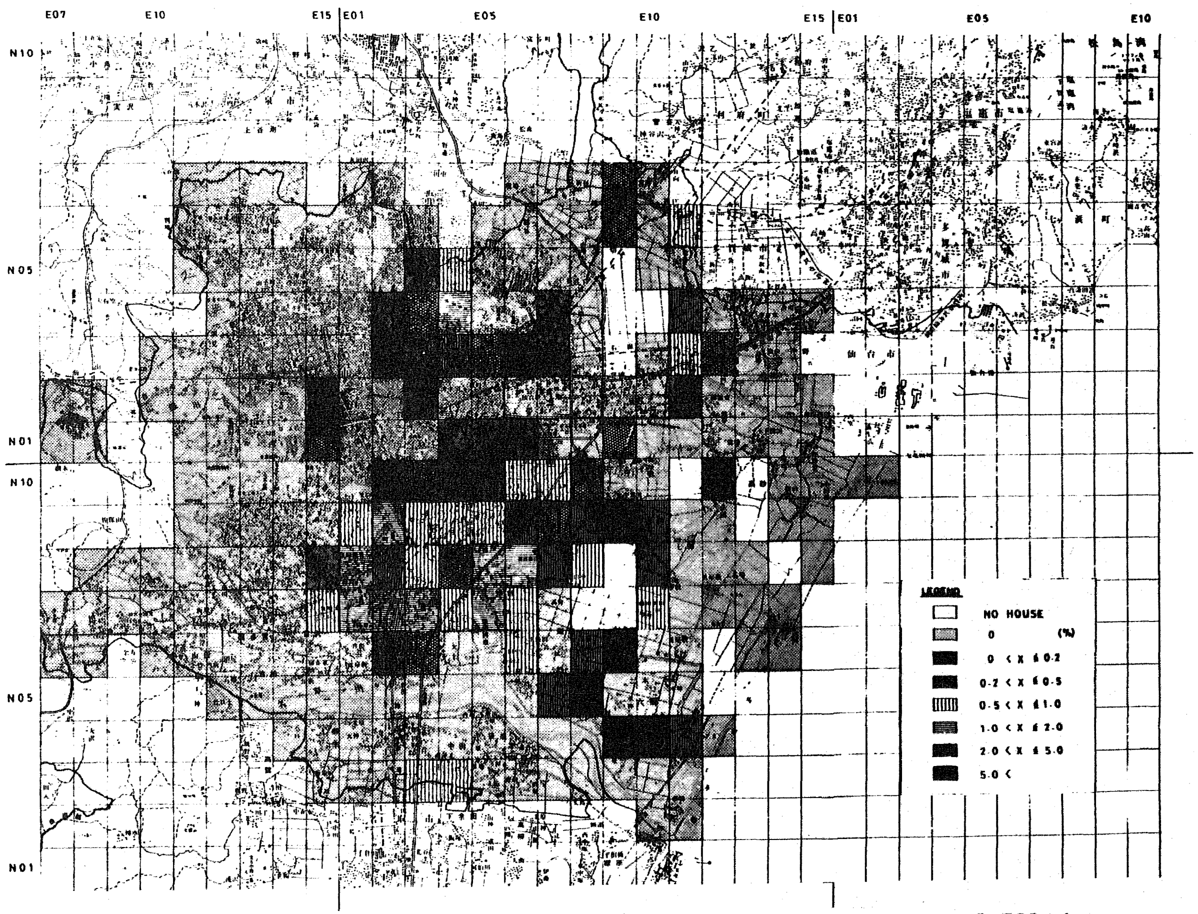

Fig. 5 Microzoning by Damage Ratio of Wooden Houses Caused by Vibrational Effects