

Earthquake damages and characteristics of microtremors at large-scale artificial housing sites

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ABSTRACT: The detailed investigation by a house-to-house visit on the earthquake damages and the measurement of microtremors are carried out at two large-scale artificial housing sites. The extent of the earthquake damages corresponds to the soil condition of the fills at each housing site. The amplitudes of microtremors on the fill at damaged housing site are large compared to those at less damaged housing site. The largest cause for the serious damage of houses is insufficient compaction of the fill. Microtremor is worth using as the method of judgement for the damage potential in large-scale artificial housing sites.

1 INTRODUCTION

A lot of recent housing sites in the suburbs have been constructed by filling valleys with soil. These constructed housing sites in the Sendai area were damaged by the 1978 Miyagiken-oki Earthquake. However, there were differences in the extent of damage according to the housing sites. In order to clarify the cause, we investigated the real state of earthquake damages, soil condition and microtremor characteristics at two large-scale housing sites, Nankohdai and Tsurugaya. Both housing sites are adjacent to each other, but Nankohdai housing site was damaged seriously by the earthquake in comparison with Tsurugaya housing site.

2 EARTHQUAKE DAMAGES

Both Nankohdai and Tsurugaya housing sites had been constructed by cutting of the rugged hills and filling the valleys. We investigated earthquake damages by a house-to-house visit of 3364 houses in Nankohdai, and 1160 houses in Tsurugaya. Fig.1 and Fig.2 show the positions of damaged houses in Nankohdai and Tsurugaya respectively. As is obvious from the figures, Nankohdai was damaged seriously in comparison with Tsurugaya. The large majority of heavy damages are located at nearby boundaries between the earth cut and the fill. Table 1 shows the relation between the thickness of the fill and the ratio of house damage. The ratios of slight damage are almost same without relation with the thickness of the fill, but the ratios of complete collapse and half collapse have a maximum for the thickness of 0~5m.

Fig.3 shows the locations of cracks at the

ground surface investigated in Nankohdai housing site. About ten years after since the earthquake occurred, this house-to-house visit investigation had been carried out. So it is possible that we overlooked some cracks. However, it is considered that the impressive cracks were not overlooked. The large cracks are located at the nearby boundaries between the earth cut and the fill, and are almost parallel to the boundary. It can be considered that these large cracks were caused by the slumping of the fill. The locations of heavy damages correspond nearly with the locations of large cracks. It is considered that the large majority of heavy damages were caused by these large cracks of ground.

Table 2 shows the ratio of house collapse on the cut ground and on the fill separately in both housing sites. A large difference in the collapse ratio between Nankohdai and Tsurugaya is recognized.

Table 3 shows the relation between the kind of the material and the damage ratio of water pipe. The hard vinyl chloride pipe is apt to be damaged. In case of the ductile cast iron pipe, the damage ratio shows high resistance against earthquakes.

3 SOIL CONDITION OF THE FILL

From the difference of earthquake damage in two housing sites, it can be estimated that there are some differences in the soil condition of the fill. Fig.4 and 5 show the results of the standard penetration tests for the fill in Nankohdai and Tsurugaya respectively. In Nankohdai, the N-value are small generally in comparison with Tsurugaya, and the N-value near the bottom of the

fill are smaller than those near the surface of the ground. These indicate that the fills were constructed without removal of the humus soil, and also without sufficient compaction of the soil. The soils in Nankohdai have many sand fraction more than the soils in Tsurugaya, and the groundwater level is high more than it in Tsurugaya. These N-value, soil property and groundwater level indicate the possibility of liquefaction of the ground at the earthquake in Nankohdai.

4 MICROTREMORS CHARACTERISTICS

Microtremors were measured at midnight in both housing sites. Three components of displacement were measured simultaneously for six minutes using three transducers with a natural period of 1.0 second. The maximum amplitudes of horizontal component of microtremor in Nankohdai and Tsurugaya are plotted with the thickness of the fill in Fig.6. At the cut ground the majority of the maximum amplitudes are within the range of $0.06 \sim 0.11 \mu\text{m}$ and almost same in both housing sites. As shown in Fig.6, the maximum amplitudes in Nankohdai are scattered widely, but are more proportional to the thickness of the fill in comparison with Tsurugaya. It can be considered that there are large dif-

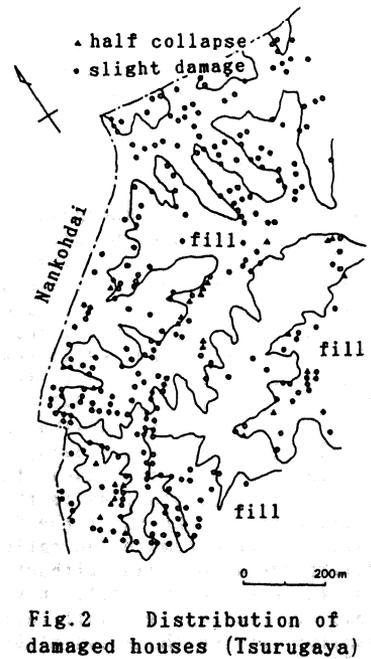
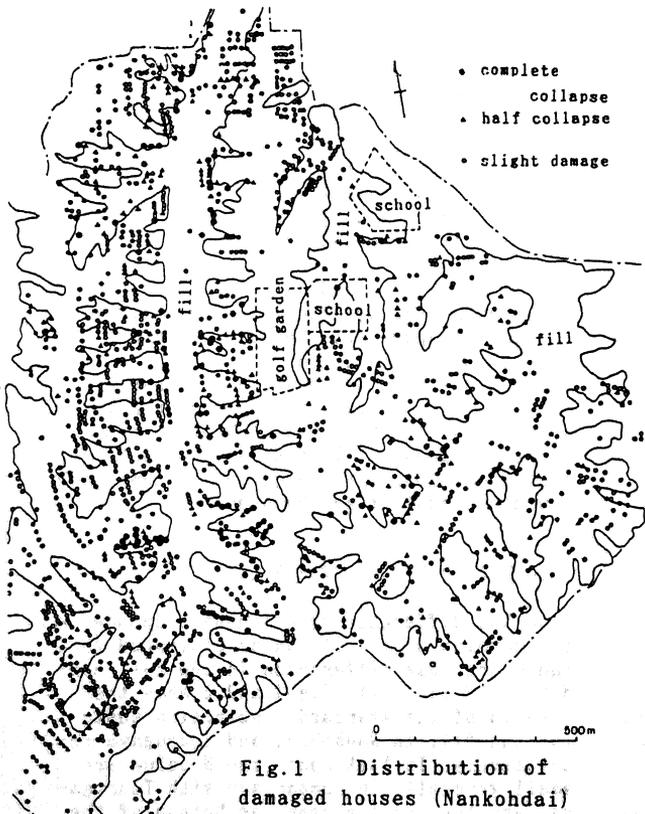
ferences in the shear modulus between the cut ground and the fill in Nankohdai.

Fig.7 shows the relation between the predominant period and the maximum amplitude. The envelop curve has a peak at the period of about 0.36 second. Fig.8 shows the change of natural period of the building before and after the 1978 Miyagiken-oki Earthquake, and also shows the grade of the damage¹⁾. The building which natural period was about 0.36 second had been damaged severely. In Nankohdai too, the resonance phenomena might be occurred at the 1978 Miyagiken-oki Earthquake

5 CONCLUSIONS

The largest cause for the severe damages in Nankohdai housing site was the lack of compaction for the fill. In addition to this cause, the fill had been constructed without removal of the humus soil, and the drain in the housing site was insufficient on the whole.

In Nankohdai damaged severely, there were large difference in the shear modulus between the cut ground and the fill. We can detect the difference in the shear modulus by the measurement of microtremors. This measurement becomes a very useful method of judgement for the damage potential in large-scale artificial housing sites.



REFERENCE

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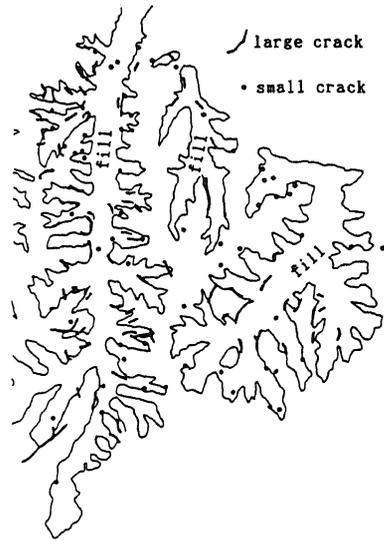


Fig. 3 Distribution of cracks (Nankohdai)

Table 1 Relation between the thickness of the fill and the ratio of house damage

(Nankohdai housing site)	cut ground	thickness of fill (m)					total
		0~ 5	5~10	10~15	15~20	20~	
complete collapse (%)	3.2	10.6	4.2	0.7	0.9	0	4.4
half collapse (%)	6.7	14.8	9.7	4.7	7.1	0	8.5
slight damage (%)	46.0	43.1	45.5	36.3	38.9	31.3	43.7
no damage (%)	44.1	31.5	40.6	58.3	53.1	68.7	43.4
investigation number	1575	669	547	444	113	16	3364

Table 2 Ratio of house collapse on the cut ground and the fill

(a) Nankohdai				(b) Tsurugaya			
	cut	fill	total		cut	fill	total
complete collapse (%)	3.2	5.5	4.4	complete collapse (%)	0	0	0
half collapse (%)	6.4	10.1	8.5	half collapse (%)	0.5	4.5	2.6
slight damage (%)	46.0	41.8	43.7	slight damage (%)	19.5	29.3	24.6
collapse ratio (%)	6.5	10.5	8.7	collapse ratio (%)	0.3	2.2	1.3

Table 3 Relation between the kind of material and the damage ratio of water pipe in cut ground and fill, in Nankohdai housing site

material of pipe	total length (km)	number of damage			damage ratio (number/km)		
		cut	fill	total	cut	fill	total
carbon steel	7.0	38	46	84	8.5	18.0	11.9
hard vinyl chloride	1.4	6	19	25	9.8	24.5	18.0
asbestos-cement	24.9	43	101	144	3.5	8.0	5.8
ductile cast iron	0.8	0	0	0	0	0	0

Depth	No.1	No.2	No.3	No.4	No.5	No.6
	N-value	N-value	N-value	N-value	N-value	N-value
	30	30	30	30	30	30
5						
10						
mean	10	7	4	4	4	6

Fig. 4 N-value of the fill (Nankohdai)

Depth	No.1	No.2	No.3	No.4	No.5	No.7
	N-value	N-value	N-value	N-value	N-value	N-value
	30	30	30	30	30	30
5						
10						
mean	9	12	20	8	13	8

Fig. 5 N-value of the fill (Tsurugaya)

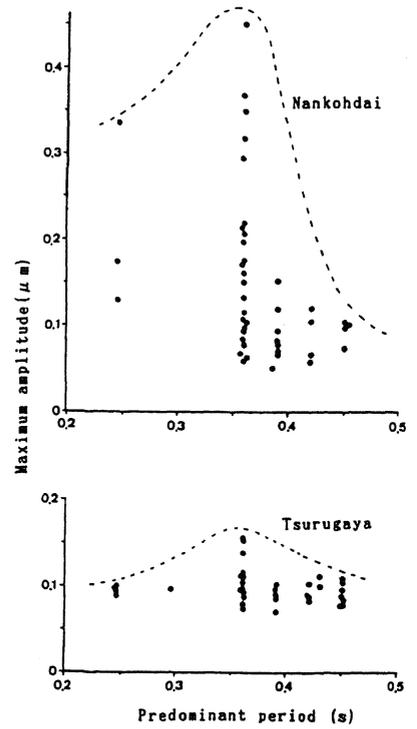


Fig. 7 Relation between the predominant period and the maximum amplitude

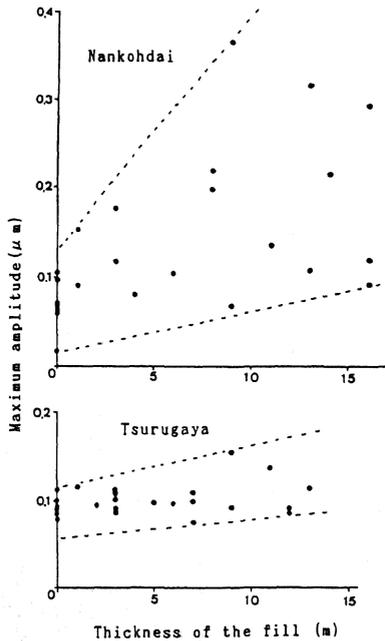


Fig. 6 Relation between the maximum amplitude of microtremors and the thickness of the fill

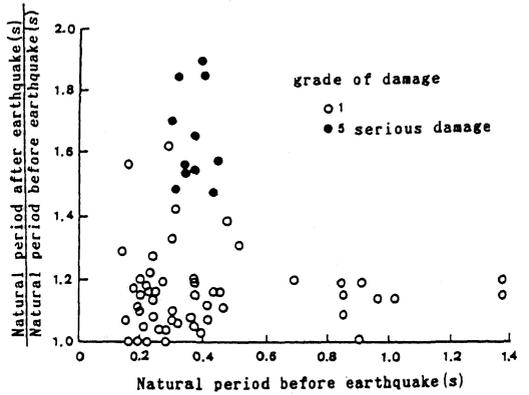


Fig. 8 Change of natural period of the building before and after earthquake and the grade of damage