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17. *Relation between Earthquake Damage and Nature of the Ground. II.*

(Case of Nagaoka Earthquake)

By Kiyoshi KANAI and Toshizo MORISHITA,
Earthquake Research Institute.

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In order to investigate the relation of the ground conditions and the earthquake damage to the buildings, a vibration test was made on actual wooden houses standing on the area damaged by the Nagaoka Earthquake of February 2, 1961.

The magnitude of the earthquake was 5.0 and the isoseismal map is shown in Fig. 1. Data of the damage is represented in Table 1.

Vibration experiments by means of not only a vibration generator but also by microtremors were made upon four two-storied wooden dwelling houses, namely Arakawa, Hirokawa, Watanabe and Takano's dwelling houses. The former three houses and the last one, respectively, were of similar construction to the totally- and the half-destroyed houses involved in the Nagaoka Earthquake.

The constants of a vibration generator installed on the second floor

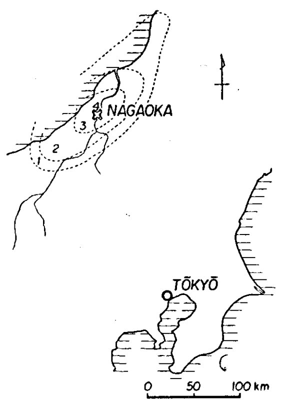

Fig. 1. Isoseismal map of the Nagaoka Earthquake of February 2, 1961.

Table 1. Data of damage from the Nagaoka Earthquake of Feb. 2, 1961. (After Y. Osawa)

Lives lost		5
Injured		30
Dwelling houses	Totally destroyed	220
	Half destroyed	465
	Slightly damaged	804
Other buildings	Totally destroyed	39
	Half destroyed	28
	Slightly damaged	17

Table 2

Vibration generator		Weight of eccentric mass	1.5 kg
		Radius of eccentric mass	8 cm
Seismograph	Period		1.0 sec
	Overall magnification	Arakawa, Hirokawa and Watanabe's d.h.	310
		Takano's d.h.	98

in each house as well as a seismograph used are represented in Table 2.

Rough sketches of the houses are shown in Figs. 2–5. The vibrational force produced by a vibration generator is represented by $f = m(4\pi^2/T^2)r$, where m=eccentric mass, r=radius, T=period. Therefore, the observed values represent the amplitudes corresponding to the appiled force which changes according to frequency. This makes analytical consideration rather complicated, so the values are converted into the amplitudes supposing that the constant force of 4.7×10^7 dyne, that is, force corresponding to the period of 0.10 sec, acts regardless of period.

The resonance curves of four houses thus obtained are shown in Figs. 6–9. In addition the period distribution curves of microtremors on the houses are shown in Figs. 10–13. The main results are summarized in Table 3.

It will be seen in Figs. 6–9 and 10–13 as well as in Table 3 that the resonance periods and the predominant periods of microtremors of the respective houses are in agreement.

Figs. 6–9 and 10–13 as well as Table 3 also tell us that the natural periods of Arakawa, Hirokawa and Watanabe's dwelling houses in which the constructions are similar to that of a totally-destroyed house differ from that of Takano's dwelling house which has similar construction to that of a half-destroyed house. On the other hand, we can see from Figs. 6–9 and Table 3 that there are slight differences of strength between the houses.

From the above considerations, and the results of the microtremor measurements in the damaged region, (the predominant periods of microtremors in the severely damaged areas seem about 0.4 sec),[1] it may be concluded that the cause of damage to houses at the time of the

1) T. TANAKA and T. MORISHITA, "Microtremor Measurement in the Disaster Area of the Nagaoka Earthquake of February 2, 1961," *Bull. Earthq. Res. Inst.*, **41** (1963), 313-327.

Nagaoka Earthquake has been ascertained mostly from the resonance-like phenomena, in other words, the synchronization of the natural period of houses with the predominant period of earthquake motions.

The conclusions of the present investigation agree well with those of the previous paper in which in up-town Tokyo having a natural period of 0.3–0.4 sec the largest damage rate occurred on 2-storied wooden houses at the time of the 1923 Kwanto Earthquake, on the contrary, in down-town Tokyo having a natural period of 0.5–0.8 sec, the damage rate on the same kinds of houses took the following relation, that is, 3−>2−>1−storied houses.[2]

In conclusion, we wish to express our sincere thanks to Dr. Y. Osawa, and Mr. H. Fujikawa for their help in arranging for the experiment on the houses and to the members of the Nagaoka City Office who gave them important help towards the experiments. The author's thanks are also due to Dr. K. Nakagawa, for his cooperation in making a vibration generator available to them.

Table 3. The periods and damping coefficients of experiment houses.

Name		Direction	Period in sec		Fraction of critical damping
House	Town		Predominant period of microtremors	Resonance period	
ARAKAWA, SHIN-ICHIRŌ	Ōbaden	girder	0.40, 0.44	0.44	0.04
		beam	0.39	0.41	0.04
HIROKAWA, MATSUICHI	Takano	girder	0.38	0.44	0.05
		beam	0.44	0.43	0.06
WATANABE, SŌZIRŌ	Jihō	girder	0.31	0.33	0.07
		beam	0.34	0.38	0.06
TAKANO, ISHIZIRŌ	Ōarato	girder	0.45	0.47	0.05
		beam	0.42	0.50	0.05

2) K. KANAI, "Semi-empirical Formula for the Seismic Characteristics of the Ground," *Bull. Earthq. Res. Inst.*, **35** (1957), 309-325, Figs. 12 and 13.

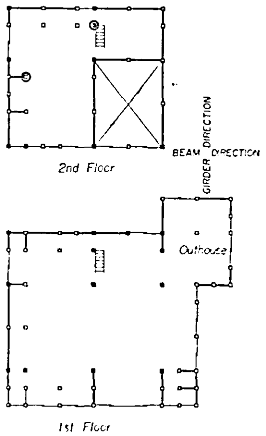

Fig. 2. Takano's dwelling house. Scale: 1/400.

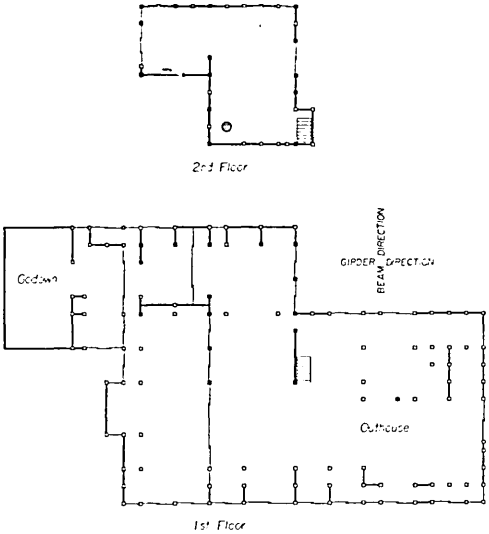

Fig. 3. Arakawa's dwelling house. Scale: 1/400.

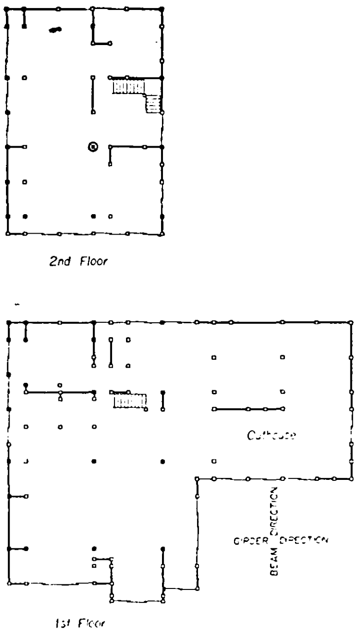

Fig. 4. Hirokawa's dwelling house. Scale: 1/400.

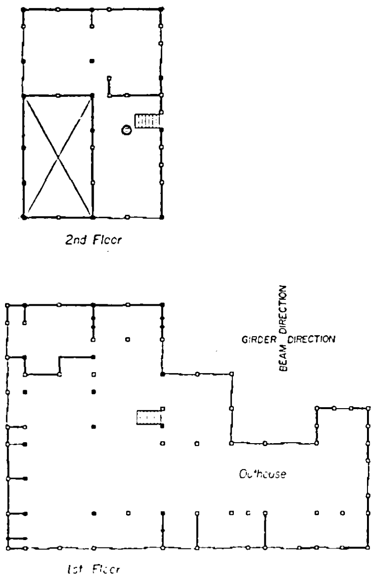

Fig. 5. Watanabe's dwelling house. Scale: 1/400

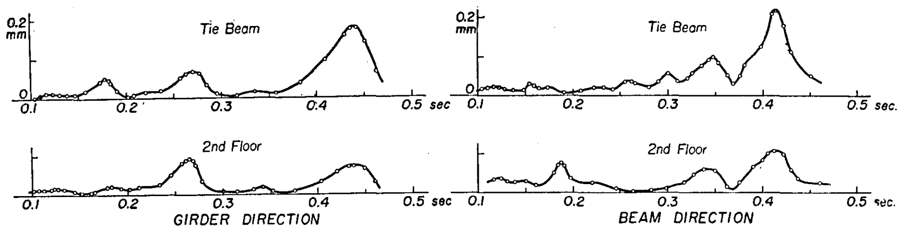

Fig. 6. Resonance curves of Arakawa's dwelling house.

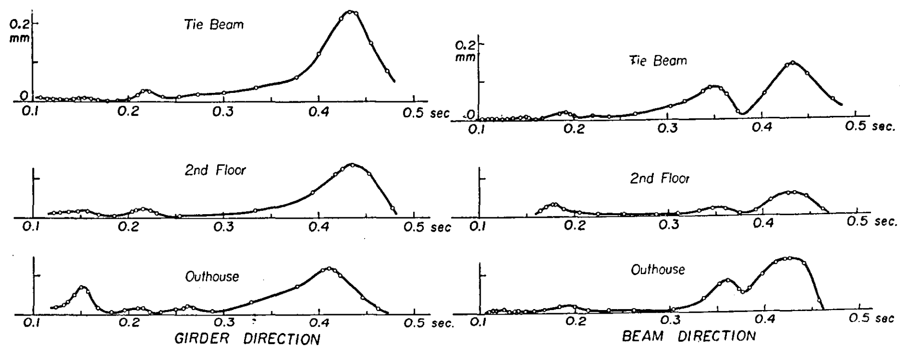

Fig. 7. Resonance curves of Hirokawa's dwelling house.

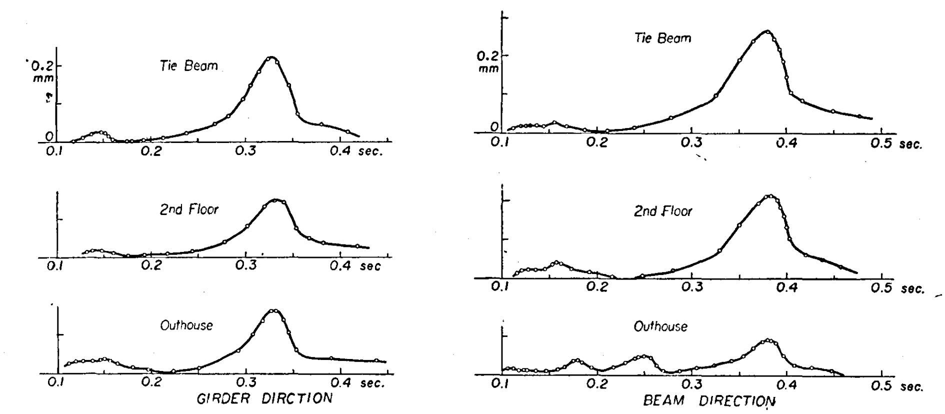

Fig. 8. Resonance curves of Watanabe's dwelling house.

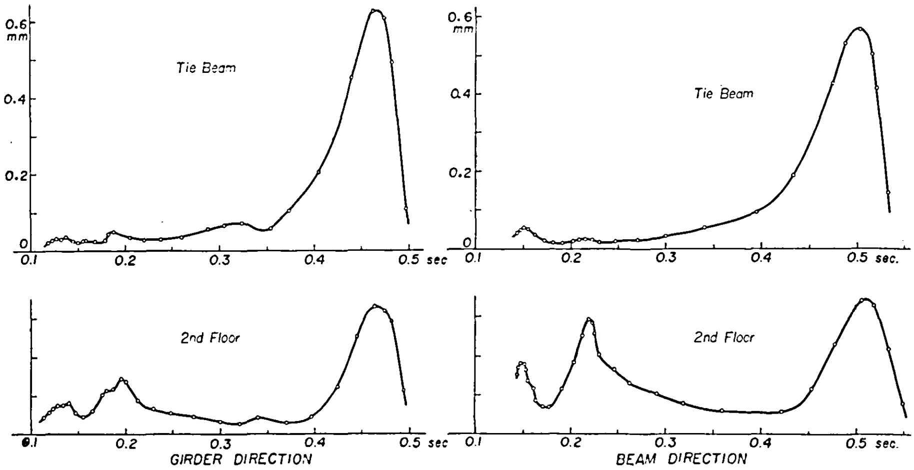

Fig. 9. Resonance curves of Takano's dwelling house.

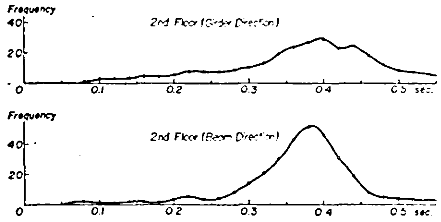

Fig. 10. Period distribution curves of microtremors on Arakawa's dwelling house.

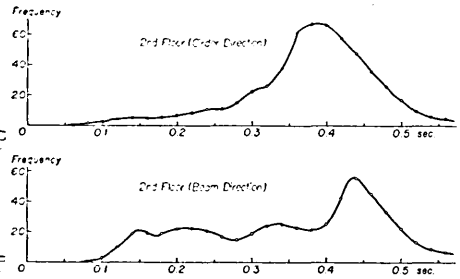

Fig. 11. Period distribution curves of microtremors on Hirokawa's dwelling house.

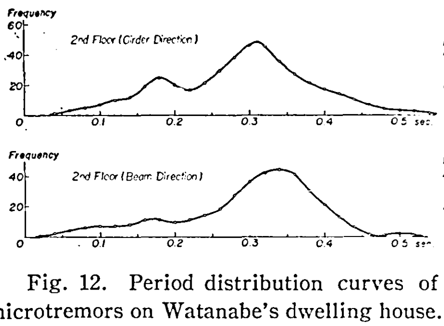

Fig. 12. Period distribution curves of microtremors on Watanabe's dwelling house.

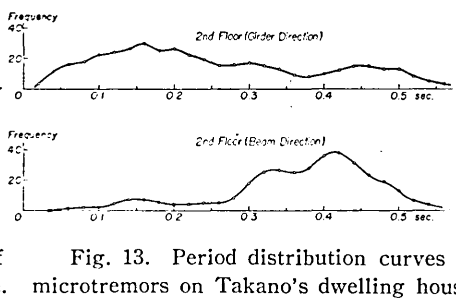

Fig. 13. Period distribution curves of microtremors on Takano's dwelling house.

17. 震害と地盤の関係 第2報

地震研究所 {金井 清
森下利三

1961 年 2 月 2 日の長岡地震で，全潰した家屋と同じ構造の 3 棟の家屋，並びに半潰した家屋と同じ構造の 1 棟の家屋について，起振機による振動試験並びに常時微動による振動測定を行い，家屋の振動性状と地盤の振動性状との関係が，いかに震害の上にあらわれるかをしらべた.

結論的に言うと，建物の固有周期が，地盤の常時微動の卓越周期に近い場合に，震害が大きいこと，言い換えると，建物の震害は，共振的作用で増大するらしいことが一層明らかになつた.