The Seismic Intensity at a Certain Dam Site

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1 Introduction and some remarks

The vibration of any system due to an earthquake may be discussed conveniently by means of spectra. Let B(T) be the spectrum of incident earthquake wave at the boundary of bed rock, and G(T) and S(T) be the vibrational characteristics of the overlying ground, and the structure, respectively. Then spectrum of actual earthquake motion at the ground surface is expressed by $B(T) \times G(T)$, while the spectral response of a structure on the ground surface in an earthquake may be obtained by $B(T) \times G(T) \times S(T)$.

Therefore, for the design of earthquake-proof construction we must have recourse to each of the spectra, above mentioned. It is now well recognized that the structure is liable to resonate with the predominant motion of the ground so that the coincidence of the two natural periods of the structure and the ground has a serious effect on the structure. Moreover, recently the general characteristics of grounds have been investigated, especially by K. Kanai, and empirical formulas for these spectral responses are derived. But the earthquakes studied in the derivation of his formulas are almost limited to weak ones. Therefore, there still remains some doubt whether the formulas are applicable to destructive earthquakes or not. Our main effort in the present study has been devoted to the clarification of this question.

Another important factor for the design of an earthquake-proof structure is to estimate the maximum seismic intensity to be expected at its construction site in the life time of the structure. As our knowledge is still too meagre to guarantee the prediction of the earthquake occurrence, we are obliged to discuss the activity in the future on the statistical point of view based on the data of past seismic activity.

With this view in mind, we estimated the maximum seismic intensity to be expected at least once in 100 years at Yokoyama, Gifu Prefecture, where a dam is being constructed. We also made some efforts to study vibrational characteristics of the ground at that dam site.

2 Comparison of the seismic intensity

Observations of seismic intensities in this area under the Meteorological Agency have been made by an observer living at Higashiyokoyama Power Station, located at a distance less than 1000 meters from Yokoyama Dam Site. We compared the seismic intensity at this point with that observed at the Gifu Meteorological Station. The former is located in a mountainous district and the latter is situated on the Plain. They are 34km apart.

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The result of this comparison is shown in Table 1.* For destructive earthquakes, the seismic intensity at Higashiyokoyama is about 1/4 times that at Gifu, while, on the contrary, for weak earthquakes the former is about 1.7 times of the latter.

3 Acceleration spectrum of an earthquake motion

Empirical formulas to estimate the acceleration spectrum of an earthquake motion are given by K. Kanai as follows 4) :

$$\alpha(T)_{T_0} = B(T) \cdot G(T)_{T_0} \qquad \cdots\cdots \qquad (1)$$

where $\alpha(T)_{T_0}$, $B(T)$ and $G(T)_{T_0}$ are the acceleration spectrum of an earthquake motion, the spectrum of the earthquake waves arriving at the bed rock, and the vibrational characteristics of the ground overlying the bed rock, respectively. Suffix T_0 shows the predominant period of the ground while T denotes an arbitrary period to which we are concerned.

First, Kanai expressed B(T) as follows:

$$B(T) = C(M,\Delta)\ T^{-1}, \qquad \cdots\cdots \qquad (2)$$

for $T \leqq Tm$, which is empirically given by

$$\log Tm = 0.39\ M - 1.70 \qquad \cdots\cdots \qquad (2').$$

The meaning of the equation (2) is that the velocity spectrum of the earthquake wave arriving at the bed rock is constant upto the maximum period Tm corresponding to the maximum value of the displacement spectrum of the earthquake wave. In the above equations M shows the magnitude of the earthquake while Δ is the distance from the epicenter to the observing point.

Next $G(T)_{T_0}$ will be explained. Theoretically speaking, as Sezawa and Kanai have shown, there exist many high harmonics in the vibration of the stratified ground. Kanai took only the fundamental mode into consideration, and simulated the vibrational characteristics of the ground by that of a displacement seismometer. This assumption well conforms with the observational fact for motions having periods near the predominant period of the ground. But if we want to apply the formula for the motions of longer period, Kanai's formula for $G(T)_{T_0}$ coverges to zero and does not tend to a finite theoretical value. This inconsistency is revised if we introduce a factor u^2 into his formula, and put

$$G(T)_{T_0} = 4(1+\beta)^{-1}\ u^2 \left\{ (u^2-1)^2 + (\tau u)^2 \right\}^{-\frac{1}{2}} \qquad \cdots\cdots \qquad (3)$$

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* In Table 1, the seismic intensity I is connected to the acceleration by the following relation $\alpha = 0.45 \times 10^{0.5I}$ (by H. Kawasumi).

In this comparison, the correction of the seismic intensity by the epicentral distance is made as follows: Since we are eventually dealing with the damage brought by earthquakes, we examined $\alpha - \Delta$ relation in $\Delta < 200$ km for many earthquakes, and found the relation $\alpha \propto \Delta^{-1\sim-2}$. However, we could find no appreciable difference between the mean values of their intensity ratios for several available earthquakes, worked out for two cases.

By this revision, the formula obtained does not mark any appreciable difference from Kanai's formula in the vicinity of u = 1, around which his formula is intended to be used. And the range of applicability of $G(T)_{T_0}$ is much extended to the larger values of T. In this formula β denotes the ratio of mechanical impedance of the overburden to that of the bed rock. According to Kanai's study β is nearly constant regardless of the kinds of grounds.

$$\beta = 1/5 \qquad (3')$$

The damping constant in terms of critical damping$(1/2)\tau$ is also given by Kanai by the following formula

$$\tau = 0.2 / \sqrt{T_0} \qquad (3'')$$

for the grounds of various kinds.

By these equations, we can calculate the acceleration spectra of an earthquake on various grounds. The results are shown in Fig. 1.

4 Vibrational Characteristics of the Ground at Yokoyama Dam Site and at Gifu Meteorological Observatory.

We carried out seismic observations by means of high sensitive electromagnetic seismographs and an ordinary seismograph at various points in Yokoyama Dam Site.

The observations by high sensitive seismographs were made for 3 months only at night, but 335 small earthquakes could be recorded. The tremors caused by an explosion of 150 ton dynamite at Miboro were also recorded at various points near the Dam Site simultaneously with fast paper speed of recording. In calm times, micro-tremors in a horizontal hole made in the Dam Site were recorded too, with a super-high sensitivity of about 10 mm/kine. In the routine observation by means of an ordinary seismograph with a starter and a stopper we could catch 4 felt earthquakes.

The dominant periods obtained by analyses of these seismograms are shown in Tables 2 and 3. It was recognized that many dominant periods exist, but the period near 0.15 second is the most predominant.

The predominant period of the ground at Gifu Meteorological Observatory was searched from the seismograms of past destructive earthquakes, recent weak earthquakes, and micro-tremors. The results are shown in Table 4. The predominant period to be noted seems to be 0.4 - 0.5 second.

5 Interpretation of the Result of § 2.

In § 2, we found that the seismic intensities at Yokoyama are smaller than those at Gifu for destructive earthquakes, but for weak earthquakes, on the contrary, the former are larger than the latter. This phenomenon must be examined quantitatively by the use of equations mentioned in § 3 using predominant periods T_0 at Yokoyama and at Gifu, and paying due consideration for the value of T.

The period T is to correspond to the maximum acceleration observed actually at each place for each earthquake.

Let us first examine the results for destructive earthquakes.

The determination of seismic intensities at Gifu and Yokoyama must have been made mainly from the response of ordinary wooden houses, because the intensities were larger than III at both points. As Japanese wooden houses are usually most sensitive to the vibrational force having a period near 0.5 second, the period of the motion taken up for the estimation of the seismic intensity must have been about 0.5 second. Then the seismic intensity observed at Yokoyama is calculated as

$$\alpha_Y^{(d)}(0.5) = B(0.5) \cdot G(0.5)_{0.15} \qquad \cdots\cdots (4)$$

and that at Gifu is calculated as

$$\alpha_G^{(d)}(0.5) = B(0.5) \cdot G(0.5)_{0.5} \qquad \cdots\cdots (4')$$

Let us next see the result for weak earthquakes. As the seismic intensities were I ~ II at both places, the determination of the intensities must have been made by human senses. The human senses have an almost uniform sensitivity for the vibration with a period above 0.1 second as reported by M. Ishimoto. Therefore, we may consider that both of the seismic intensities observed at Yokoyama and Gifu were the true maximum values of the ground motions, consequently the periods to be taken in our calculation may be put equal to the predominant periods T_0 at both sites. Then, the seismic intensity at Yokoyama is to be calculated by

$$\alpha_Y^{(w)}(0.15) = B(0.15) \cdot G(0.15)_{0.15} \qquad \cdots\cdots (5)$$

and that at Gifu is similarly

$$\alpha_G^{(w)}(0.5) = B(0.5) \cdot G(0.5)_{0.5} \qquad \cdots\cdots (5')$$

Consequently, the ratio of seismic intensities at Yokoyama and Gifu is expressed by (4)/(4') for destructive earthquakes; and by (5)/(5') for weak earthquakes. In performing these calculations by equations (2) and (3), we can omit $C(M,\Delta)$, for M and Δ are common. Magnitudes of all earthquakes used here are larger than 4, consequently Tm's are all larger than 0.725 second by eq. (2"). As the periods T dealt with here are smaller than this value, eq. (2) is applicable. Then we obtain the ratios as follows.

$$\alpha_Y^{(d)} / \alpha_G^{(d)} = B(0.5) \cdot G(0.5)_{0.15} / B(0.5) \cdot G(0.5)_{0.5}$$

$$= \frac{0.5 \times 3.3}{0.5 \times 12.5} = 0.264 \qquad \cdots\cdots (4")$$

and

$$\alpha_Y^{(w)}/\alpha_G^{(w)} = B(0.15)\cdot G(0.15)_{0.15}/B(0.5)\cdot G(0.5)_{0.5}$$

$$= \frac{0.5 \times 6.4}{0.15 \times 12.5} = 1.7 \qquad \text{..........} \quad (5'')$$

These calculations may also be carried out directly on Fig. 1.

We have thus been able to explain the phenomena described in § 2 not only qualitatively, but also quantitatively by using equations (2) and (3) of the acceleration spectrum mentioned in § 3. We could see at the same time that the smaller seismic intensities at mountainous area in destructive earthquakes do not necessarily show that the motions in the mountainous area were actually smaller than those on alluvial plain. But they show that the motions of structures in the former area may be smaller than those of the same kind of structures on the alluvial plain, provided the natural periods of the structures are longer than the predominant period of the ground at the former site. Therefore, we can see also that in the mountainous area accelerations of long period vibrations are small but those of the short period vibrations may become remarkably large. All these mentioned above are shown in Fig. 1. Such a good agreement of the observational result with the present theory shows that the applicable range of Kanai's formulas may be extended to destructive earthquakes if it is slightly modified as above mentioned. The characteristics of destructive earthquake motion will be studied in detail again in § 8.

6. Activity of past earthquakes

H. Kawasumi has investigated the earthquakes in historical times and obtained the expectancy of the maximum intensity throughout our country. For instance, the expectancy for 100 years is shown in Fig. 2. But the values of the seismic intensity are determined under the assumption that the ground throughout the country has a uniform vibrational characteristics.

For Yokoyama Dam Site particularly, the expectancy of the seismic intensity estimated from the earthquakes occurred in the neighbourhood in historical times is obtained as follows.

If the number of earthquakes with intensities exceeding I at Yokoyama is expressed by S(I), the statistics show that

$S(5) = 20$, $S(6) = 11$, $S(7) = 7$, in past 1300 years,

where 5, 6 and 7 means the strong (80 ~ 250 gal), the disastrous (250 ~ 800 gal), and the ruinous (800 gal <), respectively.

The results obtained from the activity of earthquakes during these 72 years since the beginning of the Meiji era (1868) are

$S(5) = 16$, $S(6) = 6$, $S(7) = 3$.

These numbers are extremely large as compared with those in historical times. This is due to the fact that the cycle of seismic activity is very long (over 300 years), and, new phase of high activity set in recently with the Nobi earthquake of 1891 and the activity following it in this region were extremely high. Since the seismic activity in this region seems to have fallen to rest at present we may regard the activity of earthquakes in historical times (1300 years) as a standard activity in this region. Then the maximum seismic intensity to be expected to occur at least once in 100 years at Yokoyama area on the fictitious standard ground comes out to be about 200 gals, from the condition $S(I) = 1300/100$.

7. Estimation of the Expectable Seismic Intensity at Yokoyama Dam Site with Reference to the Vibrational Characteristics of the Ground

Important ground characteristics, from engineering point of view, consist of the vibrational characteristics and the fracture strength.

As rocky grounds are hardly broken, we have only to give attention to the vibrational characteristics. Now we are to estimate the expectable seismic intensity at Yokoyama Dam Site with due consideration of the vibrational characteristics of the ground. That is

$$\alpha_M(T_0) = B_M(T_0) \cdot G(T_0)_{T_0} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6),$$

where suffix M is written to show the maximum earthquake motion to be expected at Yokoyama within coming 100 years. On the other hand the expectable value on a standard ground in this district is expressed as follows.

$$\alpha_{M,S}(T_{0},S) = B_M(T_{0},S) \cdot G(T_{0},S)_{T_{0S}} = 200 \text{ gals} \quad \cdots\cdots (7),$$

where suffix S means "on a standard ground*".

The reason we put T equal to $T_{0,S}$ in eq. (7) will now be explained. If the estimation of seismic intensity at every point was made from the data on vibrations or damage of Japanese wooden houses, it may be appropriate to take T in eq. (7) equal to the proper period of the usual wooden houses. However, the observations of seismic intensities used by Kawasumi were made by means of an intensity scale based on damage of various structures, deformation of the earth's surface and other items, and corresponding maximum accelerations were calculated by the intensity ~ maximum acceleration relation determined from the observations by acceleration - seismographs. The period of the vibration which gave the maximum acceleration must therefore be the predominant period of the ground.

Then the expectable maximum value is calculated as follows,

$$\alpha_M(0.15) = \alpha_{M,S} \times B_M(0.15) \cdot G(0.15)_{0.15} / B_M(0.35) \cdot G(0.35)_{0.35}$$

$$= 200 \text{ gals} \times 0.35 \times 1.9/0.15 \times 3.0 = 306 \text{ gals} \quad \cdots\cdots\cdots (8)$$

* It is assumed here that on the standard ground the predominant period is 0.35 sec.

8. Seismograms of Great Earthquakes and the Relation $B(T) \propto T^{-1}$

The value of the acceleration given in eq. (8) seems to be larger than that used commonly in practice. The reason depends on the relation $B(T) \propto T^{-1}$, principally. When the relation was derived by Kanai, the basic data were restricted to seismograms of weak Japanese earthquakes recorded at the depth of 300 meters at a mine, although the relation obtained is concordant with the nature of strong earthquakes observed in U.S.A. Consequently, it may still be doubted whether the relation is applicable for destructive Japanese earthquakes or not. But we can not at present expect the seismograms of destructive earthquakes at deep subterranian points or on rocky grounds in mountainous area can be obtained in near future. Therefore, we examined the seismograms of recent destructive earthquakes obtained at Gifu Meteorological observatory with special attention to the short period components in the records. We could also examine the original seismograms of the Nobi earthquake of 1891 at the Gifu and Nagoya Meteorological Observatories. 1) 2) They are shown in Fig. 3.

The accelerations of the vibrations with long periods and large amplitudes and ripples which overlap the former are shown in Table 6. The relations between α and T for each seismogram in Table 6 are shown in Fig. 7. From this figure we can recognize the relation

$\alpha = B(T)\cdot G(T) \propto T^{-n}$, $n = 1/2 \sim 1$. These results will confirm that Kanai's formula for B(T) is also appropriate in destructive earthquakes. It is interesting especially that the result from the seismogram of the Nobi earthquake at Nagoya Meteorological observatory shows the relation $\alpha \propto T^{-1/2}$, which is consistent with the envelope line of the maximum value of $\alpha(T) = B(T)\cdot G(T)_{T_0}$ for various T_0 in Fig. 1. This may be explained, if we consider that there are many predominant periods in the ground in Nagoya as the City is located on a very thick soft deposit which is likely to be composed of alluvium, diluvium and tertiary formations deposited in succession on hard paleozoic bed.

The spectrum of the earthquake motion occurred at upper part of Ibi River on Nov. 20, 1959 shows an exceptional trend in Fig. 11. The reason is probably found among the facts that the magnitude of the earthquake was small, the observing point was located on the mountain rock and Δ is small.

The seismograms of the Nobi earthquake obtained at Gifu and Nagoya are very precious from two reasons that firstly they were obtained near the origin of an earthquake of the greatest class ($M = 8.4$), and secondly that because of fast recording speed, we can very clearly read the vibrations with short periods and small amplitudes.

9. Conclusions

In order to determine the acceleration for the earthquake resistant structure design, we must investigate primarily, the expectancy of the maximum seismic intensity at the place during the life time of the structure and secondarily, the vibrational characteristics of the earthquake motion.

As to the primary problem, Kawasumi investigated the maximum seismic intensity to be expected at least once in a certain length of time at places throughout Japan. But the ground in the whole area is assumed to be the same as that of a standard ground. Mathematically, the maximum acceleration is expressed as

$$\alpha_{M,S} = B_M(T_{O,S}) \cdot G(T_{O,S})_{T_{O,S}} \quad \cdots\cdots (7)$$

In regard to the second problem, Kanai proposed formulas which are cited below with a slight modification of one in (3).

$$\alpha(T) = B(T) \cdot G(T)_{T_0} \quad \cdots\cdots (1)$$

$$B(T) = C(M, \Delta) \cdot T^{-1}, \quad \text{for } T \leqq T_m \quad \cdots\cdots (2)$$

$$\log T_m = 0.39M - 1.70 \quad \cdots\cdots (2')$$

$$G(T)_{T_0} = 4(1+\beta)^{-1} \cdot u^2\{(1-u^2)^2 + (\tau u)^2\}^{-\frac{1}{2}} \quad \cdots\cdots (3)$$

$$\beta \doteqdot 1/5 \quad \cdots\cdots (3')$$

$$\tau = 0.2/\sqrt{T_0} \quad \cdots\cdots (3'')$$

Therefore, by means of these results, and one additional knowledge of the predominant period of the ground, we can calculate the acceleration spectrum required for the design of the earthquake-proof construction by the following formula

$$\alpha_M(T)_{T_0} = B_M(T) \cdot G(T)_{T_0} = \frac{B_M(T) \cdot G(T)_{T_0}}{B_M(T_{O,S}) \cdot G(T_{O,S})_{T_{O,S}}} \times \alpha_{M,S} \quad \cdots\cdots (8)$$

We tried in this paper to deduce an acceleration spectrum at Yokoyama Dam Site especially and examined the applicability of above formulas for destructive earthquakes from some points of view.

The results obtained in this paper are as follows:

(1) When we compare the seismic intensities at Yokoyama to those at Gifu in recent five destructive earthquakes and ten weak ones separately, the seismic intensities at Yokoyama for the destructive earthquakes were smaller (about 1/4 times) than those at Gifu, while for the weak earthquakes the former were larger (about 1.7 times) than the latter.

(2) We carried out a temporary observation by means of high sensitive seismographs and a routine observation by an ordinary seismograph at Yokoyama Dam Site. From the seismograms obtained we could see the predominant period at Yokoyama Dam Site is about 0.15 second. And from the seismograms obtained at Gifu Meteorological Observatory we could estimate the predominant period of the ground as about 0.5 second.

(3) Putting these values of predominant periods into Kanai's formula $G(T)_{T_0}$, and with due considerations of the periods to be particularly sensitive to human senses and to cause resonances of Japanese wooden houses, the phenomena shown in (1) are explained not only qualitatively, but also quantitatively. It is therefore to be noted that in case of destructive earthquakes, their accelerations on the ground in the mountainous area were not smaller than those on the ground in the alluvial plain, but the vibrations having short periods and large accelerations were left unnoticed in the mountainland owing to the lack of appropriate meters to estimate the seismic intensity of high frequency vibrations.

(4) Relying upon the result investigated by Kawasumi, the maximum acceleration to be expected at Yokoyama Dam Site at least once in 100 years is about 200 gals on a standard ground.

(5) Consequently, taking the vibrational characteristics into consideration and its period of the earthquake motion to be expected at Yokoyama Dam Site are calculated as about 300 gals and about 0.15 second.

(6) The acceleration obtained above seems to be rather large as compared to the values usually adopted in practice. It is primarily due to the smallness of the predominant period and the nature of earthquake motion that $B(T) \propto T^{-1}$. Although the earthquakes used by Kanai in the derivation of above relations had been restricted to rather weak ones, we were able to examine and verify the relations also in destructive earthquakes. Particularly from the seismograms of the Nobi earthquake of 1891 recorded at Nagoya and Gifu Meteorological Observatories we could make sure the relations above mentioned.

10. Acknowledgement

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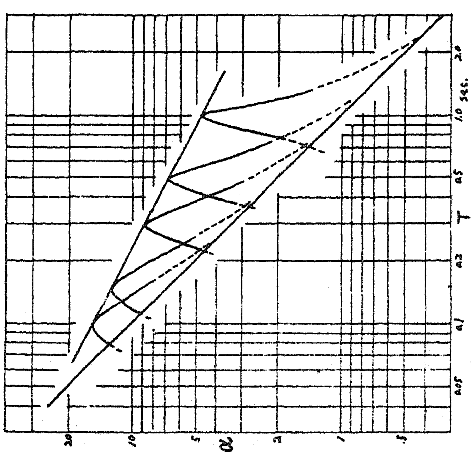

Fig. 1 Acceleration spectra of an earthquake motion on various kinds of ground, α = B(T)·G(T)

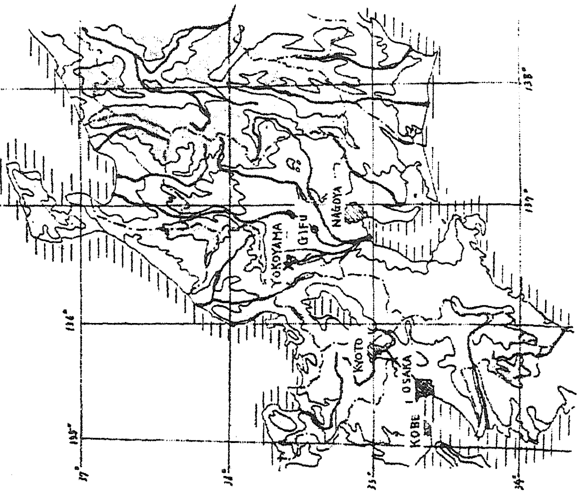

Fig. 2 Topographical map of central Japan and the location of Gifu and Yokoyama

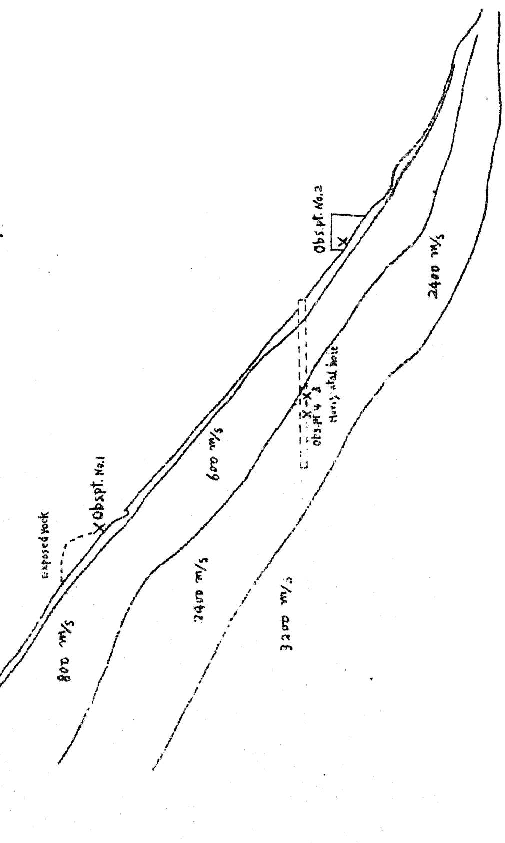

Fig. 3 Subterranian Structure of Yokoyama dam site and locations of observation points

Fig. 4a Seismograms obtained at Yokoyama dam site

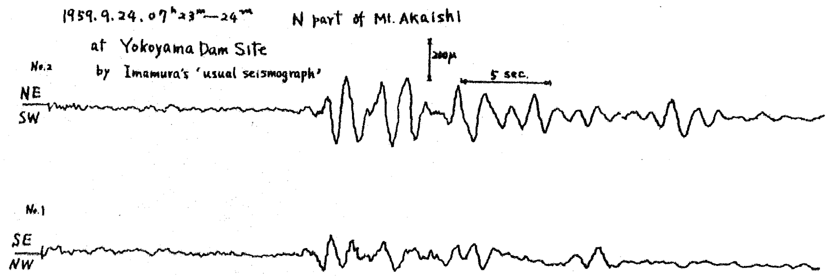

Fig. 4b

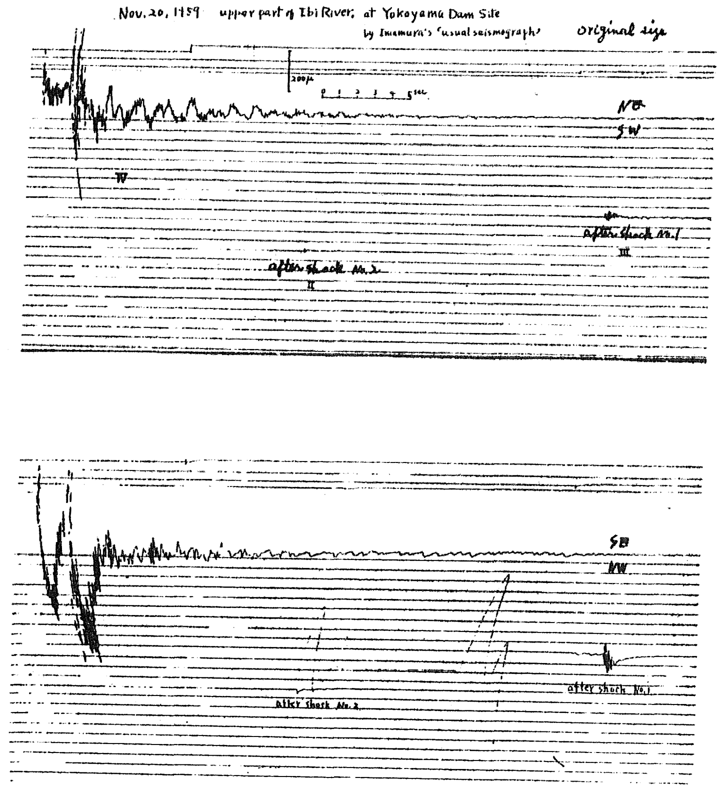

Fig. 4c Seismograms obtained at Gifu M. O. by Wiechert's seismograph

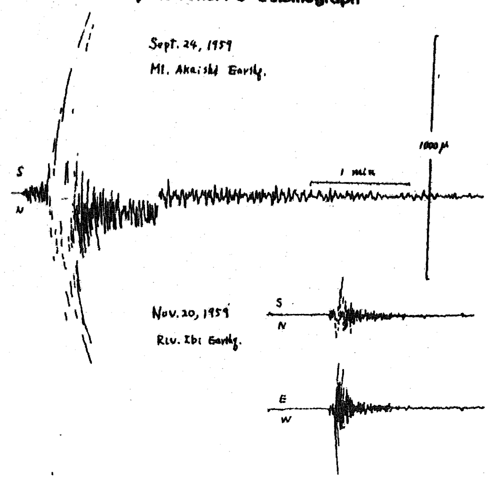

Fig. 5 Distribution of expectable maximum acceleration of earthquakes in 100 years in Japan (After Kawasumi).

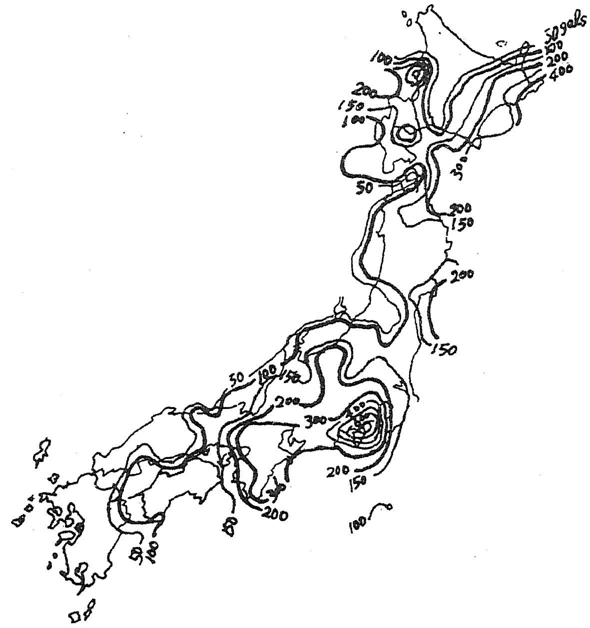

Fig. 6a Seismogram of The Nobi Earthquake at Nagoya M. O. Oct. 28, 1891

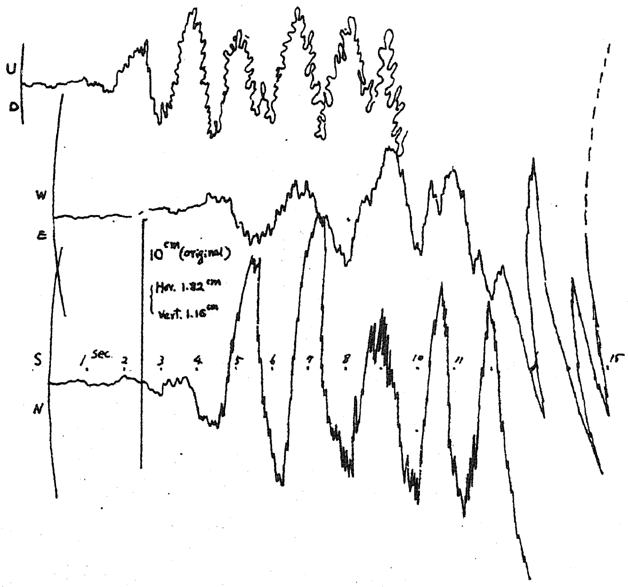

Fig. 6b Seismogram of The Nobi Earthquake at Gifu M.O. Oct.28, 1891

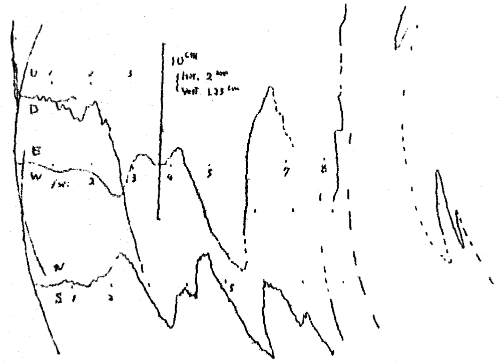

Fig. 6c Seismograms of The After Shock of The Nobi Earthq. Dec.3, 1892

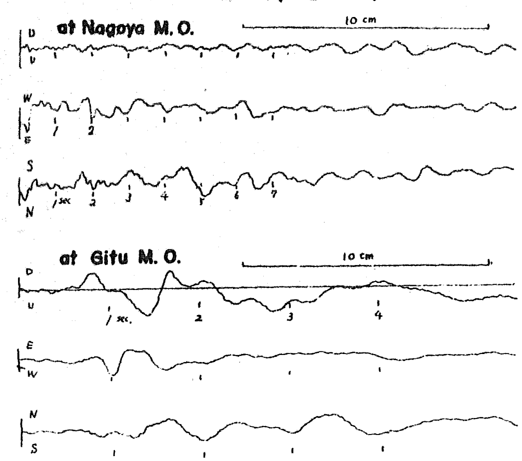

Fig.7 Acceleration spectra obtained from seismograms of great earthquakes

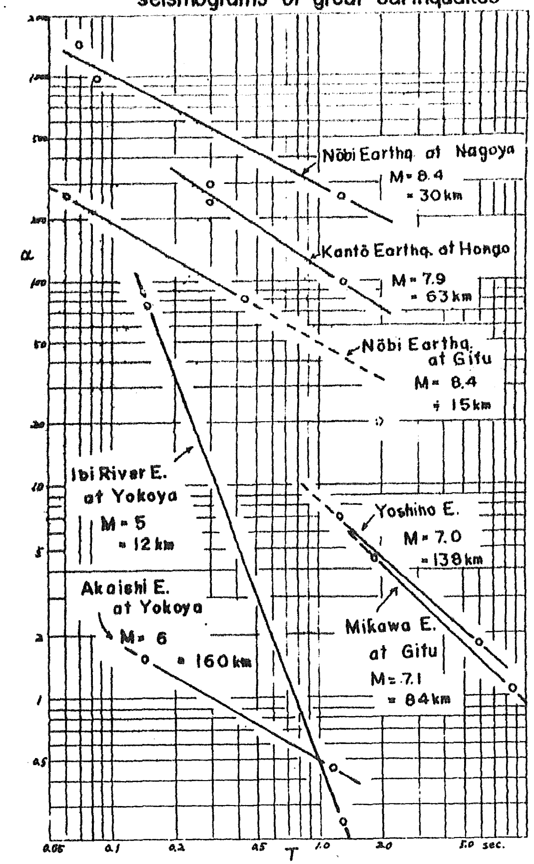

Table 1 Comparison of the seismic intensity at Yokoyama with that at Gifu

Earthquake	Time	φ	λ	D	M	I		Δ		A	T	$\frac{(\alpha\Delta^2)_Y}{(\alpha\Delta^2)_G}$	$\frac{(\alpha\Delta)_Y}{(\alpha\Delta)_G}$
		°	°	Km		G	Y	G (Km)	Y (km)	G (mm)	G (sec.)		
Yoshino Earthq.	1952. 7. 18	34.45	135.8	70	7.0	4	3	138	138	18.5	1.85	0.367	0.340
Fukui Earthq.	48. 6. 28	36.1	136.2	20	7.3	4	3	100	68	41.3	1.87	0.146	0.210
Nankai Earthq.	46.12.21	33.0	135.6	30	82	5	3	284	298	out	3.4	0.110	0.105
Mikawa Earthq.	45.1.13	34.7	137.0	0	7.1	4	3	84	114	28.7	1.55	0.590	0.425
Tonankai Earthq.	44.12. 7	33.7	136.2	0-30	8.0	5	4	196	210	out	2.5	0.304	0.340
												0.283	0.260
E. Aichi	1958. 5. 4	35.0	137.4	50	48	2	2	73	105	190μ	0.4	2.06	1.445
M. Gifu	58. 2. 9	35.7	137.2	0	4.3	2	1	51	68	84	0.3	0.56	0.435
M. Fukui	57.12.31	35.8	136.1	20	4.6	2	2	75	43	133	0.35	0.335	0.564
Gifu-shiga border	57. 12. 3					1	3	36	13.5	72	0.44	1.27	5.67
W. Mie	57.11.27	34.7	136.2	70	4.6	1	2	93	99	89	0.36	3.68	3.47
W. Aichi	56.12.18	35.2	136.7	40	4.4	1	2	23	46	98	0.44	13.2	6.55
S. Aichi	56.12.11	34.9	137.1	30	4.0	1	1	63	94	25	0.3	2.25	1.46
M. Aichi	56. 2. 8	34.9	137.2	20	5.0	3	3	68	100			2.21	1.43
W. Gifu	52. 6. 26	35.5	136.6	30	4.7	2	3	19	14			1.58	2.3
S. Mie	51. 9.23	34.3	136.2	40	4.8	1	1	134	143			1.18	1.09
												1.72	1.73

Table 2 Seismic observation at Yokoyama Dam Site

Routine observation of earthqakes

Observation point	Instrument	Results
On the surface layer (on the concrete base in the observation hut)	Imamura's usual seismograph Horizontal 2 component T_0= 2sec., h ≑ 0.5, V= 63, p.s.= 5.32 mm/sec With starter and stopper Smoked paper recording	Since Aug. 1958 to the present time untelt earthqaake No.325 felt, III, Aug. 22, 1959 felt, I~II, Aug. 31, " felt, I, Sept. 24, " felt, IV, Nov. 20, "
On an exposed rock	Electro magnetic seismograph with amp. MG II, Trancducer N.D. Hor. NS T_0=0.80sec, h ≑ 0.5, V=0.022 mm/μkine p.s.= 8 mm/sec Smoked paper recording	From evening to next morning Aug. 29~Dec. 10, 1958 335 micro earthquakes were recorded

Temporary observation (1) Observation of the ground motion due to the explosion of 150 ton dynamite at Miboro

Observation point	Instrument
	Electromagnetic seismograph with amp. MG II, p.s. 34 MM/SEC
On the serface layer	T_0= 0.455sec, h ≑ 0.5, V=0.12 mm/μkine, Hor. NS
On the exposed rock	T_0= 0.80 ", h ≑ 0.5, V=0.50 ", Hor. NS
In the horizontal hole (compact rock, velocity of P wave = 2400 m/sec)	T_0= 0.475 ", h ≑ 0.5, V=0.37 ", Hor. NS
In the horizontal hole (loose rock, V_p=2400 m/s)	T_0=0.27 ", h ≑ 0.5, V=0.06 ", Hor. NS

(2) Observation of the ground noise

Observation point	Instrument
In the horizontal hole	Electromagnetic seismograph of which electric power is supplied by batteries T=0.80sec, h ≑ 0.5, V= 4. mm/μkine, p.s. = 50 mm/sec

Table 3 Predominant periods obtained by micro-seismic observation at Yokoyama Dam Site

Predominant periods obtained from the ground motion caused by the great explosion of 150 tons dynamite at Miboro Dam. $\Delta \fallingdotseq 70^{KM}$

Observation point	Initial part	Main part	Tail
On the surface layer	0.12 sec.		(0.036) 0.13
On the exposed rock	0.12	0.14	0.175
In the horizontal hole (compact rock)	0.175		(0.070) 0.215
In the horizontal hole (loose rock)	0.175		0.175

Predominant period obtained from 335 micro-earthquake picked up on the exposed rock is

T_0 = 0.15 sec.

Pred. periods obtained from ground noise on the surface layer,

T_0 = (0.036) and 0.15 sec.

Pred. period obtained from ground noise in the horizontal hole (compact rock)

T = 0.10 sec.

Table 4 Predominant periods obtained from the seismograms of weak earthquakes obtained by 'usual seismograph' on the surface layer

Time	Δ	Short period NE/SW comp.	Short period SE/NW	Long period NE/SW	Long period SE/NW
Aug. 22, 1959	about 12 km	0.10 sec	0.11	1.0	3.75
Aug. 31, 1959	12	0.103	0.115	1.6	3.8
Sept. 24, 1959	160	0.15	0.15	1.2 1.6	1.12
Nov. 20, 1959	11	(0.10) 0.15	(0.10) 0.23	1.37	1.8

Table 5 Predominant periods obtained from the seismograms of destructive earthquakes, weak earthquakes and ground noise at Gifu Meteorological Observatory. By Wiechert's seismog.

Earthquake	Prdominant period			
Fukui Earthquake (by Wiechert Seismograph)		0.47 sec.	1.29	6.2
Mikawa Earthquake			1.1	9.3
Yoshino Earthq.			1.3	6.5
Nobi Earthq.	0.06	0.445	2.0	
Weak Earthquakes		0.3—0.44		
Ground Noise	0.09, 0.2	0.5		
Ground Noise (by electro-magnetic seismog.)	0.05, 0.07			

Table 6 Acceleration spectra obtained from seismograms of great earthquakes

Earthq.	Epic.	Time	M	T_M	Obs.pt	Δ	I	T_{short}	A_s	α_s	T_{long}	A_L	α_L	Seismograph T_0	V	v	p.s.
Nobi E.	WNW of Gifu	Oct. 28 1891	8.4	4.0 SEC	Gifu	15 KM ~	6 ~7	0.06 SEC 0.444	0.024 CM 0.410	270 GAL 84	2.0 SEC	>2 CM	>20 GAL	Miln's s. 2 ~3 SEC	5 (8)	no	21.4 MM/SEC
Nobi E.	WNW of Gifu	Oct. 28 1891	8.4	40	Nagoya	30 ~	6 ~7	0.067 0.084	0.175	1560 990	1.3	(11)	260	Miln's s. 2 ~3	5.5 (9)	no	14.6
Kanto E.	35.33 139.33 ?	Sept. 1 1923	7.9	25	Hongo	63	5 ~6	0.30	0.6 0.8	250 300	1.35	4.43	100	?			
Mikawa E.	34.7 137.0 0	Jan. 13 1945	7.1	12	Gifu	64	4	could not read for the slow paper running speed			1.1 9.3	0.45 2.4	14.9 1.11	Imamura's strong s. 6	2	no	0.6
Yoshino E.	34.45 135.8 7.0	July 18 1952	7.0	11	Gifu	138	4	could not read for slow p.s.			1.3 6.5	0.3 1.9	7.1 1.8	Imamura's strong s. 6	2	no	0.6
Mt. Akaishi E.	35.6 138.2 20	Sept. 24 1959	6	5	Yokoyama	160	1 ~2	0.15 SEC	8.75 μ	1.55 GAL	1.2	0.017	0.47	Imamura's usual s. 1.8	6.3	2.5	5.32
Riv. Ibi E.	35.6 136.6 20	Nov. 20 1959	5	2	Yokoyama	12	4	0.15	435 μ	77	1.37	0.012	0.26	Imamura's usual s. 1.8	63	2.5	5.32