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19. *A Short Note on Seismic Intensity and Seismic Intensity Scale.*

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For many years seismologists have tried to measure the violence of earthquake motions by means of so-called seismic intensity scales, which were divided into a number of grades and were based exclusively on the effects of earthquake motions on animate and inanimate objects.

The relation between instrumental seismic intensity data and seismic intensity scale has been investigated by Ishimoto. An empirical formula concerning the relation between the Japan Meteorological Agency Seismic Intensity Scale and the maximum acceleration of earthquake motions as observed at the underground vault of the old building of the Earthquake Research Institute by means of the 0.1 sec period seismograph obtained by Ishimoto[1] is as follows:

$$a_{max}=0.125\times10^{0.602I_{JMA}}\ , \qquad (1)$$

in which a_{max} and I_{JMA} represent the maximum acceleration in gals and the Japan Meteorological Agency Seismic Intensity Scale, respectively. Ishimoto noticed that the relation mentioned above should be a function of the predominant period of ground and Eq. (1) is the result as obtained at the place in which the predominant period of ground is 0.3 sec. Kawasumi[2] later made a thorough investigation on the problem based on the same data of Ishimoto plus new data, and obtained the following empirical formula, that is,

$$a_{max}=0.253\times10^{0.5I_{JMA}}\ . \qquad (2)$$

The correlation of seismic intensity scale with the instrumental data on destructive earthquake motions at nine strong motion seismograph stations obtained by the U. S. Coast and Geodetic Survey has been in-

1) M. ISHIMOTO, "Echelle d'intensité sismique et accélération maxima," *Bull. Earthq. Res. Inst.*, **10** (1932), 614-626.

2) H. KAWASUMI, "Seismic intensity and seismic intensity scale," *Jour. Seism. Soc. Japan*, **15** (1937), 6-13. (in Japanese)

vestigated by Neumann[3]. One of the results obtained by Neumann is as follows:

$$a_{max}=0.91\times 10^{0.308 I_{MM}}\ , \qquad (3)$$

in which a_{max} and I_{MM} represent the maximum recorded acceleration in gals and the Modified Mercalli Seismic Intensity Scale, respectively.

In the present paper, the correlation stated just previously will be investigated from a different point of view.

Table 1.

	Name of earthquake	Date	Instrumental data				MM scale
			Station		Max. accel. (gal)	Predom. period (sec)	
1	Long Beach	Mar. 10, 1933	I	Vernon	120	0.30	7.5
			II	Subway Terminal	40	0.65	6.5
2	Los Angeles Country	Oct. 2, 1933	I	Vernon	80	0.30	6
			II	Subway Terminal	30	0.65	5.75
3	Hardy River-Lake Macato	Dec. 30, 1934	III	El Centro	140	0.20	6
4	Montana	Oct. 31, 1935	IV	Helena	120	0.40	8
5	N. California	Sept. 11, 1938	V	Ferndale	70	0.40	6
6	Imperial Valley	May 18, 1940	III	El Centro	330	0.20	7.5
7	Punta Gorda	Feb. 9, 1941	V	Ferndale	50	0.40	6
8	Santa Barbara	June 30, 1941	VI	Santa Barbara	160	0.30	7
9	Eureka	Oct. 3, 1941	V	Ferndale	70	0.40	6
10	W-Central California	Mar. 9, 1949	VII	Hollister	140	0.35	7
11	Pugte Sound	Apr. 13, 1949	VIII	Olympia	180	0.35	8
			IX	Seattle	50	0.90	8

The data used in the present investigation are represented in Table 1, and the relation between the maximum value of the recorded acceleration and the grade of the Modified Mercalli Seismic Intensity at each place is shown as a small circle in Fig. 1.

3) F. NEUMANN, "Some Generalized Concepts of Earthquake Motion," *Proc. Symp. Earthq. & Blast Effects on Structures, Earthq. Engg. Res. Inst.* (1952), 8-19.

As seen in Fig. 1, the intensity-maximum acceleration relationship is not simple, and a most presumable reason of it is that earthquake motions depend largely on the vibrational characteristic of ground, especially, on the predominant period of ground. Under the above consideration, it seems that, in general, the maximum acceleration increases with decrease of predominant period for each grade of *MM* intensity from the relation represented in Fig. 1.

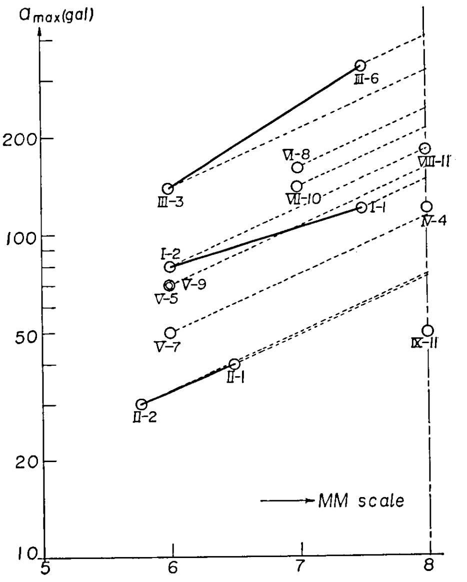

Fig. 1.

Three full lines in Fig. 1 which connecting two data of the same stations appear to be approximately equal inclinations, the average of them becoming as follows:

$$a_{max}=c\times10^{0.18I_{MM}}\ , \qquad (4)$$

in which c is a function of the vibration characteristics of ground.

The lines passing through each point in Fig. 1 and parallel to a line derived from Eq. (4) are represented as broken lines in Fig. 1. Utilizing the broken lines in Fig. 1, the value of the maximum accelerations corresponding to grade 8 of *MM* intensity at each place will be estimated. The relation between the estimated values of the maximum accelerations and the predominant periods of the grounds is shown in Fig. 2. An empirical formula derived from Fig. 2 becomes as follows:

$$a_{max.\ MM=8}=42\times T_G^{-1.3}\ , \tag{5}$$

in which T_G is the predominant period of ground in sec. From Eqs. (4) and (5), we get

$$c=1.6\times T_G^{-1.3}\ . \tag{6}$$

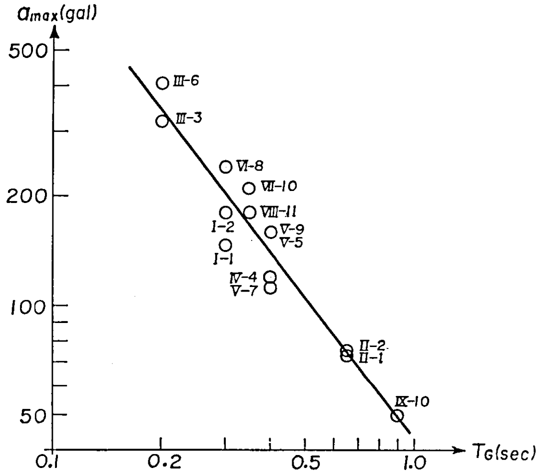

Fig. 2.

Applying (6) in (4), we obtain

$$a_{max}=1.6\times T_G^{-1.3}\times 10^{0.18 I_{MM}}\ . \tag{7}$$

From (7), the velocity-intensity relationship is obtained as follows:

$$v_{max}(\text{cm/sec})=0.26\times T_G^{-0.3}\times 10^{0.18 I_{MM}}\ . \tag{8}$$

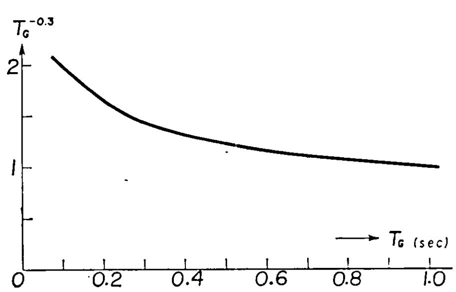

Fig. 3.

Now, the values of $T_G^{-0.3}$ may be assumed constant as 1.2 in the range of $T_G=0.3-1.0$ sec as seen in Fig. 3. Therefore, as an engineering aspect, the velocity-intensity relationship may be rewritten as follows:

$$v_{max}(\text{cm/sec})=0.31\times 10^{0.18 I_{MM}}\ . \tag{9}$$

The relationship mentioned above is shown in Fig. 4 as a full line.

From the final result of the present investigations, we can say that the damage to structures caused by earthquake motions depends mostly on the maximum velocity amplitude of earthquake motions, because the grades of seismic intensity used here were estimated by the rate of damage to structures. The above explanation agrees with the conclusions

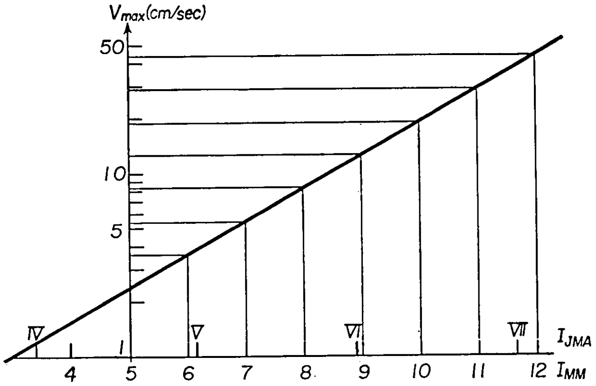

Fig. 4.

of investigations in which the correlation between the damage to buildings caused by some of the past big earthquakes and the square of the maximum velocity amplitude of earthquake motions was studied[4].

In conclusion, many thanks are due to Miss S. Yoshizawa who has assisted me in preparing this paper.

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19. 震度と震度階小引

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震度階と記録最大加速度の関係式を最初に求めた石本博士は，その実験式は卓越周期 0.3 sec の場所での観測結果を使つたものであることを，特に注意する必要があるとしている．

本研究はアメリカ合衆国で観測された強震動の最大加速度と *MM* 震度階との関係を，新しい立場からしらべたもので，最大加速度 (a_{max} 単位 gal)，卓越周期 (T_G 単位 sec)，*MM* 震度階 (I_{MM}) との間には，次の関係があることがわかつた．

$$a_{max}=1.6\times T_G^{-1.3}\times 10^{0.18 I_{MM}} \qquad (7)$$

また，(7) 式から，次の実用式をつくつた．

$$\left.\begin{array}{l} v_{max}(\mathrm{cm/sec})=0.31\times 10^{0.18 I_{MM}} \\ v_{max}(\mathrm{cm/sec})=0.012\times 10^{0.50 I_{JMA}} \end{array}\right\} \qquad (9)$$

(9) 式は，構造物に対する地震動の破壊作用は，地震動の速度振幅に最も密接な関係があることを示唆するものであり，過去のいくつかの大地震の震害の解釈とも矛盾しないようである．

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4) R. TANABASHI, "Breaking force of earthquake motions and ......," *Journ. Arch. Inst. Japan*, Vol. **49**, No. 599 (1935), 578-587. (in Japanese)