Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.II)

3-2-12

AN EMPIRICAL FORMULA ON THE ATTENUATION OF THE MAXIMUM ACCELERATION OF EARTHQUAKE MOTIONS

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SUMMARY

In the present investigation, a new type empirical formula on the attenuation of the maximum acceleration of earthquake motions has been obtained by using the strong motion seismograph records in Japan.

The empirical formula mentioned above is as follows:

$\log_{10} a = 1.29M - (0.38M - 0.99)\log_{10} x - 3.64$

in which a, M and x represent the maximum acceleration of earthquake motions in gal, magnitude and hypocentral distance in km.

INTRODUCTION

The empirical formulae concerning the attenuation on the maximum amplitude of earthquake motions have been investigated until now by numerous researchers.

In general, the type of empirical formula on the attenuation is expressed by the following equation :

$$\log_{10} a = \alpha M + \delta - n \log_{10} x \qquad (1)$$

where a, M and x are the maximum amplitude of earthquake motions, magnitude and hypocentral distance (or epicentral distance, Δ), respectively ; and α, δ and n are the constants.

In this paper, we are going to derive a new type empirical formula on the attenuation of the maximum acceleration of earthquake motions by using the strong motion seismograph records (SMAC type) of 28 earthquakes ($M>5$) obtained for the 1968~1985 period in Japan (see Ref. 1).

The data of the 28 earthquakes treated in this paper are shown in Table 1. The distribution of the mean period obtained by three waves of near the maximum acceleration in strong motion seismograph records is shown in Fig. 1. Experimentally speaking, this period may be considered as the predominant period of earthquake motions.

METHOD OF ANALYSIS AND RESULTS

A New Type Empirical Formula on the Attenuation of the Maximum Acceleration of

Table 1 Data of earthquakes

No.	Region	Date	Epicentral region	M	Dep. (km)	No.	Region	Date	Epicentral region	M	Dep. (km)
1	Keihin	'68 VII 1	Middle of Saitama Pref.	6.1	50	15	Kanto • Chubu	'71 VII 23	Eastern Yamanashi Pref.	5.3	10
2		'74 VIII 4	SW Ibaraki Pref.	5.8	50	16		'74 V 9	Near S Coast of Izu Pen.	6.9	10
3		'75 II 8	Northern Chiba Pref.	5.4	60	17		'78 I 14	Near Oshima	7.0	0
4		'80 IX 25	SE Coast of Kanto	6.1	80	18		'80 VI 29	Izu Pen. Region	6.7	10
5		'83 II 27	Southern Kanto	6.0	72	19	Chubu • Kinki	'69 IX 9	Middle of Gifu Pref.	6.6	0
6		'85 X 4	Southern Ibaraki	6.1	78	20		'71 I 5	Off Coast of Aichi Pref.	6.1	40
7	Hokkaido • Tohoku	'68 V 16	E off N Honshu	7.9	0	21		'75 III 14	Aichi-Gifu Border	5.3	50
8		'70 I 21	S part of Hokkaido	6.7	50	22		'83 III 16	S Coast of Chubu	5.7	40
9		'73 VI 17	Off Nemuro Pen.	7.4	40	23		'84 V 30	Northern Kinki	5.6	17
10		'81 I 23	S Coast of Hokkaido	7.1	130	24		'85 I 6	NE Wakayama Pref.	5.9	73
11		'82 III 21	S off Hokkaido	7.1	40	25	Chugoku • Shikoku • Kyushu	'68 IV 1	Hyuganada	7.5	30
12		'83 V 26	W off N Tohoku	7.7	14	26		'68 VIII 6	W Coast of Ehime Pref.	6.6	40
13	Tohoku	'78 II 20	Off Miyagi Pref.	6.7	50	27		'83 VIII 26	W Setonaikai Region	6.8	116
14		'78 VI 12	Off Miyagi Pref.	7.4	40	28		'84 VIII 7	SE off Kyushu	7.1	33

Earthquake Motions

In the present study, the relation between the maximum acceleration of earthquake motions a, and hypocentral distance x, is expressed as follows :

$$\log_{10} a = \beta - \nu \log_{10} x . \qquad (2)$$

As a first step, the maximum accelerations of earthquake motions against hypocentral distances may be plotted, and it will be obtained the values of β and ν in Eq. (2) by the method of least squares.

Some examples of the relation between the hypocentral distance and the maximum acceleration of earthquake motions are shown in Fig. 2. The broken line in Fig. 2 represents the value calculated by another empirical formula (case of T_G is 0.3 sec, T_G is the predominant period of earthquake motions) obtained by one of the authors (see Ref. 2).

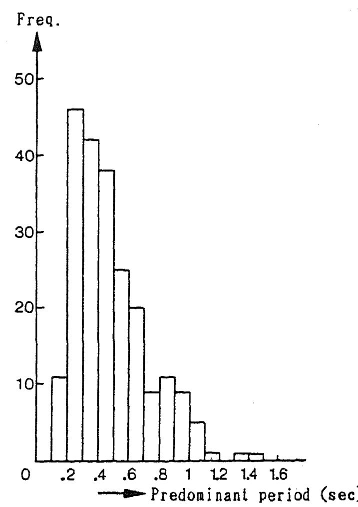


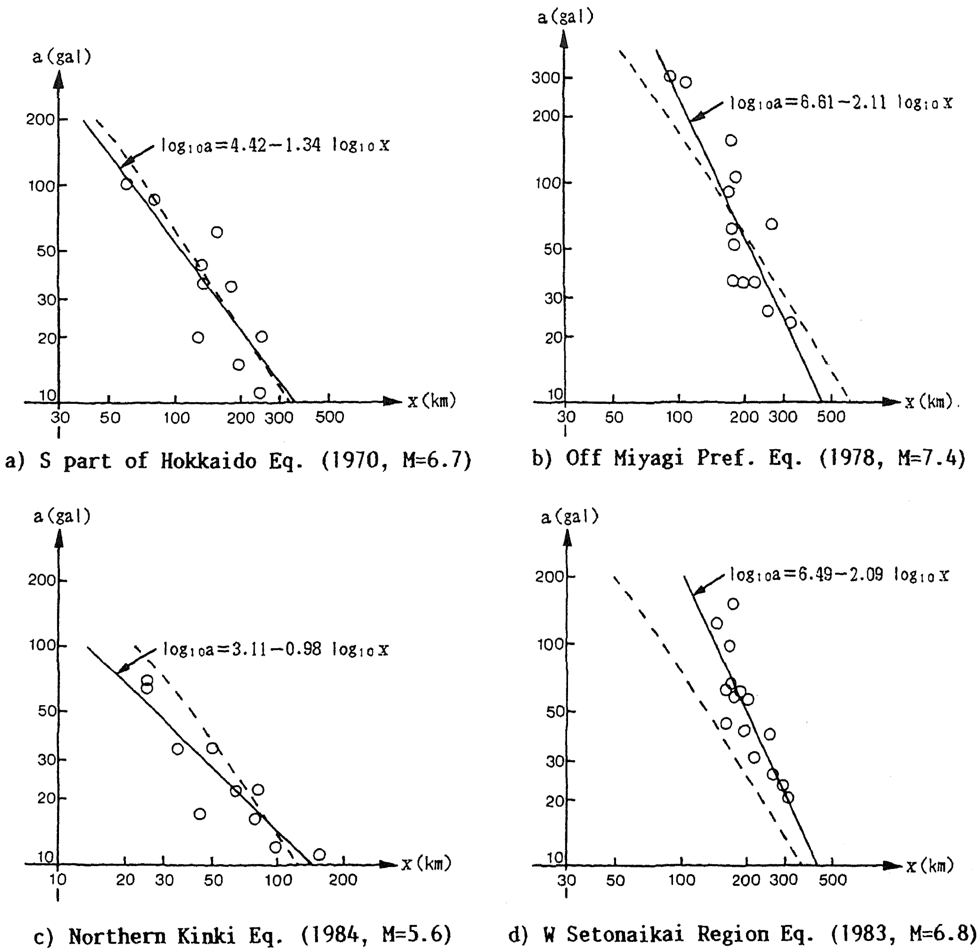
Fig.1 Predominant period of earthquake motions

The relation between M and β is shown in Fig. 3. In Fig. 3, the white and black circle marks express the 6 earthquakes in the Tokyo-Yokohama area and the 22 earthquakes in the general regions, respectivery. In the present paper, the region excepted the Tokyo-Yokohama area is called the general region. In Fig. 3, the values of β show a tendency to increase with M, the empirical formula concerning M and β in the general regions obtained as follows :

$$\beta = 1.29M - 3.64. \qquad (3)$$

The broken line in Fig. 3 represents the value calculated by an empirical formula in Ref. 2 (case of T_G is 0.3 sec).

Next, the relation between M and ν is shown in Fig. 4. In Fig. 4, the values of ν also show a tendency to increase with M.



a) S part of Hokkaido Eq. (1970, M=6.7)

b) Off Miyagi Pref. Eq. (1978, M=7.4)

c) Northern Kinki Eq. (1984, M=5.6)

d) W Setonaikai Region Eq. (1983, M=6.8)

Fig.2 Relation between the hypocentral distance and the maximum acceleration of earthquake motions

On the other hand, the investigation that the values of ν show a tendency to decrease with M have already been obtained by some researchers (see Ref. 3), but in the above researches the range of M is short and the number of earthquakes are few, then their values seem to be correspondence with the range of error in Fig.4.

The empirical formula concerning M and ν in the general regions is obtained as follows :

$$\nu = 0.38M - 0.99. \quad (4)$$

It can be considered that the value of ν is a function of M in Fig. 4, and this result has not yet been appeared in the former researchers. By substituting Eqs. (3) and (4) into Eq. (2), we have a new type empirical formula on the attenuation of the maximum acceleration of earthquake motions which is as follows:

$$\log_{10} a = 1.29M - (0.38M - 0.99)\log_{10} x - 3.64. \quad (5)$$

Moreover, the relation between β and ν are shown in Fig. 5. In Fig. 5, the empirical formula concerning β and ν in the general regions is obtained as follows :

$$\nu = 0.317\beta . \quad (6)$$

By substituting Eqs. (3) and (6) into Eq. (2), it can be obtained another equation in place of Eq. (5) as follows :

$$\log_{10} a = 1.29M - (0.41M - 1.15)\log_{10} x - 3.64. \quad (7)$$

The grade of deviation in Figs. 3, 4 (including M) are larger than those in Fig. 5. In other words, it may be said that the cause of the deviation mentioned above can be interpreted by the estimation of the values of M.

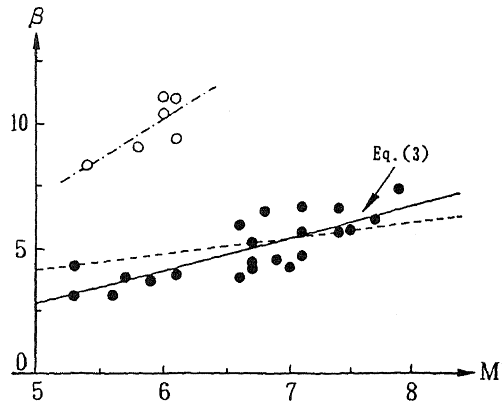


Fig.3 Relation between M and β

Comparison of an Empirical Formula on the Attenuation of the Maximum Acceleration of Earthquake Motions obtained in Japan and Those obtained by Different Processes

Comparison of an empirical formula obtained here and those by other researchers (see Ref.4) in case of $M=7$ are shown in Fig. 6 (in some formulae, hypocentral distance Δ are used. Here, for simplicity, Δ is assumed to be the same as the epicentral distance x). From Fig. 6, it will be found that the value of an empirical formula obtained here is in very good agreement with the empirical formula obtained by one of the authors (case of T_G is 0.3 sec).

Comparison of an empirical formula obtained here and those by one of the authors (case of T_G is 0.3 sec) in each of M is shown in Fig. 7.

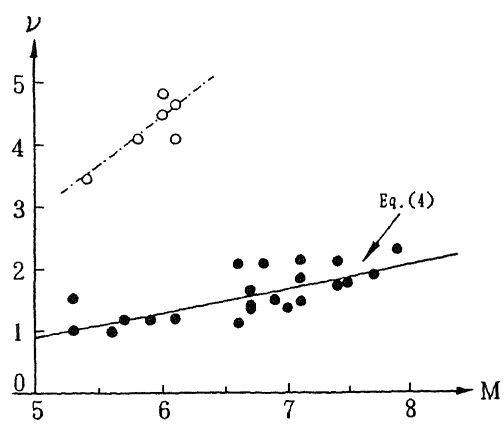


Fig.4 Relation between M and ν

Comparison of the Attenuation of the Earthquake Motions in Tokyo-Yokohama Area and Those in the General Regions

In Figs. 3, 4 and 5, the white and black circle marks express the 6 earthquakes in Tokyo-Yokohama area and the 22 earthquakes in the general regions, respectively.

From Figs. 3 ~ 5, it may be said that the group of white circle mark and the group of black circle mark are different considerably.

Fig. 4 represent that the attenuation of the maximum acceleration of earthquake motions in Tokyo-Yokohama area larger than those in the general regions. And it may be said that the result mentioned above agrees with the

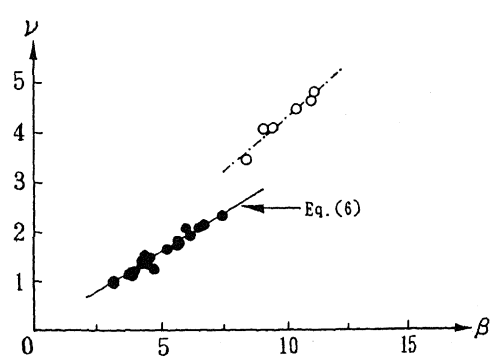


Fig.5 Relation between β and ν

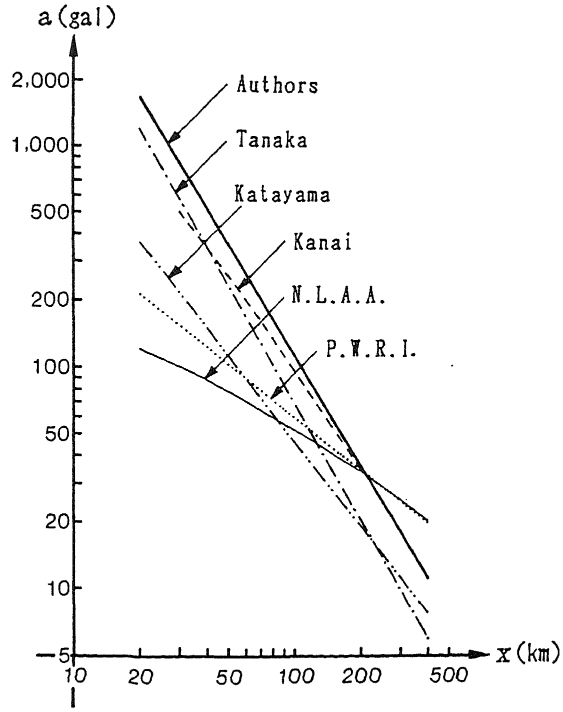


Fig.6 Comparison of the empirical formulae obtained here and those by other researchers (case of M=7)

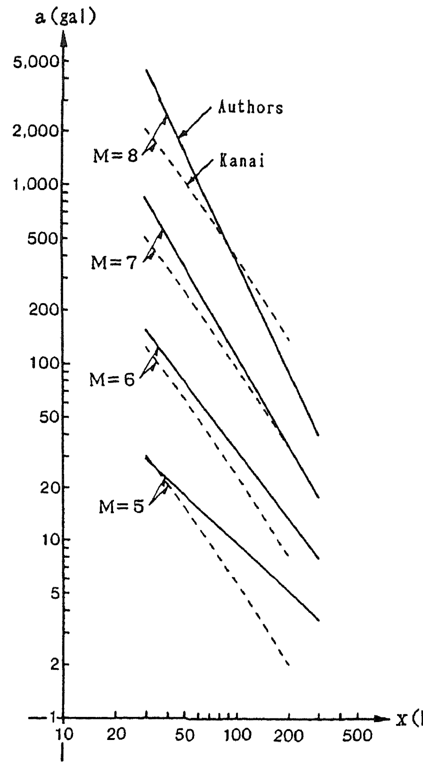


Fig.7 Comparison of the empirical formulae obtained here and those by one of the authors (case of T_G is 0.3 sec)

conclusion of our former paper (see Ref. 5).

One of the authors carried out already the measurement of the ground vibrations caused by air compressors in a site of about 20 hectares under two different conditions (see Ref. 6). In one of them, no structure was existing on the site, and in the other, 160 numbers of 2 ~ 4 storied reinforced concrete buildings (apartment houses) were constructed on the same site. The same figure of Fig. 4 and the result mentioned above are shown in Fig. 8. In Fig. 8, white marks of triangle and square express after the buildings were built, and black marks of them express before the buildings were built (triangle and square marks express radial and transverse components of waves, respectively).

In Fig. 8, it may be said that the large number of buildings in the area of a big city have a great influence on the attenuation coefficient of earthquake motions, and this result agrees with the conclusion of our former paper (see Ref. 5).

CONCLUSIONS

The conclusion of the present paper consists of three parts : that is, (1)a new type empirical formula on the attenuation of the maximum acceleration of earthquake motions was obtained as follows :

$$\log_{10} a = 1.29M - (0.38M - 0.99)\log_{10} x - 3.64$$

in which a , M and x represent the maximum acceleration of earthquake motions in gal, magnitude and hypocentral distance in km ;
(2)an empirical formula on the attenuation obtained here is in very good agreement with the empirical formula obtained by one of the authors ;
(3)the present investigation ascertained largely that the large number of buildings in the area of a big city has a great influence on the attenuation coefficient of earthquake motions.

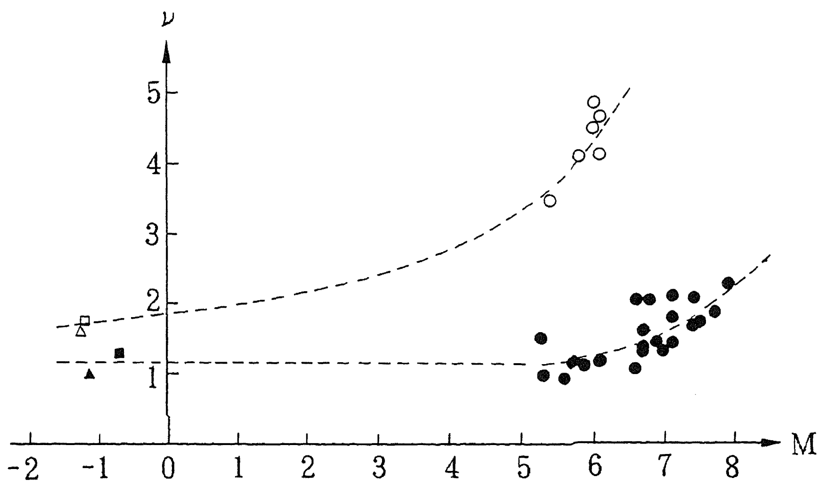


Fig.8 Relation between M and ν (triangle and square marks express the result of the measurement of the ground vibrations caused by air compressors)

ACKNOWLEDGMENTS

In conclusion, the authors wish to express their thanks to Mr. H. Moriya of Mabuchi-Kensetsu Co. Ltd. and the students of the College of Industrial Technology, Nihon University who assisted them in preparing this paper.

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