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ON A METHOD TO OBTAIN DISPLACEMENT WAVE FORM FROM THE RECORD OF EARTHQUAKE ACCELERATION

地震加速度記録から変位波形をもとめる一手法について

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1.　Introduction

It is especially necessary for the response analysis of the structure subjected to multi-seismic inputs to obtain wave forms not only of acceleration but of velocity and displacement.　It is desirable that they are observed by the adequate instruments recpectively.　　However,　at　present　only　the acceleration is taken from the view point of aseismic engineering.　It also goes without saying that if the velocity and the displacement are obtained, they are expected to be suggestive for the response analysis of the system having a long natural period and for the investigation from the energy　viewpoint.

The authors tried to obtain the wave forms of velocity and diaplacement by integrating that of acceleration through digital computer[1].　Here a method making use of analog computer will be shown.　The difficulty that the integrated wave form easily diverses during direct integral is prevented　by　carrying　out　the　approximate integral.

2.　Integral Operation

(1)　It is usually very difficult to keep the mean of the integrated wave forms around zero with direct integration using analog computer.　This is improved by performing the approximate integral. The characteristic of the system is same as that of　one-degree-of-freedom　system,　the　natural period of which is longer than the band width of the earthquake record.　If the acceleration wave form is added to the system, the integral is carried out for the frequency component, however at the same time transient response of the system with
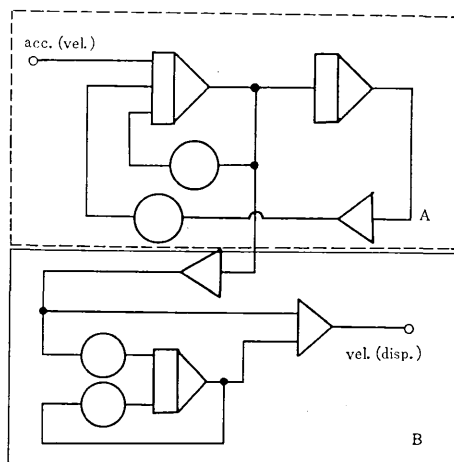
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Fig. 1　Block diagram for integral by analog computer

long　natural　period　T_0　is　excited.　From the restriction　of　the　saturation　of　operational voltage,　T_0　can　be　taken　as　10～20 sec at most. In order　to　suppress　the　latter,　at　first　certain amount　of　damping　is　introduced.　The block diagram　for　the　operation　is　shown　in　Fig. 1 as dotted-line A.

(2)　Next,　to　get　rid　of　these　long　period component,　the　integrated　wave　forms　go　through high pass filter with appropriate cut-off period T_s.　T_s　has　to　be　chosen　by　taking　the band width　of　earthquake　motions,　the　natural　period and　the　damping　constant　of　the　appropriate integral system into consideration.　This operation is shown in Fig. 1 as B.　If the integral is repeated twice　as　for　the　acceleration,　the　displacement is obtained.

3.　Examples of the Computation

As the actual earthquake records, El Centro (NS, May, 1940), Taft (NS, July, 1952) and the record at Akita for Niigata Earthquake (EW,
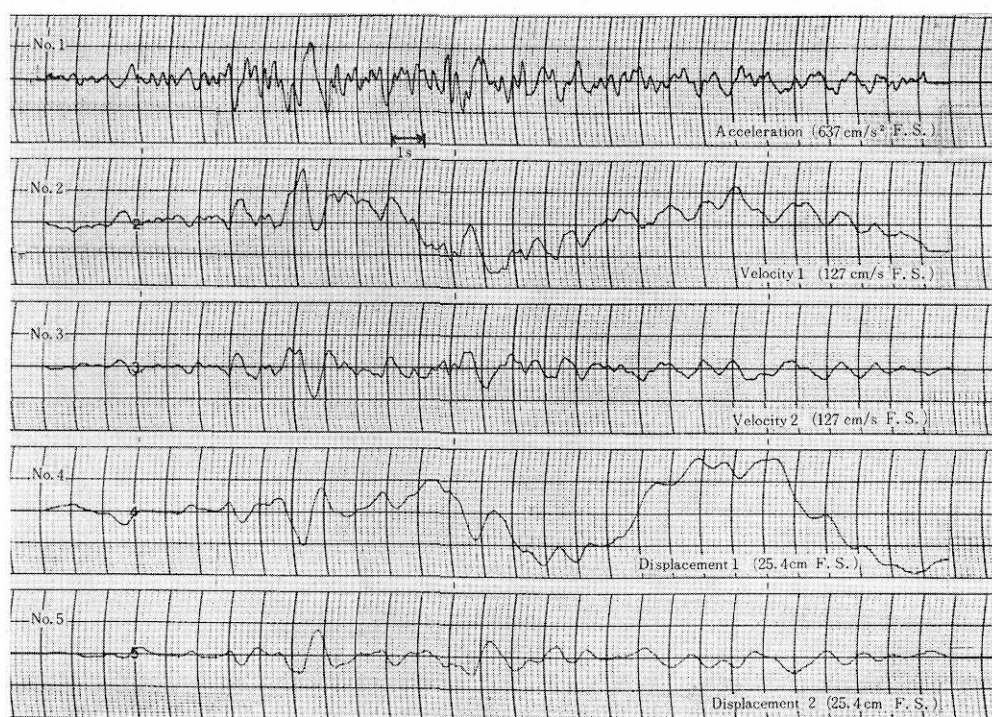
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Fig. 2　Integral of earthquake record through operation (1) and (2) for Akita Wave
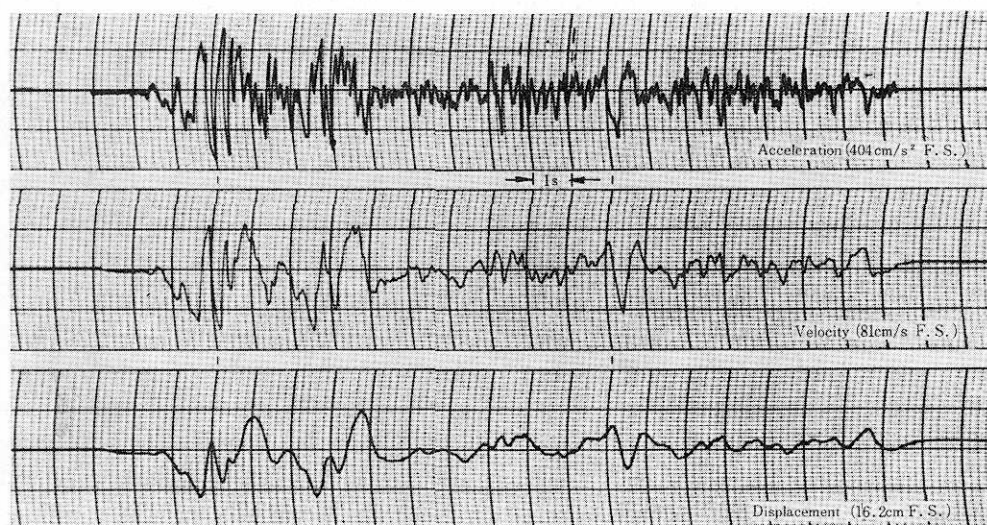$T_0=13.0$ s, $T_s=5.0$ s $(h=0)$

Fig. 3　Earthquake record and its integrated velocity and displacement for El Centro Wave $(h=0.25)$

June, 1964) are used.　In the analysis, 0.33 g for El Centro and 0.3 g for Taft and Akita are taken for their maximum acceleration[2].

Line No. 1 in Fig. 2 shows Akita acceleraticn. Line No. 2 shows integrated velocity including the component of long natural period and No. 3 is one that its long period components have been taken away through the filter $T_s=5.0$ sec.　Lines No. 4 and No. 5 are as for the displacement which are obtained by integrating the wave of No. 3 similarly.　In this case damping is not introduced.　Fig. 3 and Fig. 4 show the case

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Fig. 4　Earthquake record and its integrated velocity and displacement for Akita Wave ($h=0.10$)

that the approximate integral system have a damping.　Damping ratio is taken as 0.25 and 0.10 recpectively.　Thus obtained velocity and displacement wave forms fairly well coincide with those through the numerical integration by the digital computer[1].

4.　Frequency Characteristic of the System

　　Transfer function of the approximate integral is given as

$$G_1(s) = \frac{s}{s^2 + 2h\omega_0 s + \omega_0^2} \qquad (1)$$

where ω_0 and h are no damped circular frequency and damping ratio of the system respectively, and that of high pass filter as follows

$$G_2(s) = \frac{T_s s}{1 + T_s s} \qquad (2)$$

Therefore the transfer function for the total system is written as

$$G(s) = G_1(s)G_2(s) = \frac{T_s s^2}{(s^2 + 2h\omega_0 s + \omega_0^2)(T_s s + 1)} \qquad (3)$$

In Fig. 5 some examples of the Bode diagram that have been taken in their practice are shown. In this diagram, we see that, if components of the earthquake period are less than 3.0 sec, these integral operation have scarcely affected the gain and phase characteristic of the system.

　　If the components of longer period are to be
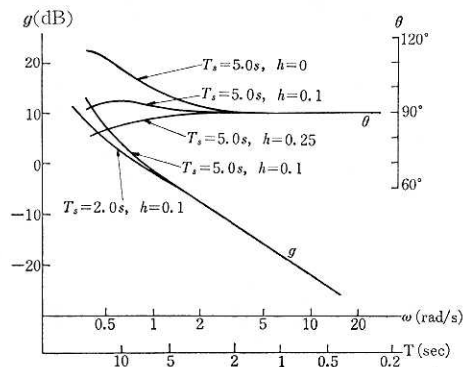
Fig. 5　Bode diagram of the tranfer function $G(s)$, ($T_0 = 10$ sec)

considered, frequency range is able to be shifted appropriately by changing T_0, T_s and h.

5.　Conclusions and Acknowledgement

　　A method to obtain the velocity and the displacement wave forms easily and stably from the record of acceleration is shown.　This is carried out by the approximate integral using analog computer.　Several examples of the computation are given.　Maximum value for these are shown in Table 1.

　　The frequency characteristic of the transfer function for the operation is studied.　An example of preferable constants of the system are shown.

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Table 1 Maximum value of acceleration and integrated velocity and displacement ($h=0.10$)

	Acc. (g)	Vel. (cm/s)	Disp. (cm)
El Centro	0.33	57.0	12.2
Taft	0.30	48.8	10.9
Akita	0.30	70.0	14.0

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Reference

1) H. Sato and K. Suzuki: Response of Structure Model Subjected to Two Seismic Motions with Certain Time-Lag Interval, Jour. I. I. S., 21-3, 1969-3.
2) SERAC: Nonlinear Response Analysis of Tall Building to Strong Earthquake and its Application to Aseismic Design. No. 6, 1966.