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EXACT SPECTRA OF KOYNA AND EL CENTRO ACCELEROGRAMS

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INTRODUCTION

Conventional methods of evaluating spectra assume that records obtained from accelerometers represent accelerations as a function of time. This is nearly true, only for periods longer than the undamped period of the accelerometer. For determination of spectra corresponding to very short period systems or for higher modes of longer period systems it is necessary to apply a correction to the recorded data to take into account the characteristics of the accelerometer. Among the methods suggested, the one recently proposed by McLennan[3] takes this into account exactly.

In this paper, the influence of accelerometer correction has been investigated for three accelerograms, namely, Longitudinal and Transverse component of Koyna earthquake of December 11, 1967 and North South component of El Centro earthquake of May 18, 1940. It is seen that for periods longer than 0.1 second there is practically no error in the conventional method. However, for shorter periods, the conventional method gives values which are smaller than the actual ones. For values of periods near the undamped period of accelerometers the error is as much as 40% for Koyna shock and about 20% for El Centro shock. The error is generally larger for Koyna shock compared to El Centro shock which may be due to the fact that Koyna shock had a preponderance of short period components compared to El Centro shock[2]. The error is of the same order both for undamped and damped spectra.

EVALUATION OF SPECTRA

To evaluate spectra by taking into account instrumental characteristics, two methods are available. One is by Jenschke and Penzien[1] and the other by McLennan[3]. The method proposed by McLennan is recent and quite simple for evaluation of exact spectra and briefly summarised below :

The equation of motion of a single degree freedom system is

$$\ddot{Z} + 2\, p\, \zeta\, \dot{Z} + p^2 Z = -\, a\,(t) \qquad (1)$$

where p is the natural frequency, ζ is the percentage of critical damping and a(t) is the ground acceleration.

The accelerometer is also a single degree freedom system, its equation of motion is

$$\ddot{X} + 2\, p_0\, \zeta_0\, \dot{X} + p_0^2\, X = -a(t) \qquad (2)$$

where the X is the instrument displacement.

Equating 1 and 2

$$\ddot{Z} + 2\, p\, \zeta\, \dot{Z} + p^2 Z = \ddot{X} + 2\, p_0\, \zeta_0\, \dot{X} + p_0^2\, X \qquad (3)$$

It has been the practice to assume $p_0^2\, X = -\, a\,(t)$ and therefore the response so obtained is not exact.

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Solution of equation 3 is given by

$$Z = \frac{1}{p_d} \int_0^t \left(\ddot{X}(\tau) + 2\, p_0\, \zeta_0\, \dot{X}(\tau) + p_0^2\, X(\tau) \right) e^{-p\zeta(t-\tau)} \sin p_d (t-\tau)\, d\tau \qquad (4)$$

where $p_d = p\sqrt{1-\zeta^2}$

The above solution involves $\dot{X}$ and $\ddot{X}$ which are difficult to obtain. Another solution of equation (3) is given by

$$Z(t) = X(t) + \alpha \int_0^t X(\tau)\, e^{-p\zeta(t-\tau)} \cos p_d(t-\tau)\, d\tau + \beta \int_0^t X(\tau)\, e^{-p\zeta(t-\tau)} \sin p_d(t-\tau)\, d\tau \qquad (5)$$

where $\alpha = 2\, p_0\, \zeta_0 - 2\, p\, \zeta$

and $\beta = \dfrac{(p_0^2\ \ p^2) - \alpha\, p\, \zeta}{p_d}$

DISCUSSION OF RESULTS

Three accelerograms have been considered for this study. One of them is the North-South (El-102) component of El Centro earthquake of May 18, 1940 and the other two are the longitudinal (EQ-111) and transverse (EQ-112) component of Koyna earthquake of December 11, 1967.

It is assumed that in each case, the accelerometer had a natural frequency of vibration of 18 cycles per second and a damping of 65 percent of critical. These were the nominal characteristics of the instruments at Koyna and the same is assumed for El Centro instrument.

Exact response as well as conventional response values have been worked out and plotted in figures 1, 2 and 3 for periods between 0.05 to 0.1 second. For values of periods above 0.1 second it is found that the two response values are nearly identical indicating that the accelerometer records nearly true values of acceleration for periods above 0.1 second. To determine the influence of damping, response values have been worked out for 5% damping in addition to zero damping.

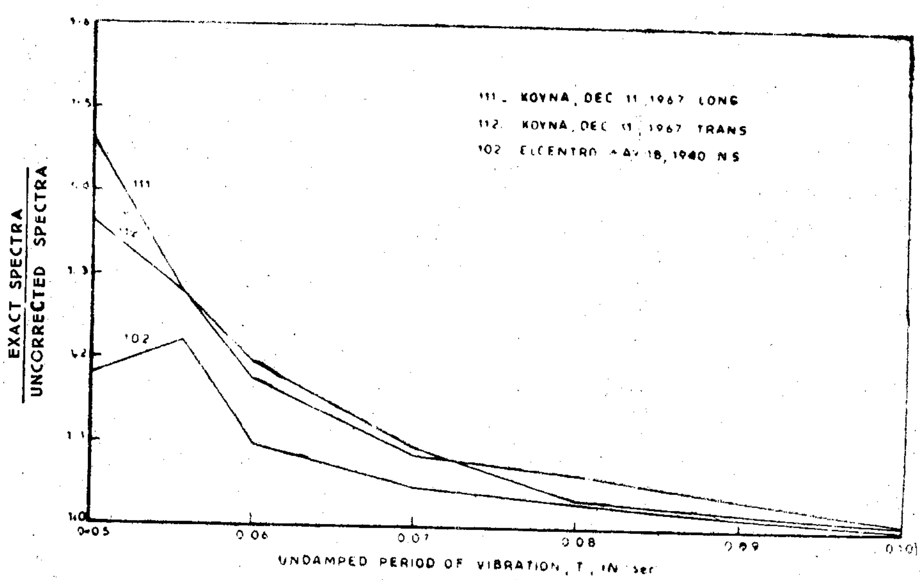

Figure 1 Influence of Accelerometer Correction on Response Spectra.

Figure 1 shows a plot of ratio of exact spectra to uncorrected spectra for various values of periods. For values of periods near the undamped period of accelerometers, the error is as much as 40% for Koyna shock and about 20% for El Centro shock. Figures 2 and 3 show plot of psuedo velocity for various periods. It is seen that the error is of the same order for both undamped and damped spectra.

The error in spectra is larger in case of Koyna shock compared to El Centro shock. This could be due to the fact that the number of zero crossings are more in Koyna record with a correspondingly greater percentage of high frequency components.

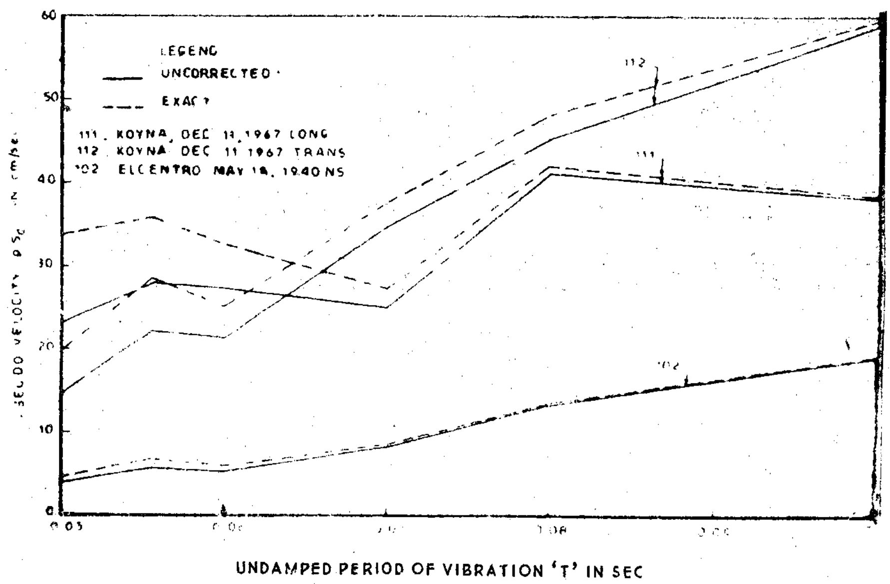

Figure 2 Max Velocity Response. A Comparision Between Exact and Uncorrected Spectra. Damping-0%

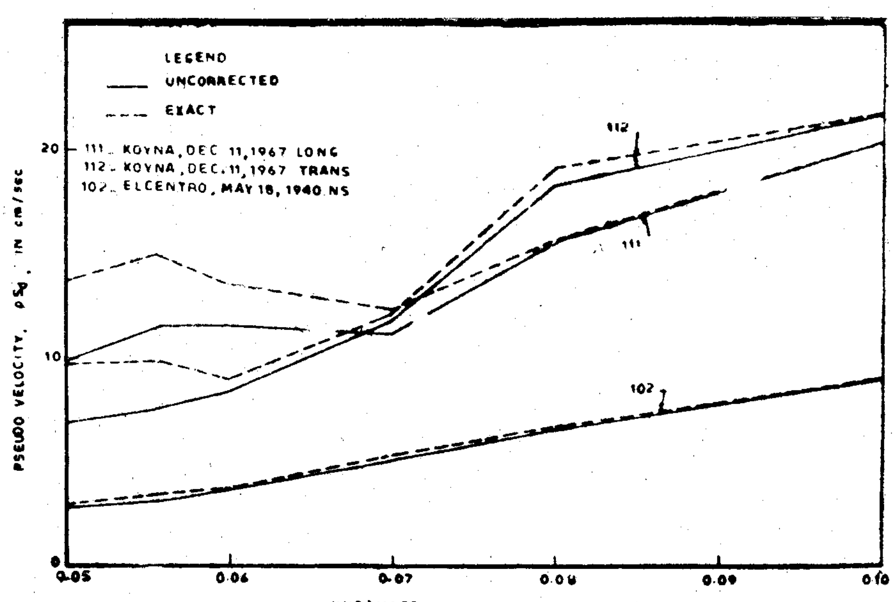

Figure 3. Max. Velocity Response. A Comparsion Between Exact and Uncorrected Spectra. Damping-5%

CONCLUSIONS

Exact spectra have been worked out for typical actually recorded ground motions. For values of periods above 0.1 seconds, no corrections are needed for instrumental characteristics. However, for very short periods, errors would be large if response is evaluated by assuming the record to represent ground acceleration.

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