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PSEUDO EARTHQUAKES DERIVED FROM RECORDED ACCELEROGRAMS

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INTRODUCTION

Accelerogram forms an important part of data in computing structural response due to an earthquake. For design of structures in seismic zones, the accelerogram of a probable future shock needs to be predicted This is a very difficult task as instrumental data for a particular site would normally not be available. A designer would therefore like to make an estimate of accelerogram characteristics based on experience in similar conditions elsewhere. Methods of generating artificial earthquakes have been developed [3,4] for use in various situations. Pseudo earthquakes can also be derived from recorded earthquakes. One such attempt[1] was made by shuffling acceleration ordinates of the accelerogram. This changed the time of occurence of the impulses while the frequency contents of the accelerogram were not much altered. Response spectra obtained for such shuffled accelerogram indicated that the spectral quantities are not much affected by this process. Such modifications, therefore, do not seem to provide a variety of data to be used in different situations.

It has been observed[2] that as the distance from epicentre increases, the accelerogram shows lower frequency components as also the acceleration amplitudes get attenuated. If an accelerogram has been obtained at a certain distance from the epicentre, it would be reasonable to assume that at greater distances than this, the frequencies present shall be lower and vice versa.

In connection with predicting an accelerogram for a dam site it was desired that it has the important characteristics of two of the strongest recorded earthquakes viz. El Centro May 18, 1940 and Koyna Dec. 11, 1967. The method of changing the time base was proposed by the authors so that the response spectra of the pseudo earthquake had the desired features in the frequency range of interest. Tsai[6], working independently, has also proposed such a method of changing time base to derive pseudo earthquakes.

A definition of intensity of the earthquakes corresponds to the area under the curve of spectral velocity versus period. A different interpretation of this definition has been given which may be useful for multiple degree and continuous systems.

INFLUENCE OF CHANGE IN TIME BASE

The equation of motion of an idealized single degree oscillator with mass m, damping c and stiffness k is given by.

$$m\ddot{x} \; c\dot{x} + + kx = - m\ddot{y}(t) \tag{1}$$

in which x is the relative displacement of mass with respect to ground and y is the ground

On page 97, equation No. : (1) should be as follows

$$m\ddot{x} + c\dot{x} + kx = - m\ddot{y}\,(t) \tag{1}$$

Modification of time base t by a factor λ can be accounted for by putting $\tau = \lambda t$, in which τ is a new time parameter. Eqn. (1) would then be as follows :

$$m \lambda^2 \frac{d^2x}{d\tau^2} + c \lambda \frac{dx}{d\tau} + kx = -m \lambda^2 \frac{d^2y}{d\tau^2} \tag{2}$$

Dividing throughout by λ^2 one obtains,

$$m \frac{d^2x}{d\tau^2} + \frac{c}{\lambda} \frac{dx}{d\tau} + \frac{k}{\lambda^2} x = - m \frac{d^2y}{d\tau^2} \tag{3}$$

Solution of Eqn. (3) in terms of spectral quantities of modified time-based accelerogram and those of original one can be written as follows :

$$(S_d^*)_{\lambda T} = (S_d)_T . \lambda^2 \tag{4a}$$

$$(S_v^*)_{\lambda T} = (S_v)_T . \lambda \tag{4b}$$

$$(S_a^*)_{\lambda T} = (S_a)_T . \tag{4c}$$

in which asterik indicates modified spectral quantities.

STUDY OF RESPONSE SPECTRA

Figs 1—3 show the spectral quantities S_a, S_v and S_d respectively for 5% damping for two recorded accelerograms Koyna Dec. 11. 1967 Longitudinal component (KL) and EL Centro May 18, 1940 N-S component (EC). Response parameters for KL with $\lambda = 1.5$ and EC with $\lambda = 0.66$ have also been plotted in the respective figures. It is interesting to note that spectral quantities for KL accelerogram compare very well with those of EC with $\lambda = 0.66$. Also, spectral quantities for EC accelerogram compare well with those of KL with $\lambda = 1.5$. This is a clear indication that accelerogram recorded at one site could be used for determining spectral quantities at another place by a suitable choice of factor λ. This factor could be obtained as the ratio of spectral velocities of two earthquakes in the range in which S_v tends to be flat. This is clear from eqn. (4 b).

It is thus seen that elongation or contraction of the time base of accelerogram results in change of the intensity potential of an earthquake. In this context, the effect of λ on 'intensity' has also been studied.

INTENSITY OF SHOCK

Intensity of earthquake has been used by various authors as a means to decribe the potential of a shock, Among these, peak ground acceleration, peak ground displacement, spectral intensity, root mean square acceleration, and time averaged r. m. s. value of ground acceleration have been suggested[5]. From the point of view of structural designer, the spectral intensity given by Housner seems to be an objective method of defining earthquake intensity. But all these definitions have limited use for single degree freedom systems and may not be applicable for systems with multiple degrees or for continuous systems.

A designer would be interested in knowing about spectral quatities in fundamental mode and a few higher modes. In such cases the quantity of interest would be the area of Sv V_s T curve upto the fundamental period. With this in view, the following parameter called 'Velocity Intensity' of shock is defined as,

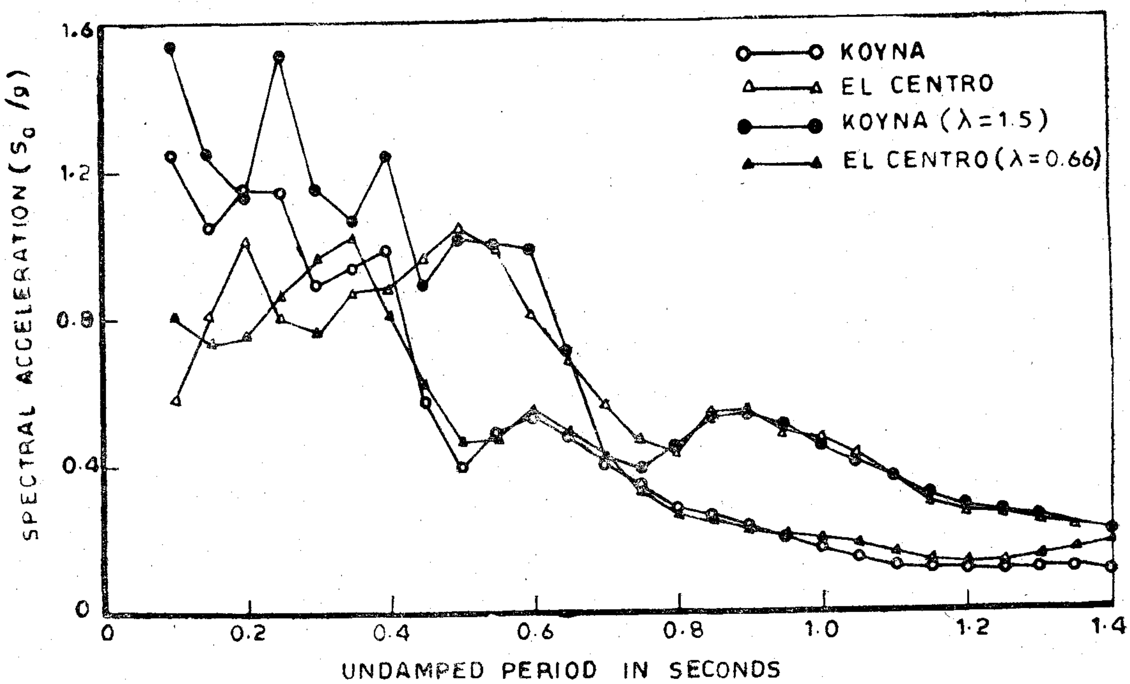

Figure 1. Acceleration Spectra for Koyna, El Centro, Modified Koyna and Modified El Centro Shocks (Damping = 5%)

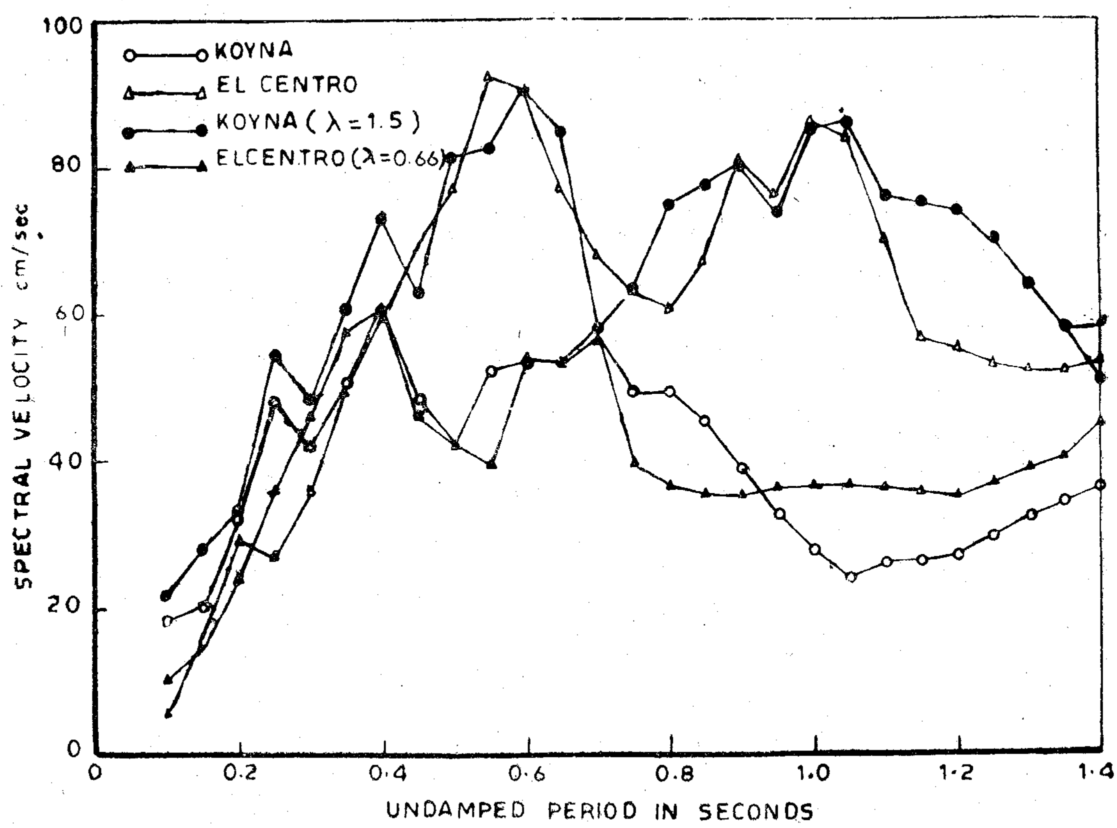

Figure 2. Velocity Spectra for Koyna, El Centro, Modified Koyna and Modified El Centro Shocks (Damping = 5%)

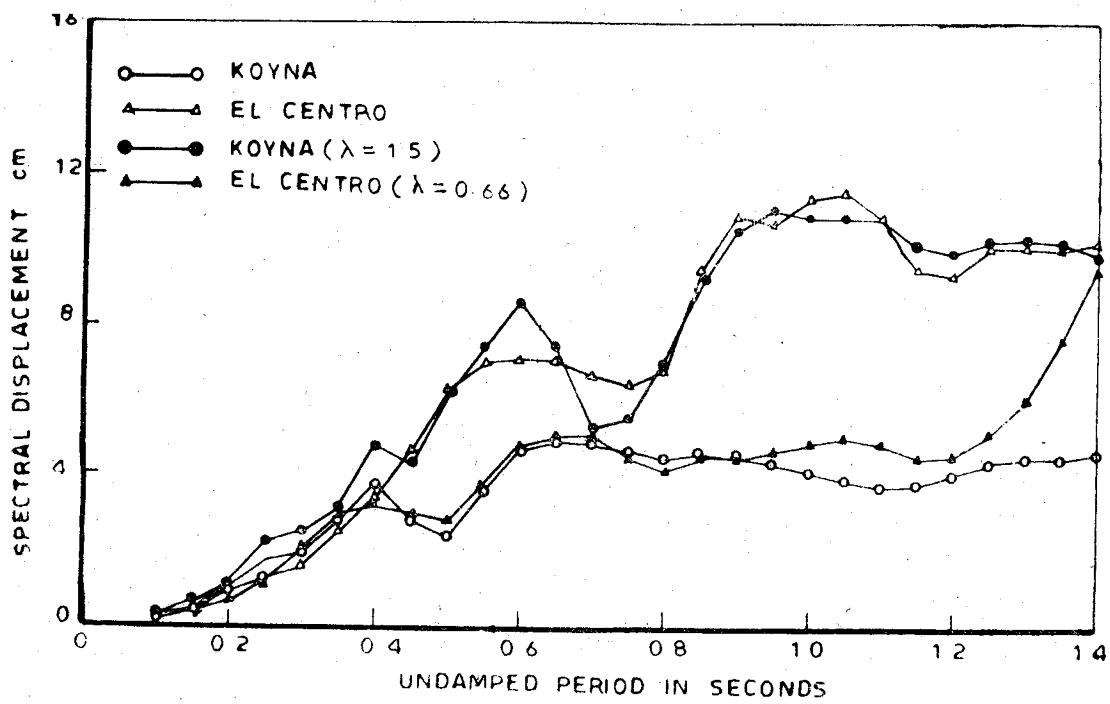

Figure 3. Displacement Spectra for Koyna, El Centro, Modified Koyna and Modified El Centro Shocks (Damping = 5%)

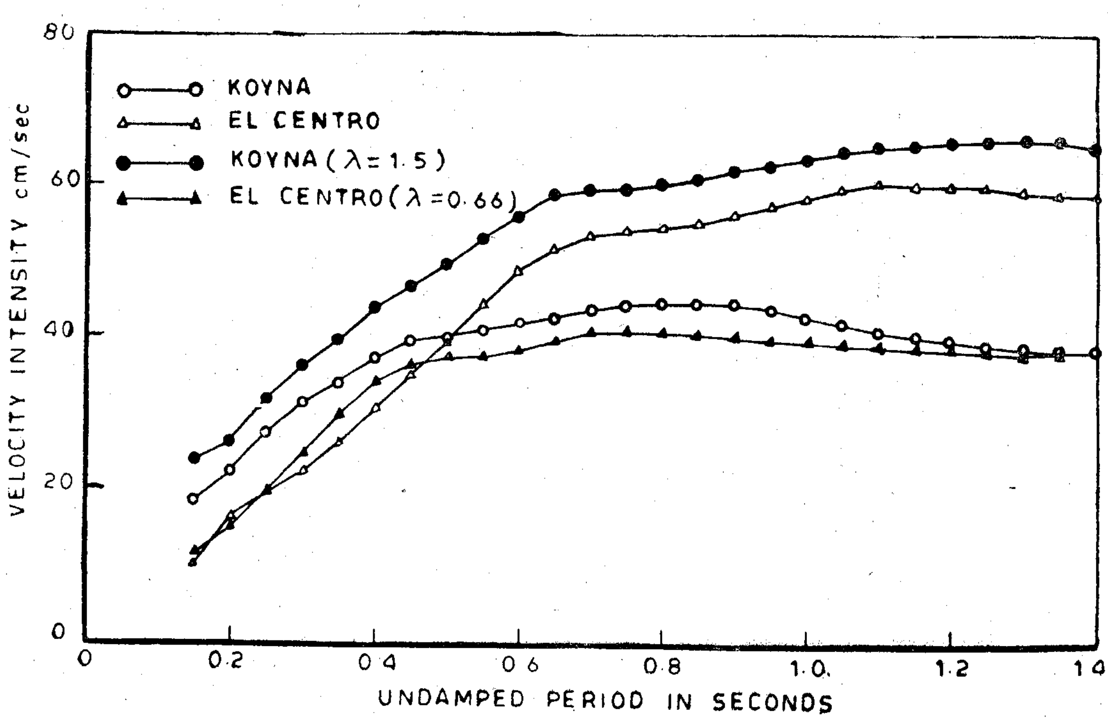

Figure 4. Velocity Intensity for Koyna, El Centro, Modified Koyna and Modified El Centro Shocks (Damping = 5%)

$$VI = \frac{1}{T-0.1} \int_{0.1}^{T} S_v (T. \zeta) \, dT \tag{5}$$

Fig. 4 shows a plot of VI versus T for accelerograms KL, EC, KL with $\lambda = 1.5$ and EC with $\lambda = 0.66$ and corresponding to 5% damping. Again, it will be noticed that VI plots for KL and EC with $\lambda = 0.66$ as also for EC and KL with $\lambda = 1.5$ are in reasonably good agreement.

For some of the examples of multiple degree systems worked out by the authors, the ratio of response as obtained for two earthquakes corresponds to the ratio of VI for those two earthquakes at the appropriate fundamental period.

CONCLUSIONS

Elongation or contraction of time base of accelerograms as described in this paper may be used for generation of pseudo earthquakes.

It is felt that velocity intensity of the earthquake as defined here will be found very helpful in comparing response of multiple degree and continuous systems under different earthquakes.

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