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SPECTRUM ANALYSIS OF STRONG-MOTION EARTHQUAKES*

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ABSTRACT

The problem of the dynamic response of a structure to earthquake ground motion has been formulated in a manner which permits separation of the characteristics of particular structures from the characteristics of the earthquake. The expression involving the characteristics of the earthquake is defined as the "spectrum" of the earthquake and it is shown that the spectrum is a plot of the maximum response of a simple oscillator versus the period of the oscillator. Eighty-eight such spectra were computed by means of an electric analog computer and are presented in this paper. It is found that damping is a very important parameter in the over-all problem; relatively small amounts of damping reduce the structural response sharply. Further research on damping in buildings is recommended, and it is also proposed that the spectrum be used as a quantitative measure of earthquake intensity.

Introduction

When an earthquake takes place the base of a structure is subjected to a variable acceleration, and dynamic stresses are developed throughout the structure. The destructive effect of strong earthquakes on structures not specifically designed to withstand such stresses has demonstrated the need for methods of aseismic structural design. In order that these methods be as realistic as possible it is desirable to have an understanding of the dynamic response of structures to earthquake motions.

The attack on this problem has utilized three principal approaches: the accumulation of empirical data by study of actual earthquake damage, the performance of experiments on structures and structural models, and the making of analytical studies. This report is of the last type and presents an analysis of certain phases of the earthquake problem.

The response of a structure to an earthquake is essentially a vibration problem; therefore an analytical solution should be possible which depends on the mass, rigidity, and damping of the structure and on the nature of the soil which supports the structure. However, certain practical difficulties are encountered which obviate a straightforward approach. First, it is not possible to know the intensity and characteristics of a future earthquake; hence, even if a complete analytical solution were possible, it would not suffice for a predetermination of earthquake stresses. Second, the precise physical properties of the structure which are pertinent to the problem are not readily determined; it is doubtful whether these properties can be determined accurately before a structure is built. It is not possible, therefore, to predict

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what stresses will be produced by an unknown earthquake acting upon a structure the properties of which are not known precisely.

If we wish to obtain meaningful results it is necessary to restate the problem; instead of asking for the actual magnitudes of the earthquake stresses, we may legitimately ask the following question: Assuming that future earthquakes will have approximately the same characteristics as past earthquakes, how should structures be designed so that all parts have approximately the same factor of safety?

To answer this question it is necessary, first, to determine the significant characteristics of past earthquakes, and then to deduce the significant dynamic behavior of structures when subjected to such earthquakes. This paper is a statement of progress on the first phase of the problem, and it is based on a report[1] which describes more fully the results of a research study sponsored by the office of Naval Research and carried out at the California Institute of Technology.

Analytical Outline of the Earthquake Problem

The problem of evaluating the forces imposed on a structure by an earthquake is that of the response of an elastic, damped system of many degrees of freedom when subjected to an irregular transient motion at its base. For simplicity, linearly elastic structures having translations in one direction only will be considered. It is known[2] that during the free vibration of such a structure the displacement, y, at any point can be represented by the sum of the normal modes of vibration

$$y = \sum_i c_i \phi_i e^{-n_i p_i t} \sin p_i t \tag{1}$$

in which

c_i = undetermined coefficient
ϕ_i = i^{th} normal mode
p_i = 2π times the frequency of vibration of the ith mode
n_i = ratio of damping in i^{th} mode to critical damping (small damping)
t = time

If the free vibrations are initiated in such a fashion that at time $t = 0$ the displacement is zero and the velocity is v_0 at every point of the structure, then the coefficients c_i are evaluated in the Fourier manner, namely,

$$c_i = \frac{v_0}{p_i} \cdot \frac{\int \phi_i \rho}{\int \phi_i^2 \rho} = \frac{v_0}{p_i} \cdot W_i \tag{2}$$

in which ρ is the density and the integrals are taken over the entire mass of the structure. The corresponding free vibrations are then

$$y = \sum_i \frac{v_0}{p_i} W_i \phi_i e^{-n_i p_i t} \sin p_i t \tag{3}$$

[1] J. L. Alford, G. W. Housner, and R. R. Martel, "Spectrum Analysis of Strong-Motion Earthquakes," first technical report, ONR Contract N6onr-244, Task Order 25, California Institute of Technology, Pasadena, 1951.

[2] Lord Rayleigh, *Theory of Sound* (New York: Macmillan, 1937), pp. 91–170.

If now the base of the structure be subjected to a variable acceleration, a, the displacement at time t, is given[3] by

$$y = \sum_i \frac{W_i}{p_i} \phi_i \int_0^t a e^{-n_i p_i (t-\tau)} \sin p_i(t - \tau) d\tau \tag{4}$$

This may be written as

$$y = \sum_i \frac{W_i}{p_i} \phi_i X_i \tag{5}$$

in which

$$X_i = \int_0^t a e^{-n_i p_i (t-\tau)} \sin p_i(t - \tau) d\tau \tag{6}$$

It should be noted that the factor W_i/p_i is a function only of the physical properties of the structure, that is, mass, rigidity, and dimensions. The factor ϕ_i is a function of the space coördinates, and the factor X_i is a function of the earthquake (ground acceleration). The physical significance of equation (6) is that X_i^2 is a measure of the kinetic energy of an oscillator with frequency $p_i/2\pi$ which is subjected to the ground acceleration.

From equation (5) it can be seen that in order to investigate the significant characteristics of earthquakes it is necessary to evaluate X and determine its behavior as a function of p and n for past earthquakes. A study of the factors W_i/p_i and ϕ_i, on the other hand, would reveal the effect of the physical properties of a particular type of structure on its response.

Evaluation of the Spectrum

It will be noted from equation (6) that X is a function not only of the ground acceleration, a, but also of n_i, the damping ratio; of p_i, which is equal to 2π divided by the period of vibration of the ith mode; and of t, the time at which the integral is evaluated.

For a complete examination of X_i, it is necessary to evaluate the integral in equation (6) for all periods of vibration which are pertinent to the structural problem. In practice the calculations are made for periods of vibration between 0.1 second and 3.0 seconds, and for several values of damping ratio.

When X_i is computed for particular values of p_i and n_i, there is obtained a time history of a simple oscillator of the specified period and damping ratio as it responds to the recorded ground acceleration. This response passes through a maximum at some time prior to the end of the earthquake and it is this maximum value which is of interest for aseismic design. The spectrum will therefore consist of a plot of such maximum responses versus period of vibration, with damping ratio n, as a parameter.

Several methods have been used in the past for calculating the response; one of the first was a direct numerical integration of equation (6) using finite time intervals. Another was a semigraphical procedure in which an integraph was used. These

[3] Lord Rayleigh, *op. cit.*, p. 74.

methods have been described in a previous paper.[4] Both methods are excessively laborious and time-consuming, and both have the disadvantage of being feasible only for the case of zero damping. The torsion pendulum has also been used[5] and it is much more rapid than the aforementioned methods. The electrical analog[6] was used to compute the responses presented in this paper and it is by far the most rapid and convenient of the methods. In essence, the analog computer utilizes an electrical circuit such that, for a voltage input proportional to the ground acceleration, the response X of equation (6) is read directly from a cathode-ray tube. The voltage input is introduced through a photoelectric cell which scans a rotating film. The film is prepared by means of a special plotting table which plots a variable-width transparent path whose width is proportional to the magnitude of the acceleration during the earthquake. By means of a scanning slit a light ray, the total intensity of which is proportional to this width, is brought to bear on the photoelectric cell.

As described above, the maximum values of X (eq. 6) were determined over a range of periods from 1/10 second to 3 seconds, that is, for each period selected the maximum X was determined. These values of X, when plotted against periods and connected by straight lines, give the so-called "velocity spectrum" of the earthquake ground acceleration. When the maximum values of $(1/p)X$ are plotted against periods, there is obtained the so-called "acceleration spectrum" of the earthquake ground acceleration. The ordinate of the acceleration spectrum at any particular period may be taken to represent the maximum acceleration attained by a simple oscillator of that period when subjected to the earthquake.

A study of the errors involved in the above-described procedure was made in order to obtain an estimate of the accuracy of the end product. The analog computer is estimated, on the basis of calibrations, to have a probable error of 3 per cent. The redrawing of the accelerograms and the plotting on the film is estimated to introduce a probable error of 3 per cent. The accuracy of reading the cathode ray oscilloscope in the manner utilized is estimated to have a probable error of 4 per cent. Compounding those errors gives a resultant probable error of 6 per cent. Considering the use to be made of the spectra and the probable errors in the original accelerograms, this accuracy is within acceptable limits. The fact that the errors do not affect the character of the response or the character of the spectra makes the use of the analog computer particularly desirable, for once the films have been prepared they may be used for successive studies. The films thus constitute "standard" accelerograms which permit one to use exactly the same accelerogram for various studies and thus facilitate comparison.

Results of the Investigation

The U. S. Coast and Geodetic Survey supplied accelerograms of the fourteen earthquakes chosen as suitable for spectrum calculations. These are listed in table 1. For each of these earthquakes both horizontal components of the ground motion were

[4] G. W. Housner, "Calculating the Response of an Oscillator to Arbitrary Ground Motion," *Bull. Seism. Soc. Am.*, 31: 143–149 (1941).

[5] M. A. Biot, "A Mechanical Analyzer for the Prediction of Earthquake Stresses," *Bull. Seism. Soc. Am.*, 31: 151–171 (1941).

[6] G. W. Housner and G. D. McCann, "The Analysis of Strong-Motion Earthquake Records with the Electric Analog Computer," *Bull. Seism. Soc. Am.*, 39:47–56 (1949).

TABLE 1

SUMMARY OF SPECTRA AND EARTHQUAKE DATA

Location	Date	Component	Damping ratios					Fig. no.	Maximum acceleration recorded on accelerogram
			0	0.02	0.1	0.2	0.4		
Vernon, Calif.	Mar. 10, 1933	N 08 E	×	..	×	×	..	1	0.13g
		S 82 E	×	..	×	×	..	2	0.19
Vernon, Calif.	Oct. 2, 1933	N 08 E	×	..	..	×	×	3	0.09
		S 82 E	×	..	..	×	×	4	0.12
Los Angeles Subway Terminal	Mar. 10, 1933	N 39 E	×	..	×	×	..	5	0.04
		N 51 W	×	..	×	×	..	6	0.07
Los Angeles Subway Terminal	Oct. 2, 1933	N 39 E	×	..	..	×	×	7	0.07
		N 51 W	×	..	..	×	×	8	0.06
El Centro, Calif.	Dec. 30, 1934	N–S	×	..	..	×	×	9	0.26
		E–W	×	..	..	×	×	10	0.20
El Centro, Calif.	May 18, 1940	N–S	×	×	..	×	×	11	0.33
		E–W	×	×	..	×	×	12	0.23
Helena, Mont.	Oct. 31, 1935	N–S	×	..	×	×	..	13	0.14
		E–W	×	..	×	×	..	14	0.16
Ferndale, Calif.	Sept. 11, 1938	N 45 E	×	×	×	×	..	15	0.09
		S 45 E	×	..	×	×	..	16	0.16
Ferndale, Calif.	Feb. 9, 1941	N 45 E	×	..	..	×	×	17	0.04
		S 45 E	×	×	×	×	..	18	0.08
Ferndale, Calif.	Oct. 3, 1941	N 45 E	×	..	..	×	×	19	0.13
		S 45 E	×	..	..	×	×	20	0.12
Santa Barbara, Calif.	June 30, 1941	N 45 E	×	..	..	×	×	21	0.23
		S 45 E	×	..	..	×	×	22	0.24
Hollister, Calif.	Mar. 9, 1949	S 01 W	×	..	×	×	..	23	0.23
		N 89 W	×	..	..	×	×	24	0.11
Olympia, Wash.	Apr. 13, 1949	S 10 E	×	..	..	×	×	25	0.18
		S 80 W	×	..	..	×	×	26	0.31
Seattle, Wash.	Apr. 13, 1949	N 88 W	×	..	×	×	..	27	0.08
		S 02 W	×	..	×	×	..	28	0.06

analyzed. For each accelerogram, spectra were computed with various amounts of damping; the 88 spectra obtained are presented in figures 1 to 28. They show the maximum acceleration of a simple oscillator of given period when it is subjected to the ground acceleration of the earthquake. Table 1 lists the earthquake components and the damping ratios (relative to critical damping) that were used.

Discussion of Results

The spectra represent the behavior of a simple oscillator under the influence of earthquake ground accelerations. From these spectra can be obtained the maximum response that a particular oscillator would have had during a particular earthquake. Such information, in itself, is largely of academic interest; the real significance of the spectra is that they characterize the earthquakes with respect to their effects on structures.

Inspection of the spectra (figs. 1 to 28) shows that most of them follow the same general pattern; those of 18 May 1940, El Centro, may be taken as typical. Some of the spectra show deviations from the typical and those will now be discussed.

10 March 1933, Vernon, California.—This was the first earthquake recorded on the strong-motion accelerometers, and because of delay in the starting device and oversensitivity of the instrument the initial portion of the accelerogram is not reliable. This may have influenced the shape of the spectra. For the same reasons the Long Beach accelerograms of this earthquake were unusable.

10 March 1933 and 2 October 1933, Subway Terminal.—There was some starting delay in the accelerometer and it is not certain how much of the initial portion of the record was lost. This may account for the fact that the undamped spectra are not as prominent at the short-period end as are the more typical spectra. Additional records are required from this station to establish the true character of the spectra.

13 April 1949, Seattle, Washington.—The spectra show a very prominent peak in the vicinity of 0.9 second period. This may be due to the fact that the accelerometer is situated on filled ground with a high water table and is within 25 feet of a sea wall. During an earthquake this filled ground can be expected to be excited into motion with its own particular frequencies of vibration, and these would show up strongly on the spectra. It may be that this peak on the spectra represents a so-called "dominant ground period" of the site. It is, of course, a characteristic only of the filled ground in the vicinity of the sea wall and is not associated with the general Seattle area. This is interesting, for it is the only instance of a so-called "dominant ground period" that was found in any of the earthquake records.

Except for the above-mentioned deviations, the general characteristics of the spectra are similar for all the earthquakes. It will be noted, however, that some of the spectra show minor deviations from the typical. For example, the spectra of the Helena, Montana, earthquake of 31 October 1935 show a marked preponderance of high frequencies as compared to low frequencies. This is attributable to the fact that the accelerometer is on base rock, for which the velocity of propagation of seismic waves is much higher than for alluvium, upon which the other instruments are located. There is also noticeable a difference in detail between the spectra of the stronger earthquakes and the spectra of the weaker earthquakes, the chief difference being that the weaker earthquakes are relatively less intense in the long-period motions.

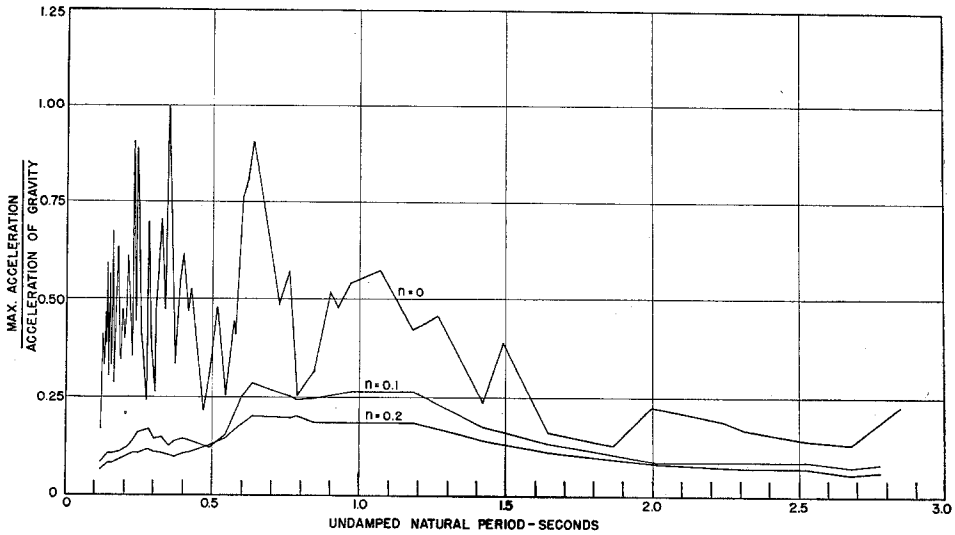

Fig. 1. Acceleration spectrum for Vernon, California; earthquake of 10 March 1933. Component N 08 E.

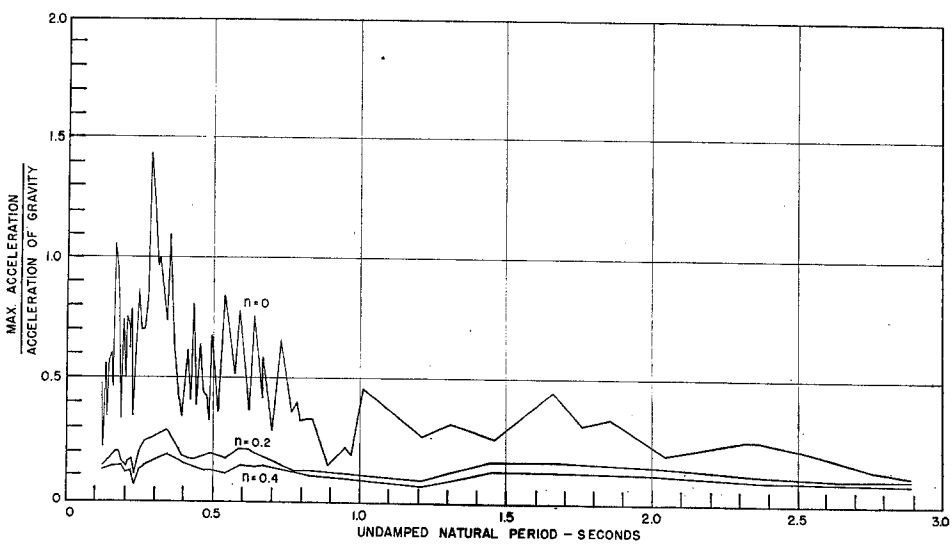

Fig. 2. Acceleration spectrum for Vernon, California; earthquake of 10 March 1933. Component S 82 E.

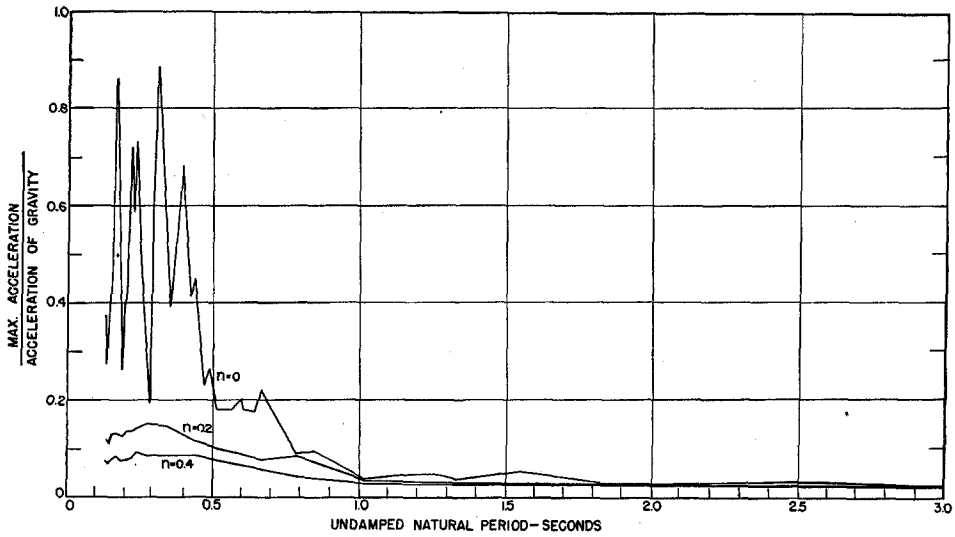

Fig. 3. Acceleration spectrum for Vernon, California; earthquake of 2 October, 1933. Component N 08 E.

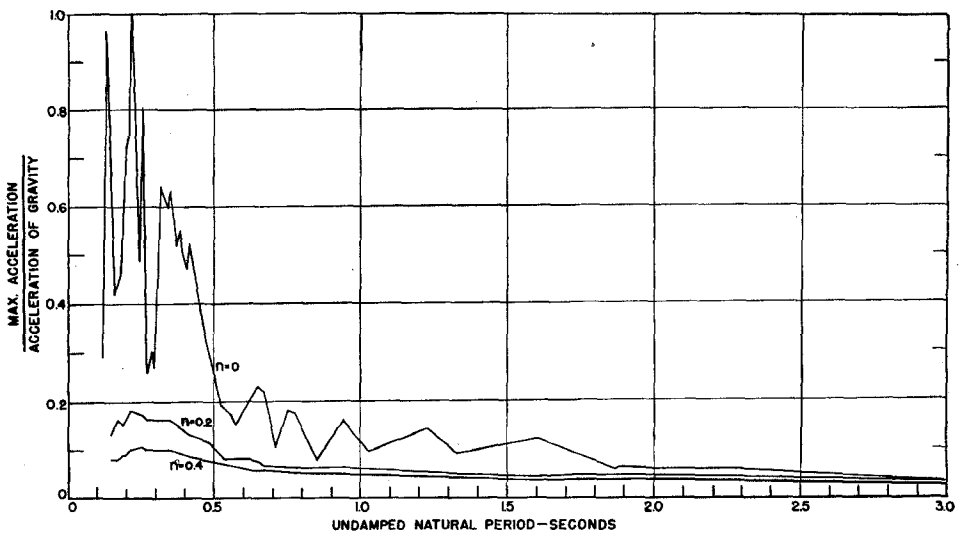

Fig. 4. Acceleration spectrum for Vernon, California; earthquake of 2 October 1933. Component S 82 E.

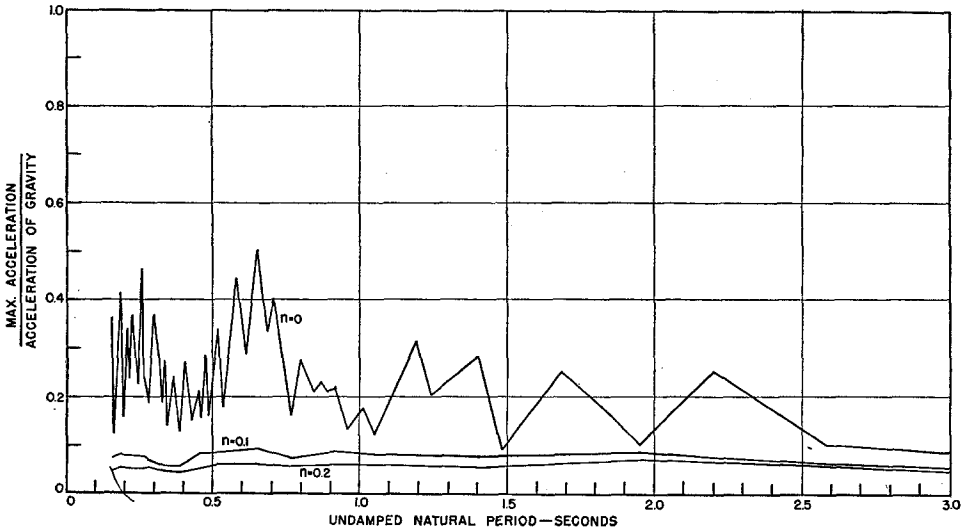

Fig. 5. Acceleration spectrum for Los Angeles Subway Terminal; earthquake of 10 March 1933. Component N 39 E.

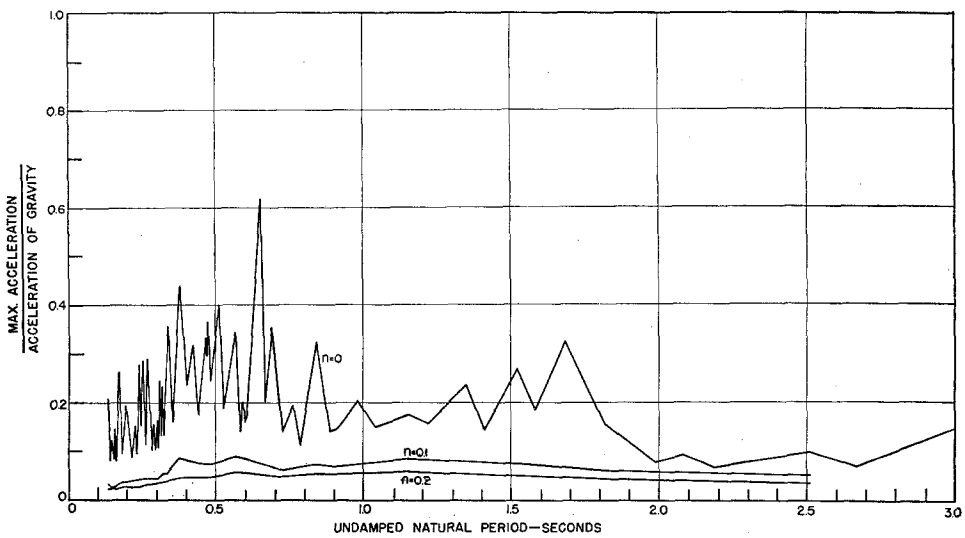

Fig. 6. Acceleration spectrum for Los Angeles Subway Terminal; earthquake of 10 March 1933. Component N 51 W.

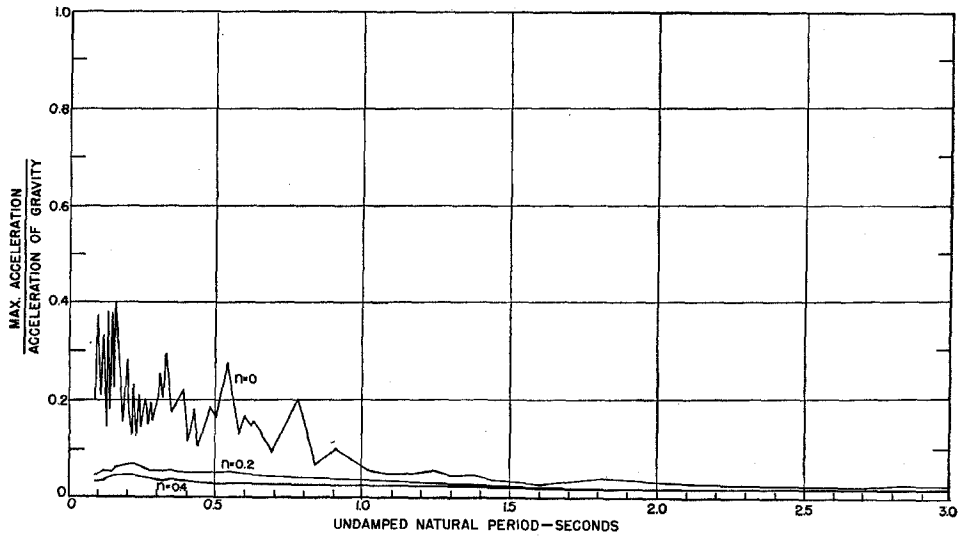

Fig. 7. Acceleration spectrum for Los Angeles Subway Terminal; earthquake of 2 October 1933. Component N 39 E.

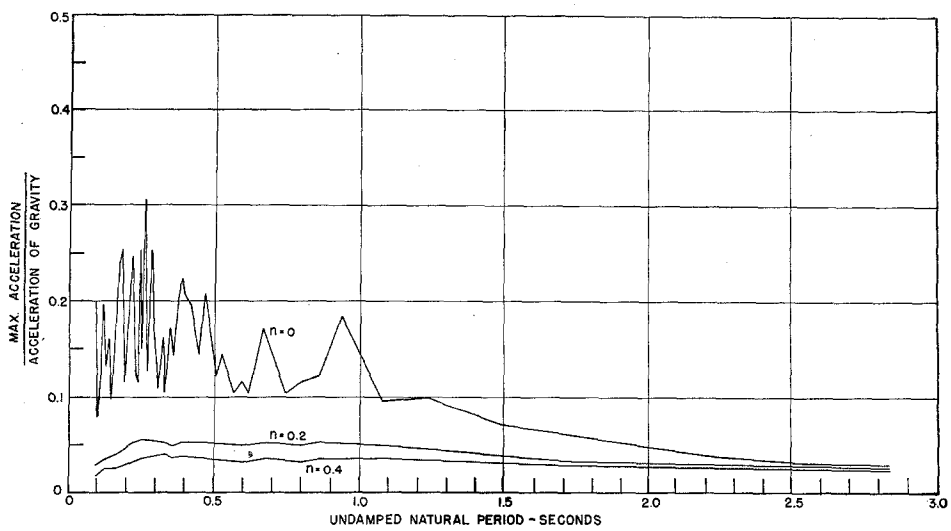

Fig. 8. Acceleration spectrum for Los Angeles Subway Terminal; earthquake of 2 October 1933. Component N 51 W.

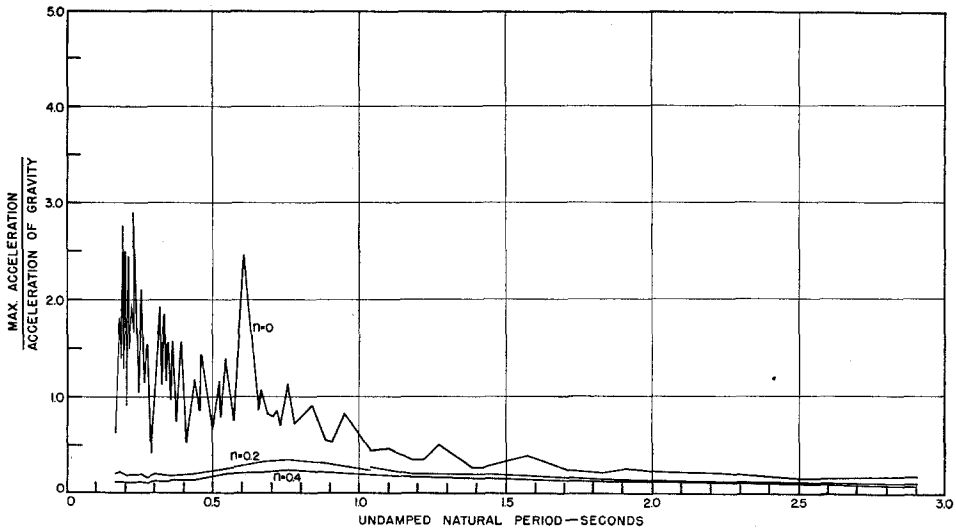

Fig. 9. Acceleration spectrum for El Centro, California; earthquake of 30 December 1934. Component N–S.

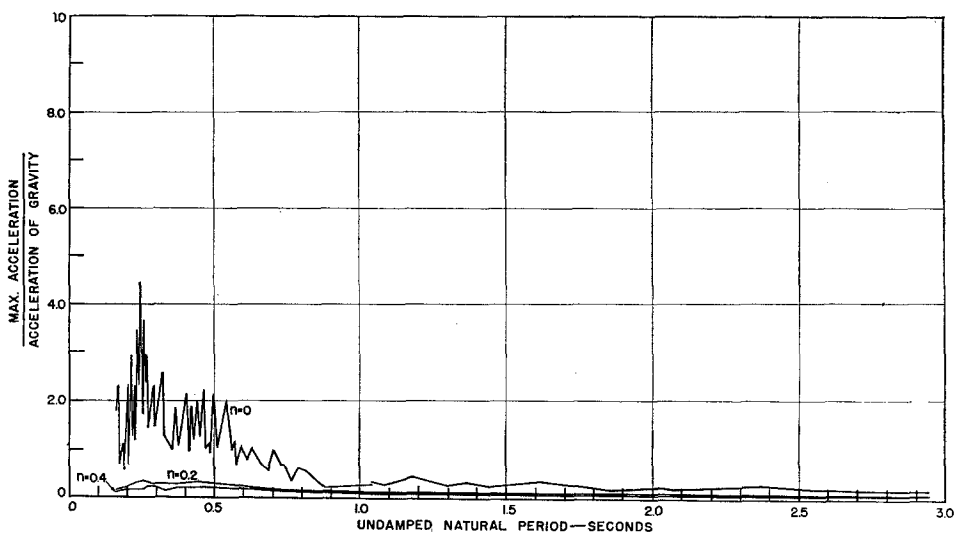

Fig. 10. Acceleration spectrum for El Centro, California; earthquake of 30 December 1934. Component E–W.

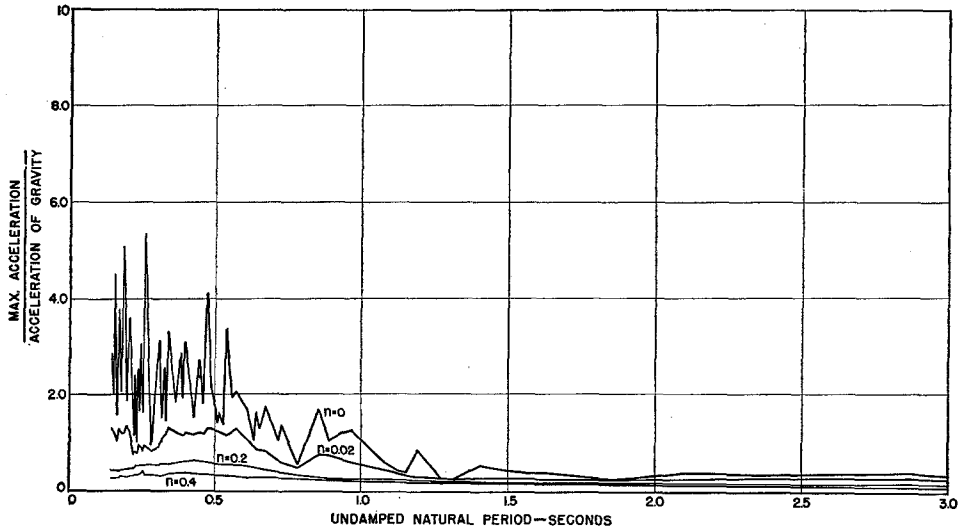

Fig. 11. Acceleration spectrum for El Centro, California; earthquake of 18 May 1940. Component N–S.

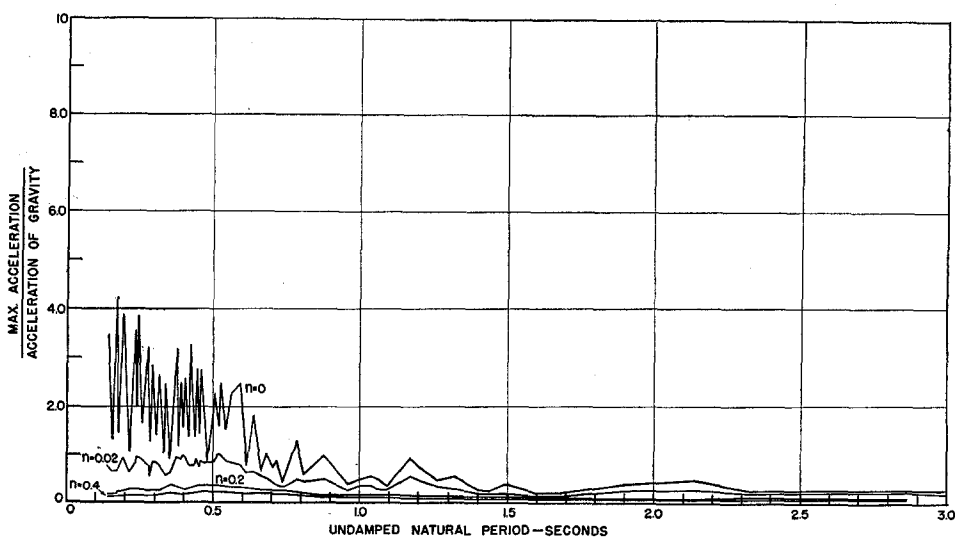

Fig. 12. Acceleration spectrum for El Centro, California; earthquake of 18 May 1940. Component E–W.

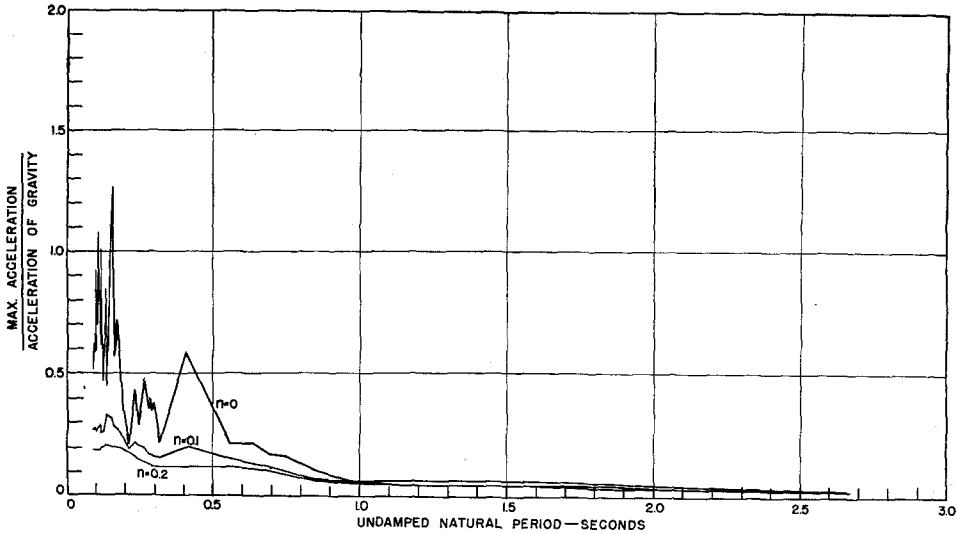

Fig. 13. Acceleration spectrum for Helena, Montana; earthquake of 31 October 1935. Component N–S.

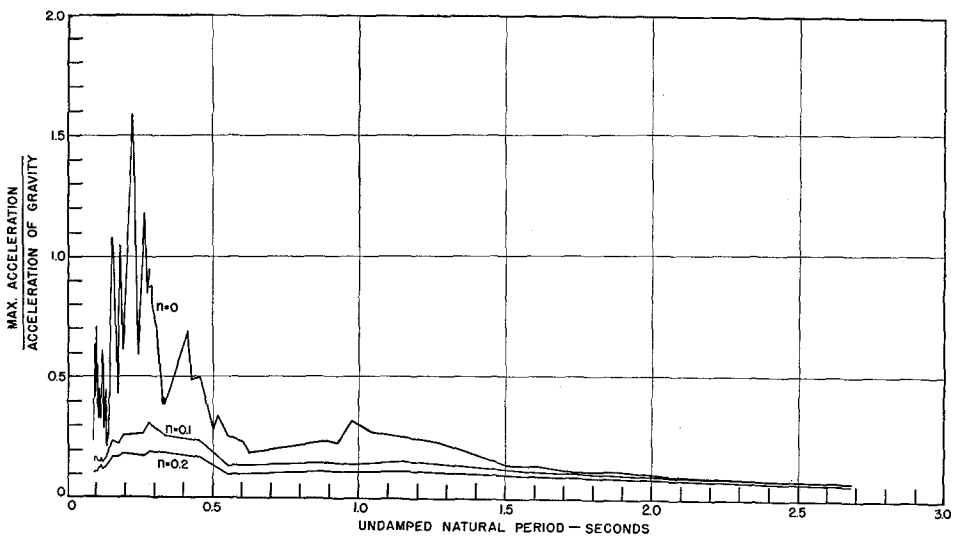

Fig. 14. Acceleration spectrum for Helena, Montana; earthquake of 31 October 1935. Component E–W.

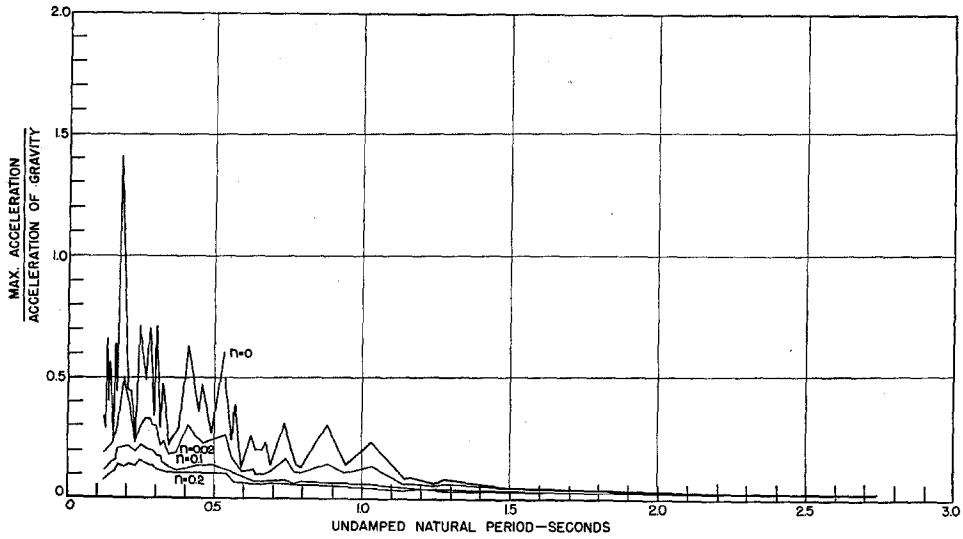

Fig. 15. Acceleration spectrum for Ferndale, California; earthquake of 11 September 1938. Component N 45 E.

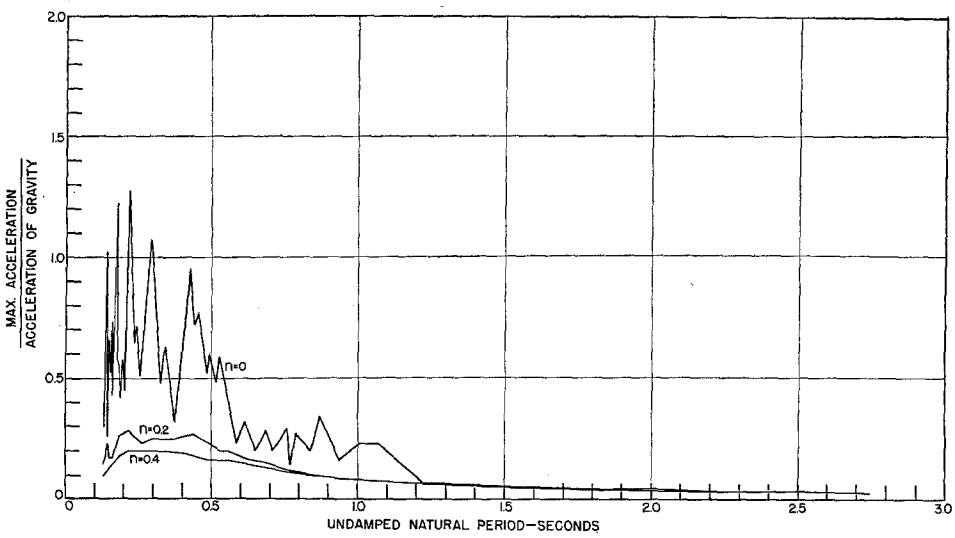

Fig. 16. Acceleration spectrum for Ferndale, California; earthquake of 11 September 1938. Component S 45 E.

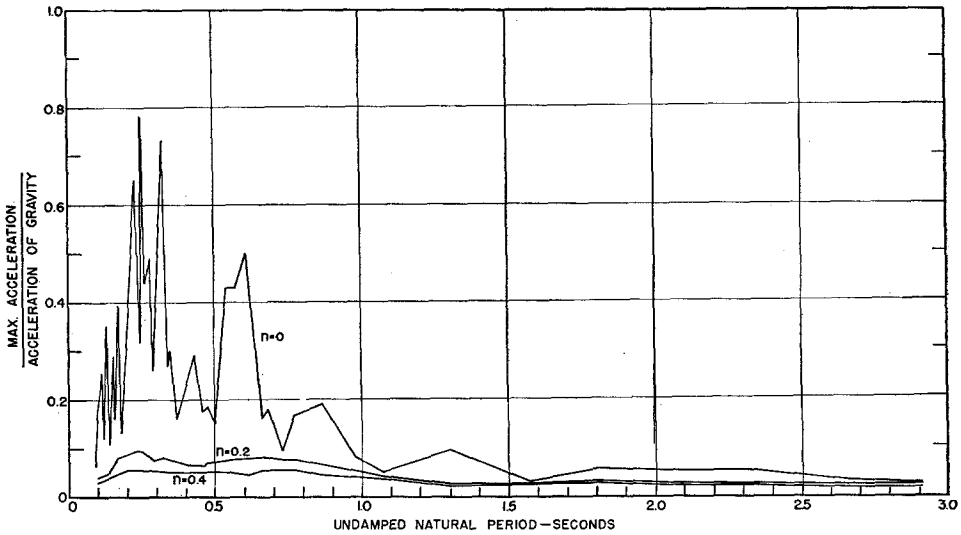

Fig. 17. Acceleration spectrum for Ferndale, California; earthquake of 9 February 1941. Component N 45 E.

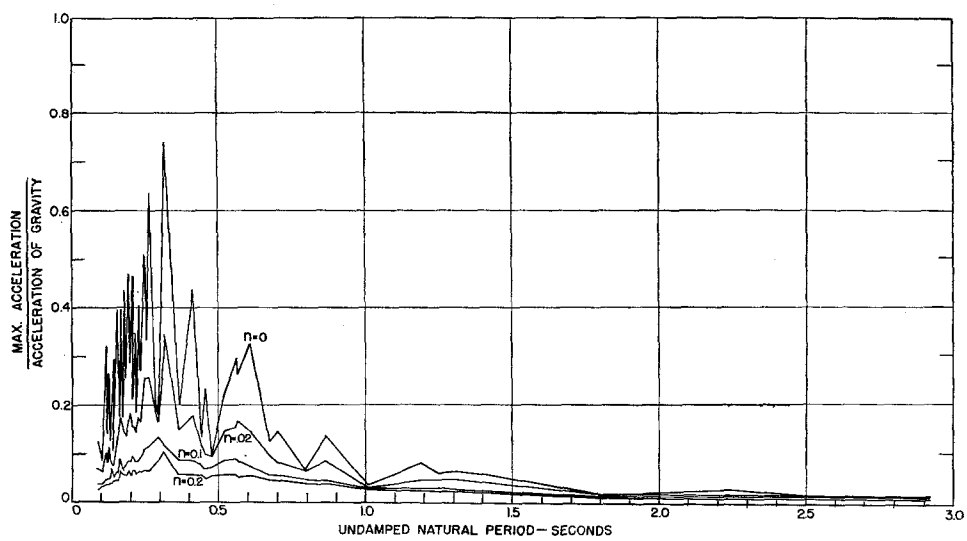

Fig. 18. Acceleration spectrum for Ferndale, California; earthquake of 9 February 1941. Component S 45 E.

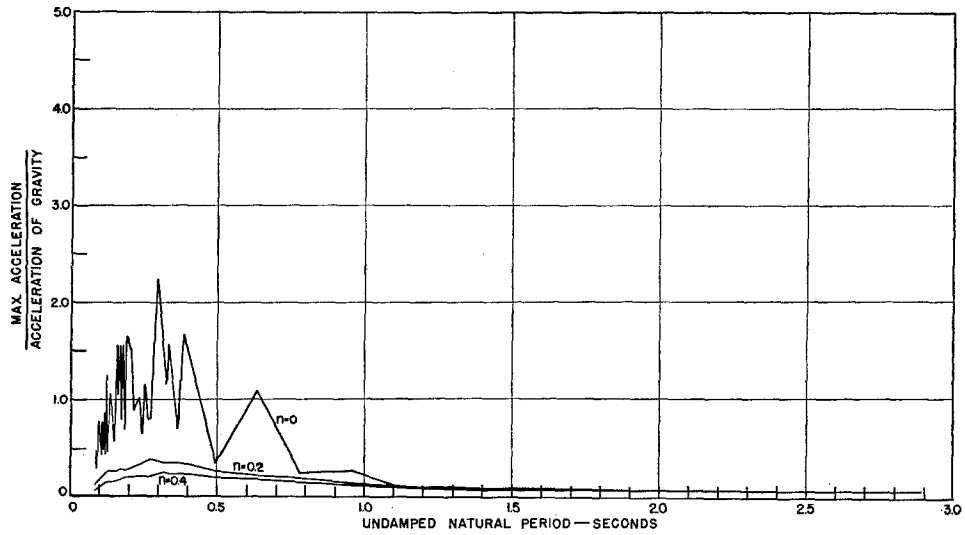

Fig. 19. Acceleration spectrum for Ferndale, California; earthquake of 3 October 1941. Component N 45 E.

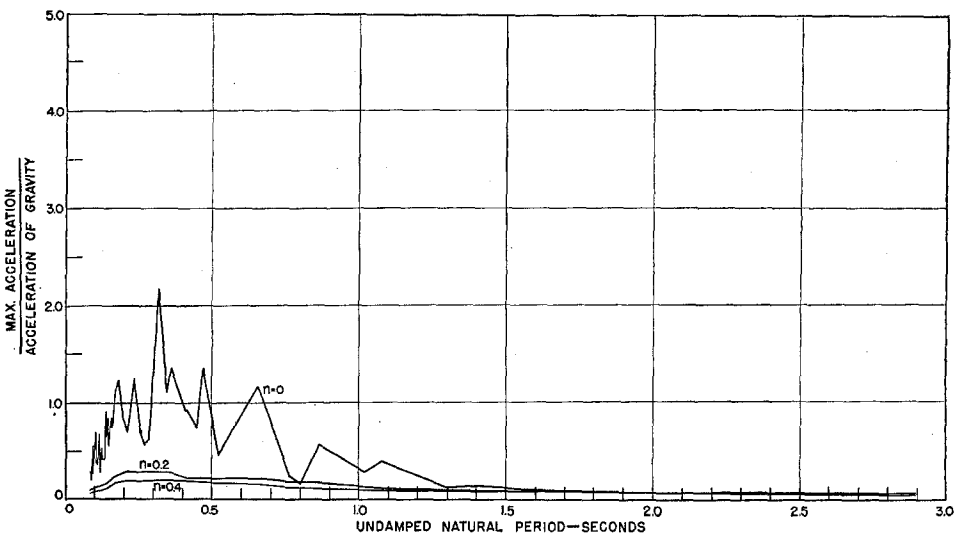

Fig. 20. Acceleration spectrum for Ferndale, California; earthquake of 3 October 1941. Component S 45 E.

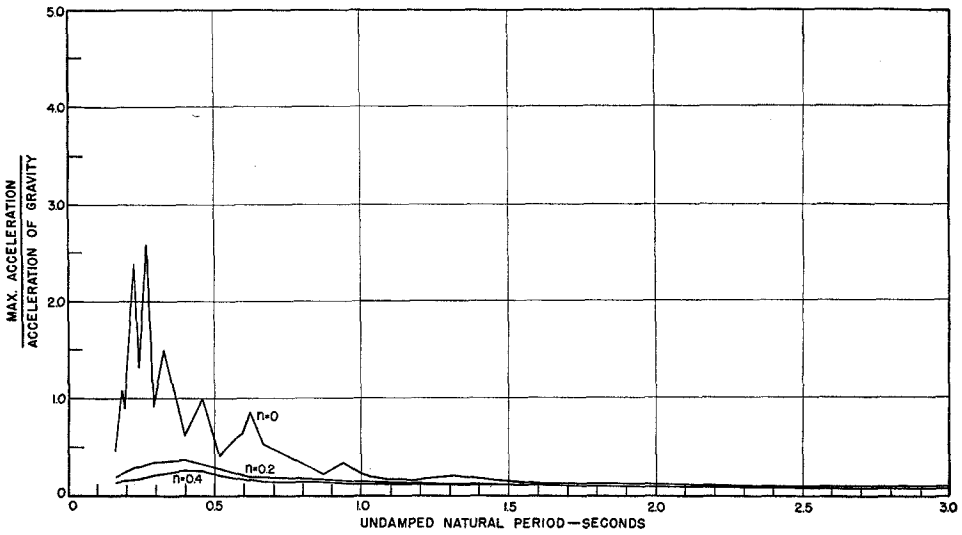

Fig. 21. Acceleration spectrum for Santa Barbara, California; earthquake of 30 June 1941. Component N 45 E.

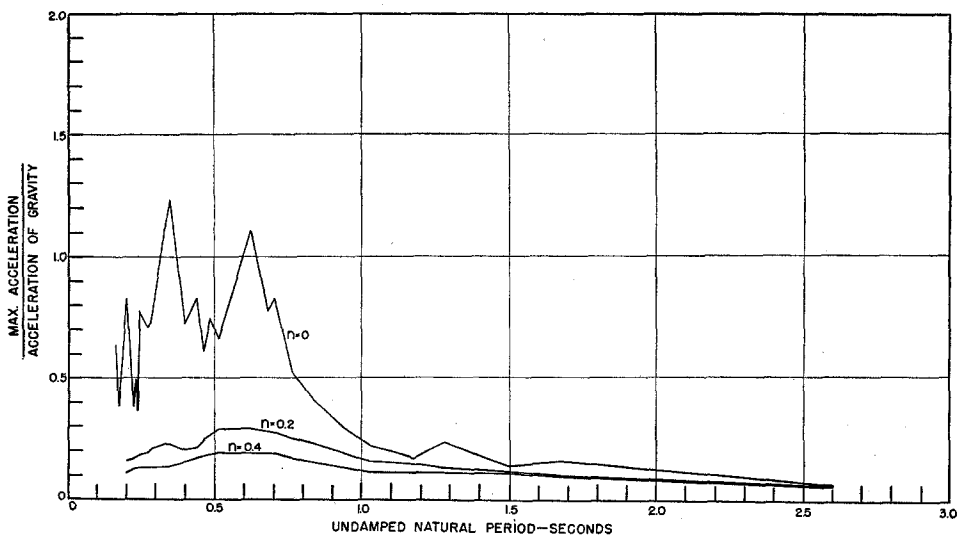

Fig. 22. Acceleration spectrum for Santa Barbara, California; earthquake of 30 June 1941. Component S 45 E.

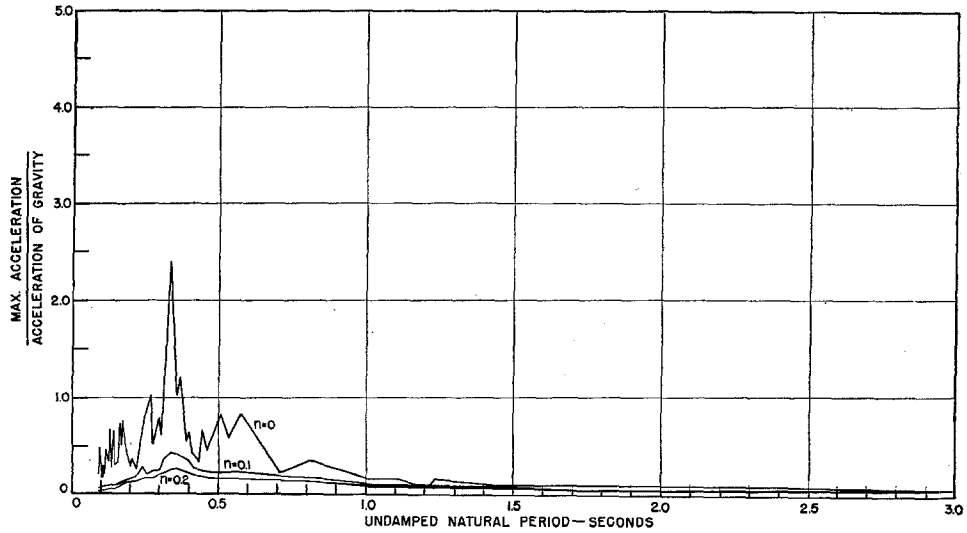

Fig. 23. Acceleration spectrum for Hollister, California; earthquake of 9 March 1949. Component S 01 W.

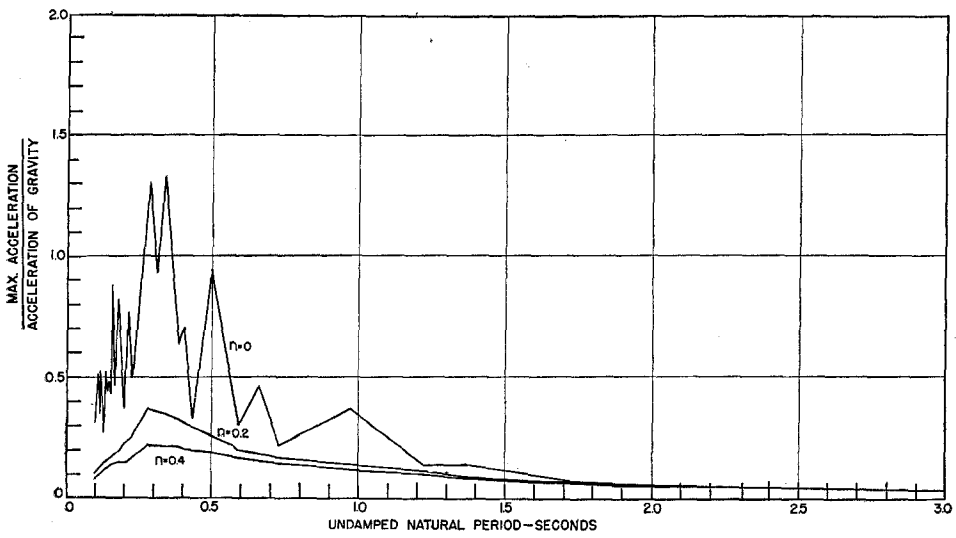

Fig. 24. Acceleration spectrum for Hollister, California; earthquake of 9 March 1949. Component N 89 W.

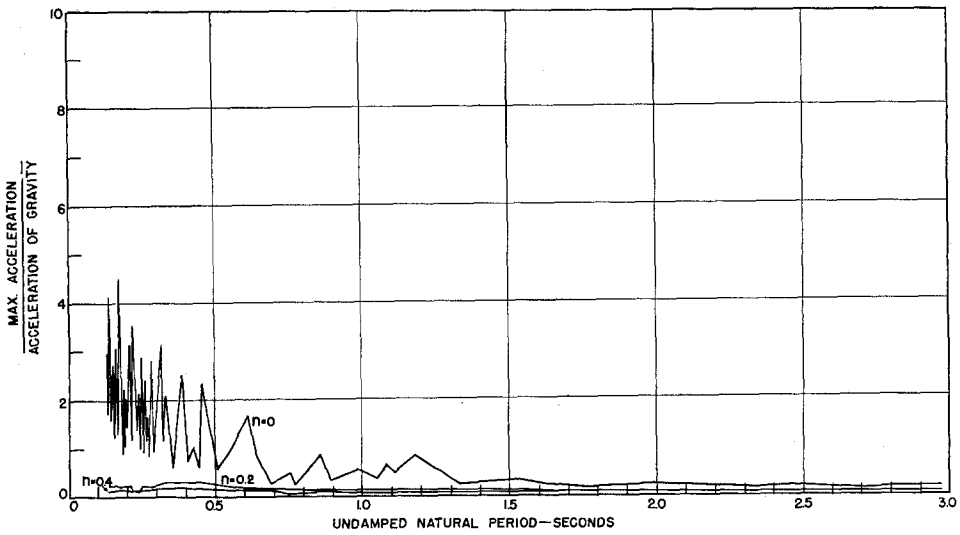

Fig. 25. Acceleration spectrum for Olympia, Washington; earthquake of 13 April 1949. Component S 10 E.

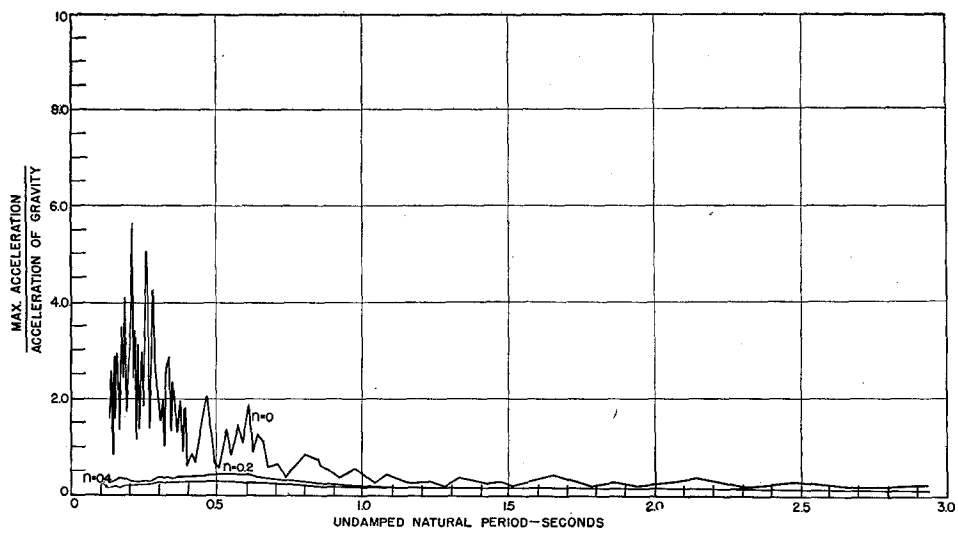

Fig. 26. Acceleration spectrum for Olympia, Washington; earthquake of 13 April 1949. Component S 80 W.

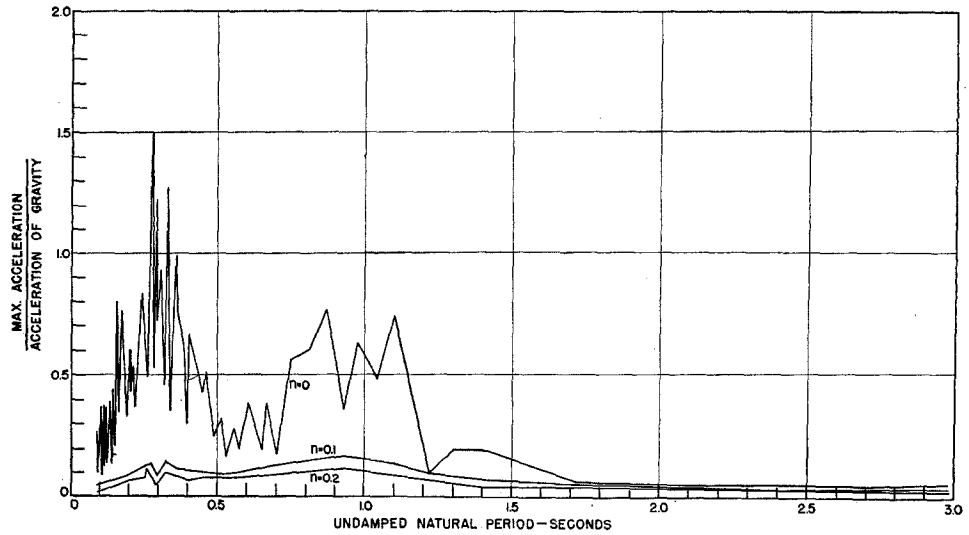

Fig. 27. Acceleration spectrum for Seattle, Washington; earthquake of 13 April 1949. Component N 88 W.

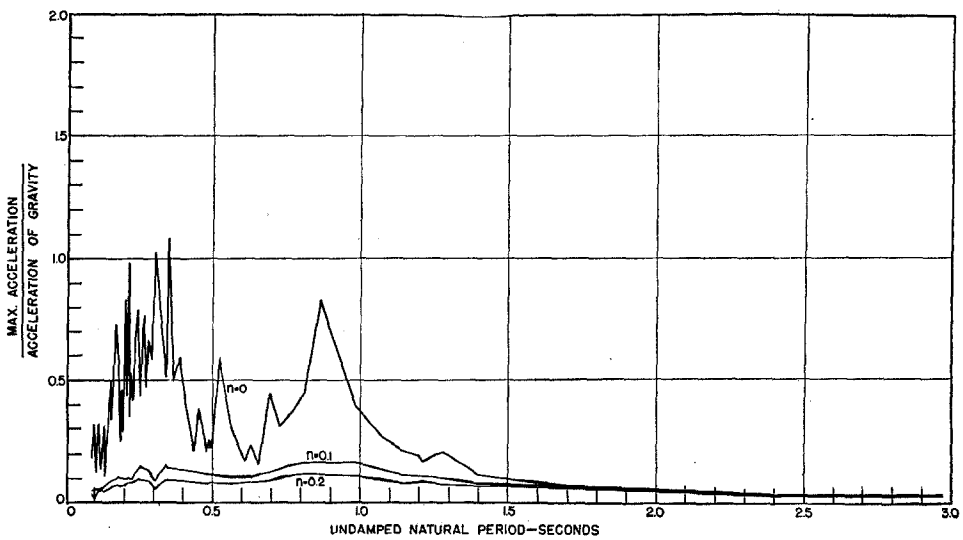

Fig. 28. Acceleration spectrum for Seattle, Washington; earthquake of 13 April 1949. Component S 02 W.

Of the earthquakes analyzed, several were recorded on the same accelerometer, namely:

Vernon, Calif.—10 March 1933 and 2 October 1933
Los Angeles Subway Terminal—10 March 1933 and 2 October 1933
El Centro, Calif.—30 December 1934 and 18 May 1940
Ferndale, Calif.—11 September 1938, 9 February 1941, and 3 October 1941

An examination of these spectra does not disclose any special features that could be attributed to the locality. In general, it can be said that except for the Seattle, Washington, and Helena, Montana, earthquakes which have been discussed above, the appearance of the spectra seems to be independent of the locality; that is, the spectra have no strong features that can be called characteristics of the locality of the earthquake. The accelerograms measure the base motion of the building in which the accelerometer is housed and thus the effect of the mass and rigidity of the building upon the ground displacements is contained in the accelerograms. The effect of the periodic vibration of the building on the spectra is not sufficiently pronounced to permit definite conclusions to be drawn.

Several opportunities exist to compare the spectra of a given earthquake at two different stations. These are:

10 March 1933—Vernon, Calif., and Los Angeles Subway Terminal
2 October 1933—Vernon, Calif., and Los Angeles Subway Terminal
13 April 1949—Seattle, Wash., and Olympia, Wash.

Comparison of the spectra in each of these groups fails to reveal any characteristic resemblance that might be attributed to that particular earthquake. Additional data in the form of spectra are needed, however, since each group contains one or more earthquakes with respect to which there is some question concerning the value of the original accelerograms.

As is seen from figures 1 to 28, damping has a marked effect upon the magnitude and shape of the spectra. The spectra are especially sensitive to small amounts of damping and, as shown in figure 12, 2 per cent of critical damping is sufficient to cut the maximum response in half. It is felt that the zero-damping spectra are not as significant as the spectra with 2 per cent or more of critical damping. This is particularly true since all structures have damping and since it is unlikely that a structure will ever be built with less than 2 per cent of critical damping.

Little information is now available on damping in buildings. White[7] reports a damping study on a monolithic reinforced-concrete building. His results, when expressed in the form used here, indicate that the damping in the building was approximately 7 per cent of critical damping. From vibration data obtained by Jacobsen[8] for a storage building with reinforced-concrete frame and floors and hollow-tile filler walls, it can be deduced that the damping in the building was approximately 14 per cent of critical. Crede[9] reports tests on a factory building which indicate damping of the order of 24 per cent of critical.

[7] M. P. White, "Friction in Buildings: Its Magnitude and Its Importance in Limiting Earthquake Stresses," *Bull. Seism. Soc. Am.*, 31: 93–99 (1941).

[8] U. S. Coast and Geodetic Survey, "Earthquake Investigations in California, 1934–1935," *Special Publication No. 201*, p. 125.

[9] C. E. Crede, "Damping of Textile-Mill Movement by Frahm System," *Trans. Am. Soc. Mech. Eng.*, 69: 937 (1947).

The experiments referred to above were conducted at very low amplitudes. Since it is probable that the damping will be larger at larger amplitudes of motion, it would be desirable to know the damping at amplitudes developed during a strong earthquake. Large-amplitude tests conducted by the Earthquake Engineering Research Institute on a four-story, monolithic, reinforced-concrete building show damping of the order of 7 to 8 per cent of critical. From the evidence available it appears that the damping in buildings will vary from approximately 5 per cent of critical for monolithic, reinforced-concrete buildings at nominal amplitudes of motion to perhaps 50 per cent or more for poorly designed masonry buildings at large amplitudes of motion. If the amplitude of motion is so large that local failures occur or materials are strained beyond the yield point, the damping will be very large.

The spectra make possible a quantitative comparison of the local surface intensities of the ground motion. For this purpose, as suggested by Benioff,[10] the area under the undamped velocity spectrum was used as the criterion of the local intensity of the earthquake. The rating of the earthquake records in decreasing order of intensity is:

1. El Centro, Calif., 18 May 1940
2. El Centro, Calif., 30 December 1934
3. Olympia, Wash., 13 April 1949
4. Vernon, Calif., 10 March 1933
5. Santa Barbara, Calif., 30 June 1941
6. Los Angeles Subway Terminal, 10 March 1933
7. Ferndale, Calif., 3 October 1941
8. Seattle, Wash., 13 April 1949
9. Hollister, Calif., 9 March 1949
10. Helena, Mont., 31 October 1935
11. Ferndale, Calif., 11 September 1938
12. Vernon, Calif., 2 October 1933
13. Los Angeles Subway Terminal, 2 October 1933
14. Ferndale, Calif., 9 February 1941

It should be noted that the Long Beach record of the 10 March 1933 earthquake is not included in this study, since a satisfactory accelerogram was not obtained. The indications are that the intensity of this record would have been somewhat greater than the El Centro, 1940.

For the purpose of engineering seismology, qualitative scales of earthquake intensity, such as the Modified Mercalli, are unsatisfactory in that they measure earthquake intensity in terms of damage to buildings without making precise allowance for the fact that buildings differ widely in design, construction, and strength. The use of the spectra for assessing intensity is independent of the physical characteristics of particular buildings, and thus it has the advantage, for engineering purposes, that it can be related to the expected dynamic stresses and deflections in buildings.

Previous studies[11] indicated that the spectra are rather sensitive to inaccuracies in the methods of computation, and the present study demonstrates the importance

[10] H. Benioff, "The Physical Evaluation of Seismic Destructiveness," *Bull. Seism. Soc. Am.*, 24: pp. 398–403 (1934).

[11] Housner, *op. cit.*, and *idem*, "Characteristics of Strong-Motion Earthquake," *Bull. Seism. Soc. Am.*, 37: 19–31 (1947).

of close control over damping in experimental methods of determination. The electric analog computer provides a reliable, rapid, and uniform method of computing the spectra. It is the only method in which damping can be treated conveniently; for example, in computing the undamped spectra the circuit was adjusted until the effective damping was exactly zero.

Summary

A total of 88 spectra of strong-motion earthquakes is presented. These spectra characterize significant engineering properties of all the strongest earthquake records obtained from United States earthquakes. The results of this investigation indicate that damping is a very important parameter in the earthquake problem. Relatively small changes in damping produce large changes in peak response, particularly when the total damping is low. This observation is significant for two reasons. First, it emphasizes the necessity for precise control over damping in the determination of the earthquake spectrum; because of this and because of its convenience in use, the electric analog computer is the most satisfactory means at present available for spectrum calculation. The second reason for the significance of the finding on damping is its implication for the earthquake resistance of buildings. Since damping is effective in reducing the dynamic stresses and strains resulting from earthquakes, it becomes of interest to know how much damping there is in each of the various types of construction. Further research on this question is essential to a more nearly complete understanding of the earthquake problem.

Most of the spectra approximate rather closely a typical form. There is no evidence that the location of the earthquake has any significant effect upon the shape of the spectrum. Except only for the Seattle, Washington, record there is no strong evidence of a so-called "dominant ground period."

The spectra provide a precise method of assessing local surface intensities of ground motion and thus can be used as measures of earthquake intensities. The spectra also characterize the earthquakes with respect to the response of structures, and, having the spectra, it is possible to answer questions of the type: What is the general character of the behavior of structures of various types when subjected to such earthquakes?

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