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Mata Kuliah : Dinamika Struktur & Pengantar Rekayasa Kegempaan
Kode : TSP – 302
SKS : 3 SKS

Respon Spektrum Gempa

Pertemuan – 10

- # TIU :
- Mahasiswa dapat menjelaskan fenomena-fenomena dinamik secara fisik.

- # TIK :
  - Mahasiswa dapat membuat spektrum respon untuk berbagai jenis eksitasi

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- Sub Pokok Bahasan :
  - Respon Spektrum
  - Penentuan Spektrum Rencana

Response Spectrum Concept

- GW Housner was instrumental in the widespread acceptance of the concept of the earthquake response spectrum – introduced by MA Biot in 1932 – as a practical means of characterizing ground motions and their effects on structures.
- A plot of the peak value of a response quantity as a function of the natural vibration period T_n of the system, or a related parameter such as circular frequnecy ω_n or cyclic frequency f_n, is called the response spectrum for that quantity.

- A variety of response spectra can be defined depending on the response quantity that is plotted.
- Consider the following peak responses :

$$u_o(T_n,\xi) \equiv \max|u(t,T_n,\xi)|$$

$$\dot{u}_o(T_n,\xi) \equiv \max|\dot{u}(t,T_n,\xi)|$$

$$\ddot{u}_o(T_n,\xi) \equiv \max|\ddot{u}(t,T_n,\xi)|$$

- The **deformation response spectrum** is a plot of u_o against T_n for fixed ξ.
- A similar plot for $\mathring{u}_o$ is the relative velocity response spectrum, and for $\ddot{u}_o$ is the acceleration response spectrum

- Deformation Response Spectrum

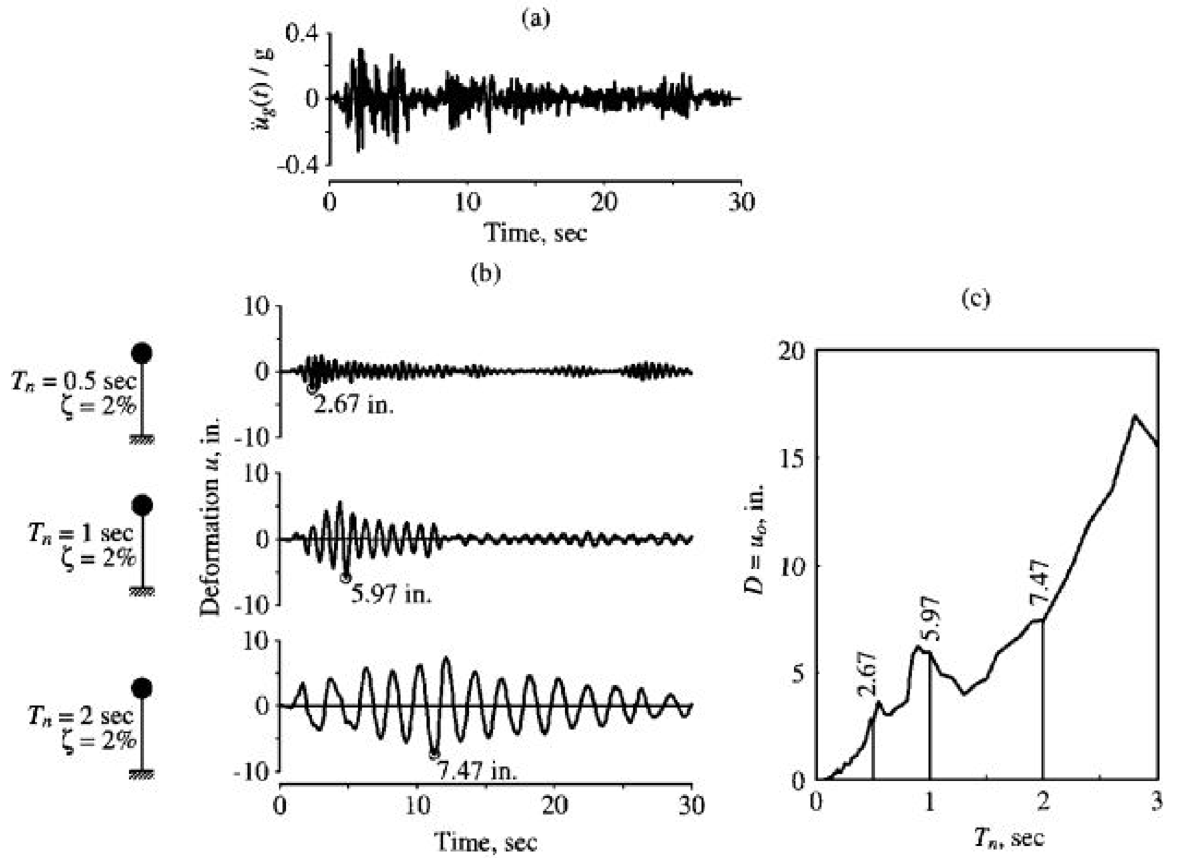


Figure 6.6.1 (a) Ground acceleration; (b) deformation response of three SDF systems with $\zeta = 2\%$ and $T_n = 0.5$, 1, and 2 sec; (c) deformation response spectrum for $\zeta = 2\%$.

Pseudo-Velocity Response Spectrum

- The pseudo-velocity response spectrum is a plot of V as a function of the natural vibration period T_n, or natural vibration frequency f_n, of the system, where :

$$V = \omega_n D = \frac{2\pi}{T_n} D \qquad \textbf{(5)}$$

- The prefix pseudo is used because V is not equal to the peak velocity ($\dot{u}_o$)

Pseudo-acceleration Response Spectrum

- The pseudo-acceleration response spectrum is a plot of A as a function of the natural vibration period, T_n, or natural vibration frequency, f_n of the system, where :

$$A = \omega_n^{\ 2} D = \left(\frac{2\pi}{T_n} \right)^2 D \qquad \textbf{(6)}$$

- The quantity A has units of acceleration and is related to the peak value of base shear V_{bo}

$$V_{bo} = f_{so} = mA = \frac{A}{g} w \qquad \textbf{(7)}$$

- A/g may be interpreted as the base shear coefficient, usually used in building codes.

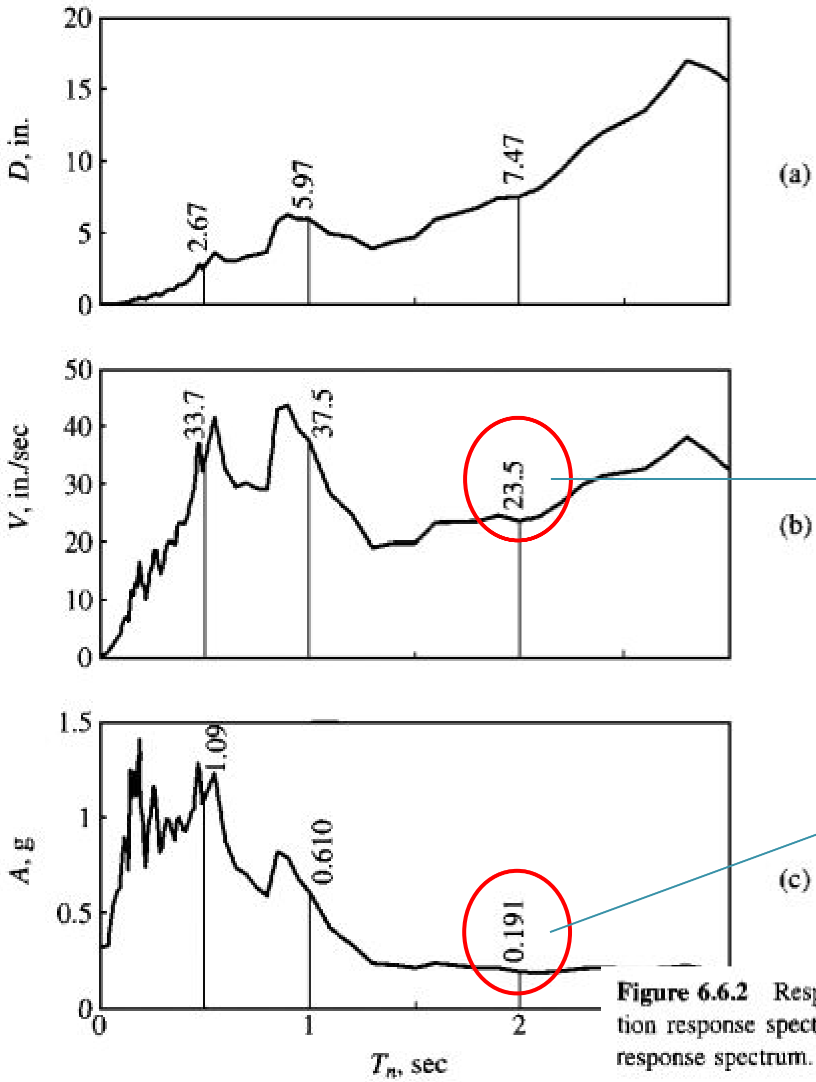


Figure 6.6.2 Response spectra ($\zeta = 0.02$) for El Centro ground motion: (a) deformation response spectrum; (b) pseudo-velocity response spectum; (c) pseudo-acceleration response spectrum.

g = 386 in/sec^2

$$= \frac{2\pi}{2} \times 7{,}47 = 23{,}46\,\text{in/sec}$$

$$= \left(\frac{2\pi}{2}\right)^2 \times 7{,}47 = 73{,}73\,\text{in/sec}^2 = 0{,}191g$$

- A combined plot showing all three of the spectral quantities (deformation, pseudo-velocity and pseudo acceleration), developed for earthquake response spectra, apparently for the first time, by A.S. Veletsos and N.M. Newmark (1960)
- This integrated presentation is possible because the three spectral quantities are interrelated by the following equation

$$\frac{A}{\omega_n} = V = \omega_n D \qquad \frac{T_n}{2\pi} A = V = \frac{2\pi}{T_n} D \qquad \textbf{(8)}$$

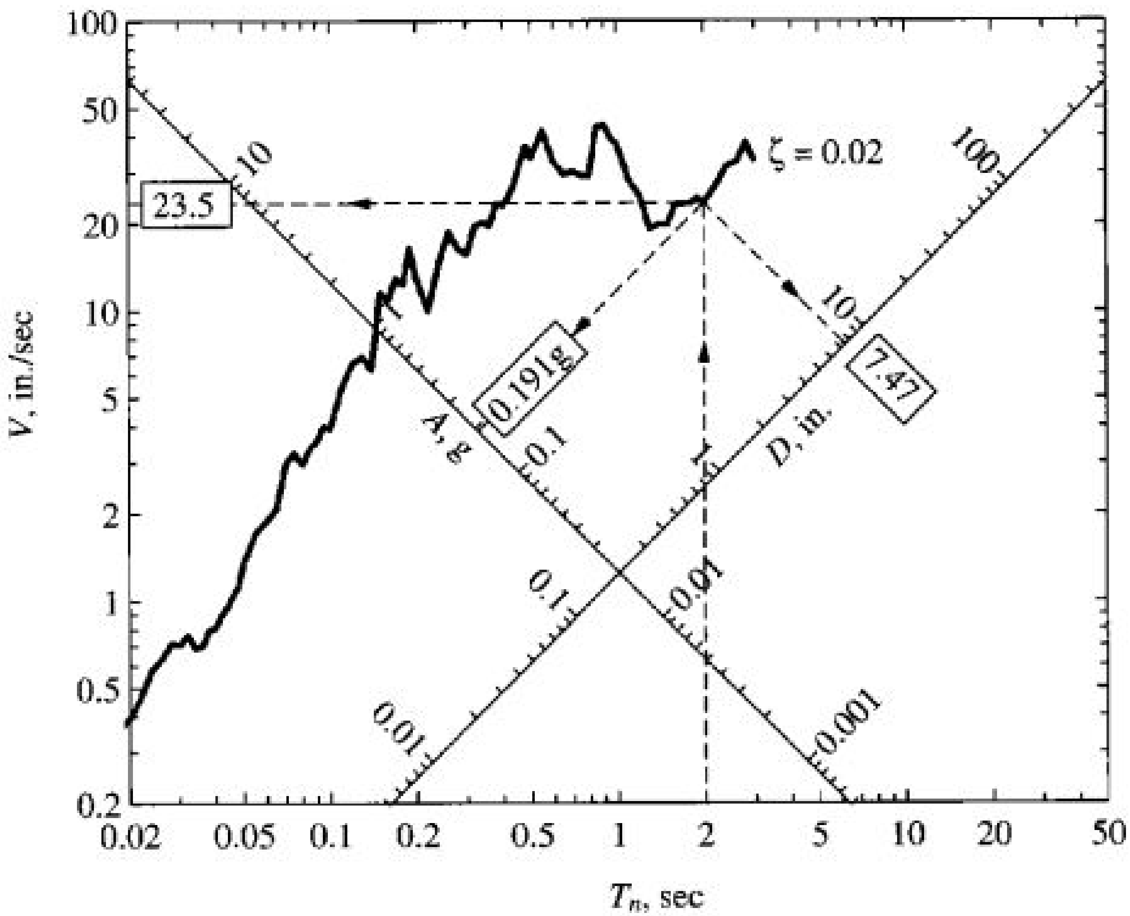
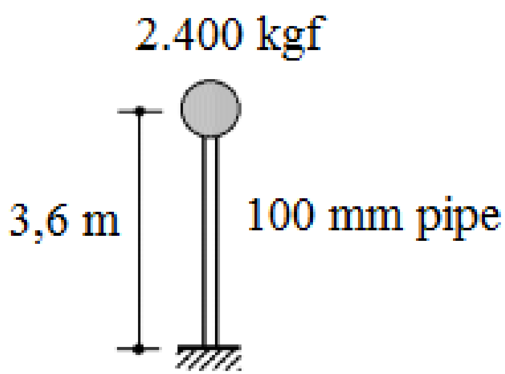


Figure 6.6.3 Combined D–V–A response spectrum for El Centro ground motion; $\zeta = 2\%$.

Example 1

- A 3,6 m-long vertical cantilever, a 100 mm-nominal diameter standard steel pipe, supports a 2.400 kgf weight attached at the tip as shown if Figure. The properties of the pipe are : outside diameter, d_o = 115 mm, inside diameter d_i = 100 mm, thickness t = 7,5 mm, and second moment of cross-sectional area, I = $3{,}7 \cdot 10^6$ mm^4. Elastic Modulus E = 200 GPa. Determine the peak deformation and bending stress in the cantilever due to the El Centro ground motion. Assume ξ = 2%.


2.400 kgf
3,6 m
100 mm pipe

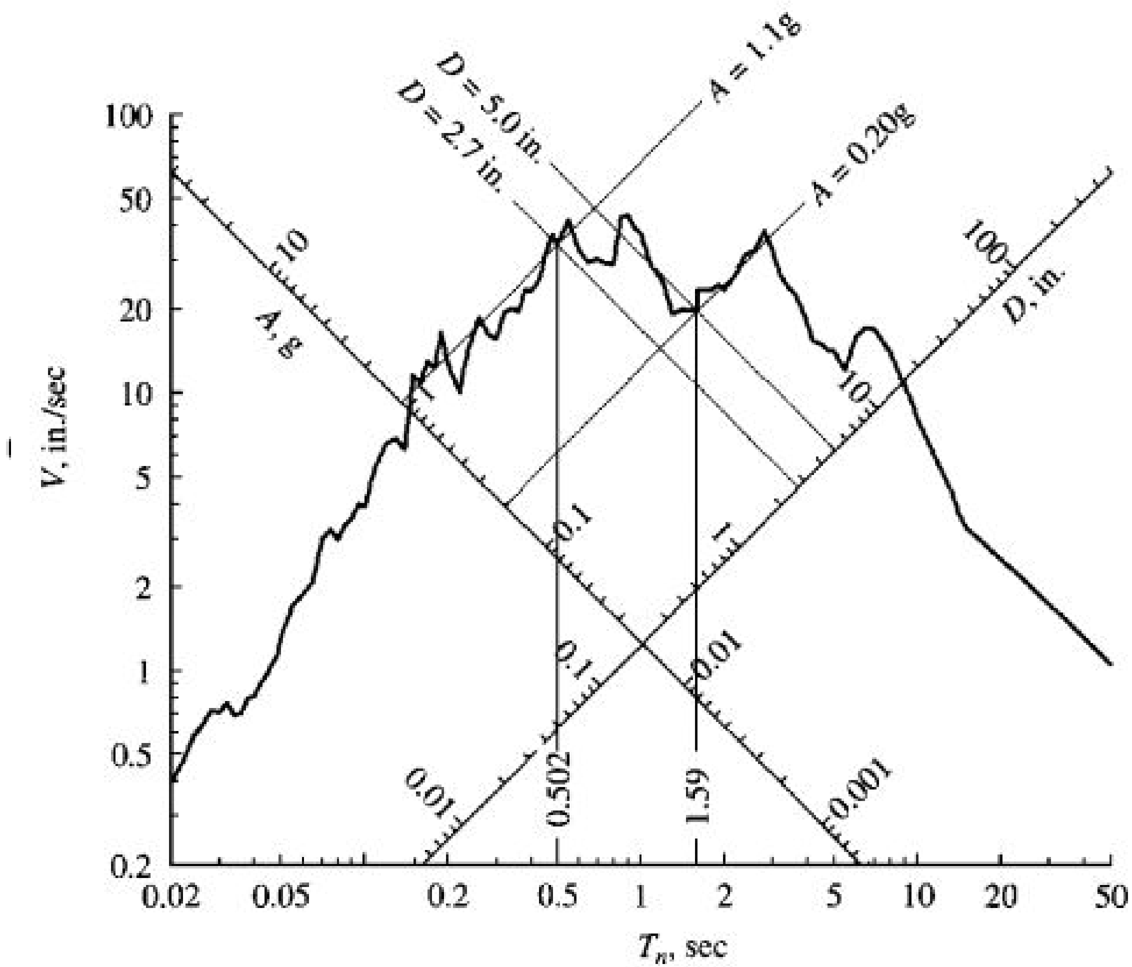

D = 5.0 in.
D = 2.7 in.
A = 1.1g
A = 0.20g
V, in./sec
A, g
D, in.
0.502
1.59
T_n, sec

Figure E6.2

Example 2 **(Homework)**

- The stress computed in Example 1 exceeded the allowable stress and the designer decided to increase the size of the pipe to an 200 mm nominal standard steel pipe.
- Its properties are d_o = 220 mm, inside diameter d_i = 200 mm, thickness t = 10 mm, and second moment of cross-sectional area, $I = 36{,}45 \cdot 10^6$ mm^4. Compute the bending stress in the pipe, and comment on the result compare with the 100 mm pipe.

Example 3

- A small one-story reinforced concrete building is idealized for purposes of structural analysis as a massless frame supporting a total dead load of 4.500 kgf at the beam level. The frame is 7 m wide and 3,6 m high. Each column and the beam has a 250 mm-square cross section. Assume that the Young's modulus of concrete is 20.000 MPa and the damping ratio for the building is estimated as 5%. Determine the peak response of this frame to the El Centro ground motion. In particular, determine the peak lateral deformation at the beam level.

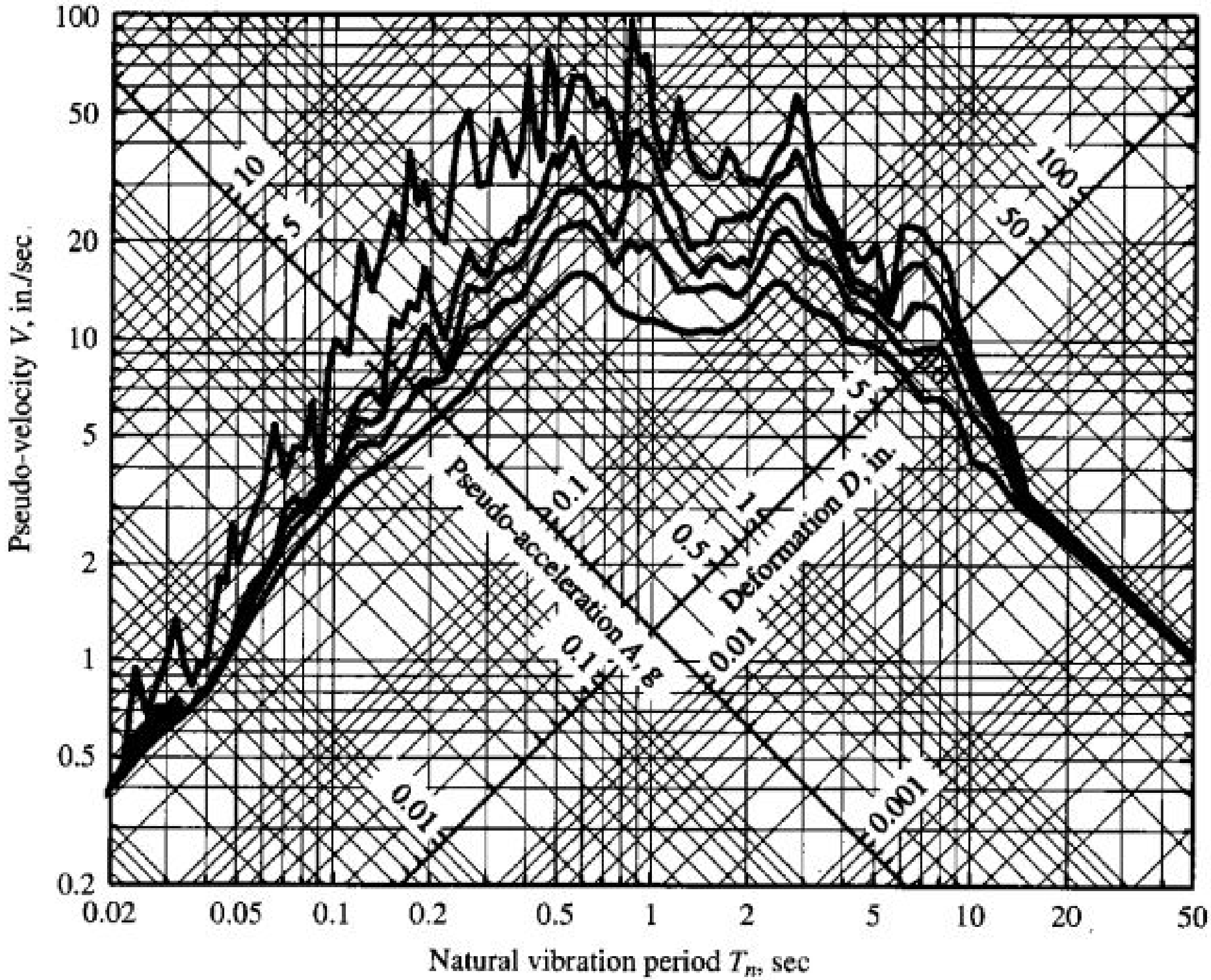


Figure 6.6.4 Combined D–V–A response spectrum for El Centro ground motion; ζ = 0, 2, 5, 10, and 20%.

- Response Spectrum Characteristic

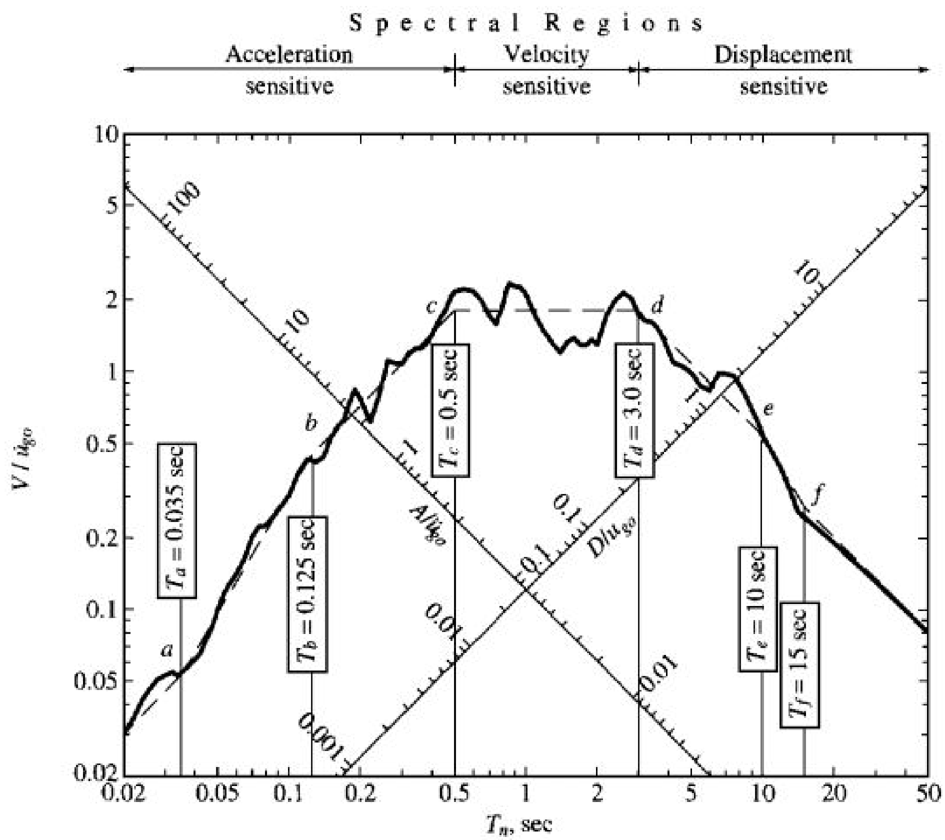


Figure 6.8.3 Response spectrum for El Centro ground motion shown by a solid line together with an idealized version shown by a dashed line; $\zeta = 5\%$.

- For , $T_n < T_a$ = 0,035 sec, the pseudo-acceleration A for all damping values approaches $\ddot{u}_{go}$ and D is very small
- For $T_n > T_f$ = 15 sec, D for all damping values approaches u_{go} and A is very small; thus the forces in the structure, which are related to mA, would be very small
- For short period system, T_n between T_a = 0,035 sec and T_c = 0,5 sec, A exceeds $\ddot{u}_{go}$, with the amplification depending on Tn and ξ.
- For long period system, T_n between T_d = 3 sec and T_f = 15 sec, D exceeds u_{go} , with the amplification depending on Tn and ξ.
- For intermediate-period system, T_n between T_c = 0,5 sec and T_d = 3 sec, V exceeds $\mathring{u}_{go}$

Elastic Design Spectrum

- The design spectrum should satisfy certain requirements because it is intended for the design of new structures, or the seismic safety evaluation of existing structures, to resist future earthquakes
- It is **not possible** to predict the jagged response spectrum in all its detail for a ground motion that may occur in the future
- The design spectrum should consist of **a set of smooth curves** or a series of straight lines with one curve for each level of damping
- The factors that influence the construction of design spectrum include the magnitude of earthquake, the distance of the site from earthquake fault, the fault mechanism, the geology of the travel path of seismic waves from the source to the site and the local soil condition

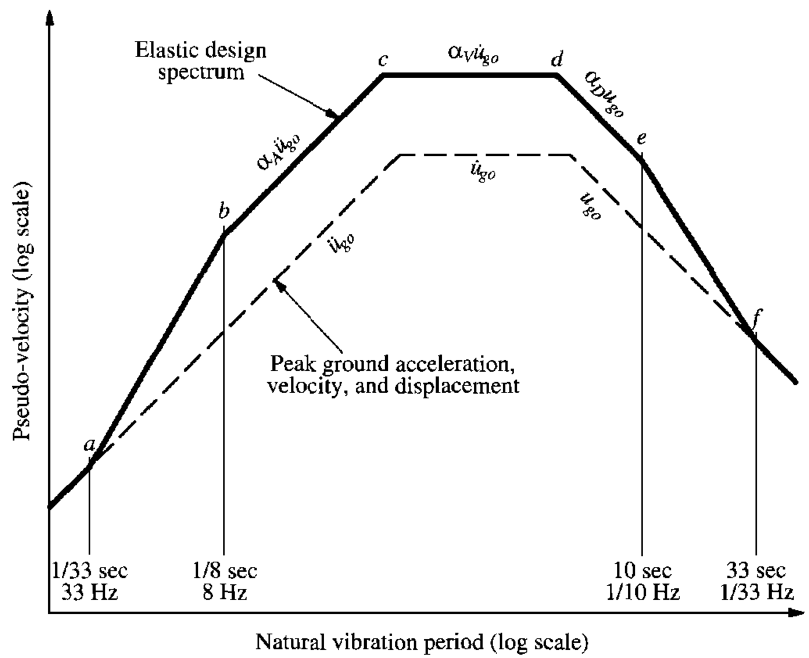


Figure 6.9.3 Construction of elastic design spectrum.

TABLE 6.9.2 AMPLIFICATION FACTORS: ELASTIC DESIGN SPECTRA[a]

	Median (50 percentile)	One Sigma (84.1 percentile)
α_A	$3.21 - 0.68 \ln \zeta$	$4.38 - 1.04 \ln \zeta$
α_V	$2.31 - 0.41 \ln \zeta$	$3.38 - 0.67 \ln \zeta$
α_D	$1.82 - 0.27 \ln \zeta$	$2.73 - 0.45 \ln \zeta$

Source: N. M. Newmark and W. J. Hall, *Earthquake Spectra and Design*, Earthquake Engineering Research Institute, Berkeley, Calif., 1982, pp. 35 and 36.

[a]Damping ratio in percent.