APPLICATION OF DIFFERENT SPECTRAL CHARACTERISTICS AT THE SEISMIC RESPONSE ANALYSIS OF STRUCTURES

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SUMMARY

In the paper there are discussed the ways of application of different spectral characteristics at the analysis of seismic response of structures. The known characteristi like power spectral density and seismic response spectrum are completed with the new characteristics - the absolute distribution function and the reduced rest response spectr For the chosen subsystems there is proposed the method of evaluation of high modes including response spectra.

BASIC SPECTRAL CHARACTERISTICS

The known characteristics frequently used in stochast random motion analysis are the correlation function $R_{xx}(\tau)$ $R_{xy}(\tau)$ and the power spectral density $S_{xx}(\omega)$, $S_{xy}(\omega)$, whi are defined in the form

$$R_{xx}(\tau)=\lim_{t_c\to\infty}\frac{1}{2t_c}\int_{-t_c}^{t_c}x(t)\ x(t+\tau)dt,\quad S_{xx}(\omega)=\int_{-\infty}^{\infty}R_{xx}(\tau)e^{-i\omega\tau}d\tau, \qquad ($$

$$R_{xy}(\tau)=\lim_{t_c\to\infty}\frac{1}{2t_c}\int_{-t_c}^{t_c}x(t)\ y(t+\tau)dt,\quad S_{xy}(\omega)=\int_{-\infty}^{\infty}R_{xy}(\tau)e^{-i\omega\tau}d\tau, \qquad ($$

where $x(t)$, $y(t)$ are the realizations of the random proces The very important property of both correlation function a power spectral density is their ability to discover the hi den periodic signals in the noise. From the shape of power spectral density curve we can determine in rough measure t range of undesirable frequencies but there is not known th amount of unpleasant effects in the seismic response of th structure.

The seismic response spectrum, this in earthquake eng neering the most used characteristic, is defined like the frequency spectrum of extremal values of seismic response one mass system. From the point of view of the edge extrem problem of the random motion and comparing to the power sp ctral density informations the seismic response spectrum seems to be a more suitable characteristic of natural eart quakes.

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Examples of the computed spectral characteristics can be seen in fig. 1 and fig. 2. The partial similarity between the shapes of power spectral density and displacement seismic response spectrum curves cannot be considered like regular.

The seismic response spectrum has some deficiency features. One of them is the absence of informations whether the extremal values of seismic response spectrum are occured only once or they are repeating several times. Let us try to remove this deficiency by using of additional characteristics - absolute distribution function AF(u) and reduced rest response spectrum S_{dr} (Fig. 3.). The absolute distribution function is defined as a probability of occurence of higher absolute response amplitude comparing to its predicted value. When the displacement seismic response spectrum S_d is defined

$$S_d = \max_{t_i \in (0,t_c)}(\mathrm{abs}(u(t_i,\omega_1,D_1))) \quad , \qquad (3)$$

then we can write

$$AF(u) = P(\mathrm{abs}(u(t,\omega_1,D_1)) \geq u) \ . \qquad (4)$$

From the shape of AF(u) there is important mainly the part describing the probability of occurence of the response of system with the amplitude higher than some limit value u_1. In addition it is suitable to use another helping value - reduced rest response spectrum S_{dr}

$$S_{dr} = \int_{u_1}^{S_d} AF(u)\, du \ . \qquad (5)$$

Shape of S_{dr} expresses the repeatness of the occurence of higher values of the response and the possibility of appearance of dangerous response in the frequency region which due to the shape of seismic response curve looks to be in general secure. On the other hand by S_{dr} there is reduced the effect of individual peak response values. (Fig. 4.)

SPECTRAL ANALYSIS OF THE HIGH MODES EFFECT

Another deficiency feature of the seismic response spectrum is the absence of the account of the interacting effect of the different mode components of vibration. Due to the usually Standard's methods this effect is comprehended by root mean square method - RMS. In general it is supposed that the values obtained in this way are rather higher comparing to the values received at the modal analysis method. There is some possibility to analyze this problem from the spectral theory point of view for a group of building structures. Frequency and modal characteristics of the building structures are varying in dependence upon the used structural bearing systems. From the obtained experimental results

(Fig. 5.) it can be seen that they are varying between the values valid for two limit dynamic models - shear rod beam and bending rod beam. For these limit dynamic models we can do the spectral analysis similar to seismic response spectrum analysis, but with the condition of application only for the systems with fixed frequency ratios f_j/f_1 and similar modes of vibration $u_j^o(z)$. General equation of seismic response is

- for bending rod:

$$\mu\ddot{\xi}(z,t) + \bar{k}\,\dot{\xi}(z,t) + C\,\xi^{IV}(z,t) = C\,x(t)\ , \tag{6}$$

- for shear rod:

$$\mu\ddot{\xi}(z,t) + \bar{k}\,\dot{\xi}(z,t) - K\,\xi^{II}(z,t) = K\,x(t)\ , \tag{7}$$

where

$$\xi(z,t) = u(z,t) + x(t)\ . \tag{8}$$

By using the separation of variables method we can write

$$u(z,t) = \sum_{j=1}^{\infty} q_j(t)\ u_j^o(z)\ , \tag{9}$$

$$q_j(t) = \bar{q}_j(t) - N_j\ x(t)\ , \tag{10}$$

$$N_j = \frac{\int_0^H \mu u_j^o(z)\ dz}{\int_0^H \mu u_j^o(z)^2\ dz}\ , \tag{11}$$

$$\bar{q}_j(t) = e^{-\varepsilon_j t}(\bar{q}(0)\cos\omega_j' t + \frac{1}{\omega_j'}(\varepsilon_j\bar{q}(0) + \dot{\bar{q}}(0))\sin\omega_j' t + N_j\frac{\omega_j^2}{\omega_j'}\int_0^t x(\tau)\ e^{-\varepsilon_j(t-\tau)}\sin\omega_j'(t-\tau)\ d\tau\ . \tag{12}$$

For the chosen deformations or internal forces (Fig. 6.) it can be put down the definition of the s-mode seismic response spectrum

- for the displacement at the level $z = z_i$

$$S_d^s(z_i,\omega_1,D) = \max_{t\in(0,t_c)}(\mathrm{abs}(u(z_i,t,\omega_1,\ .\ .\ .\ .\ .\ \omega_s,D))), \tag{13}$$

- for the shear force

$$S_S^s(z_i,\omega_1,D) = \max_{t\in(0,t_c)}(\mathrm{abs}(S(z_i,t,\omega_1,\ .\ .\ .\ .\ .\ \omega_s,D))) \tag{14}$$

- and for the bending moment

$$S_M^s(z_i,\omega_1',D) = \max_{t\in(0,t_c)}(abs(M(z_i,t,\omega_1, \; . \; . \; . \; . \; . \omega_s,D))). \qquad (15)$$

Some results of the numerical solutions of the s-mode seismic response spectra can be seen in fig. 7 and fig. 8. They are compared with the corresponding values which were obtained from the RMS method numerical solution.

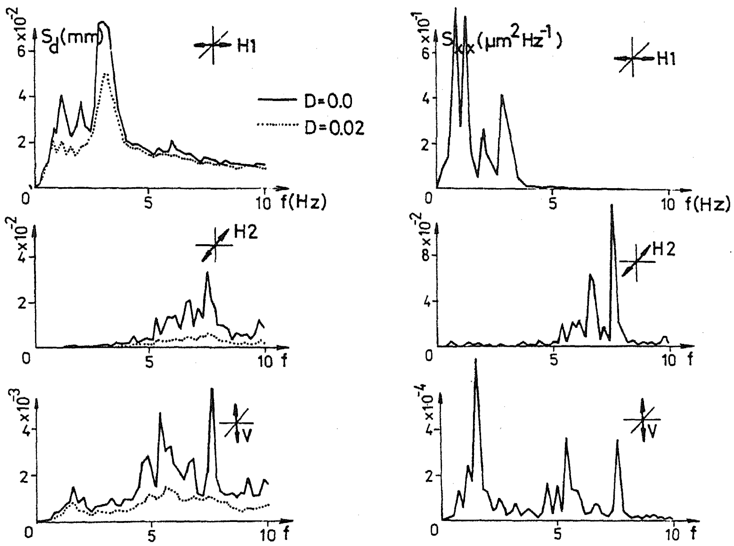
From the received results it is interesting the fact that at the 2-mode or 3-mode seismic response spectrum analysis the values obtained by RMS method are rather less than values obtained by exact modal analysis. The difference is in general about 10-20%, while usually it is supposed the reverse relation. Similar results were obtained also at the shear force spectrum analysis and at the bending moment spectrum analysis. This fact it is necessary to take into account at every case where the combination of the simple seismic response method with the RMS method is used at the design of the structure. For the important structures the exact modal analysis can be primary recommended.

CONCLUSIONS

Evaluation of spectral characteristics of weak or strong seismic motions and microtremors of soil can be carried out in the more exhausting form by using of additional characteristics like those described in this paper. For every proposed structure there is some possibility to choose the most suitable structural system and in this way to reduce the unfavourable effects to the admissible limits. Using of RMS method for the high modes effect account in the seismic response analysis of structures need not be always considered like too secure.

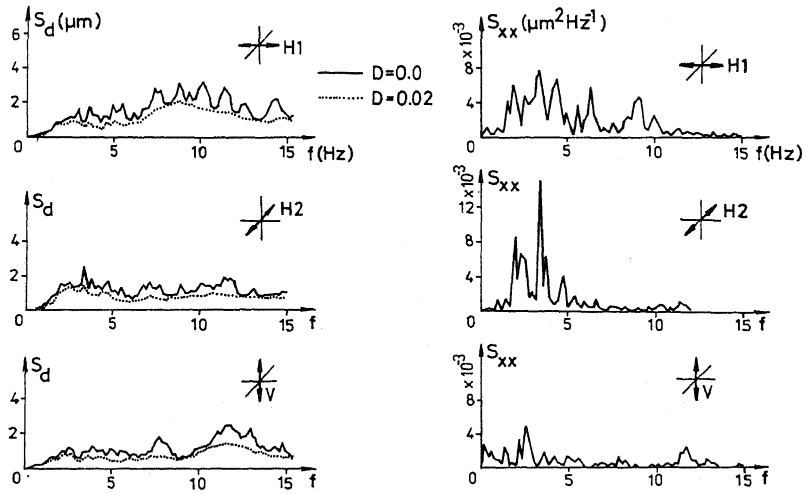
REFERENCES

1. ASADA,A. - KAWAKAMI,F. - KAMIYAMA,M.: On the Characteristics of Seismic Motion in Soft Soil Layers. In: Proc. 5-th WCEE,37, Rome, June 1973. - 2. SANDI,H. - SERBANESCU,G. - ZORAPAPEL,T,: Lessons from the Romania 4 March 1977 Earthquake. In: Proc. 6-th ECEE, Dubrovnik, Sept. 1978. - 3. TESCAN,S.S.: Microtremor Studies in Adapazari, Turkey. In: Proc. 5-th WCEE, 87, Rome, June 1973. - 4. JUHÁSOVÁ,E. - POKORNÝ, M. - FILLO,L.: The Methods of Measurements of Microvibration of Soil. In: Proc. conf. Dynamics of Engineering Structures, Smolenice, May 1977. - 5. JUHÁSOVÁ,E.: Spectral Characteristics at the Seismic Vibration of Structures. Stavebnícky časopis, 1980, N° 1. - 6. JUHÁSOVÁ,E.: Spectral Analysis of the High Modes Effect on the Seismic Response of Structures. Stavebnícky časopis, 1980 (In print). - 7. KORENEV,B.G. and coll.: Spravocnik po dinamike sooruzenij. Strojizdat, Moskva 1972. - 8. WIEGEL,A.L. and col.: Earthquake Engineering. Prentice-Hall 1970.



CHARACTERISTICS OF MICROVIBRATION - NEAR THE RAILWAY LINE

Fig. 1. Displacement seismic response spectrum S_d and power spectral density S_{xx} at the microvibration of soil



CHARACTERISTICS OF THE WEAK EARTHQUAKE AT ŠROBÁROVÁ

Fig. 2. Displacement seismic response spectrum S_d and power spectral density S_{xx} at the South Slovakia Earthquake

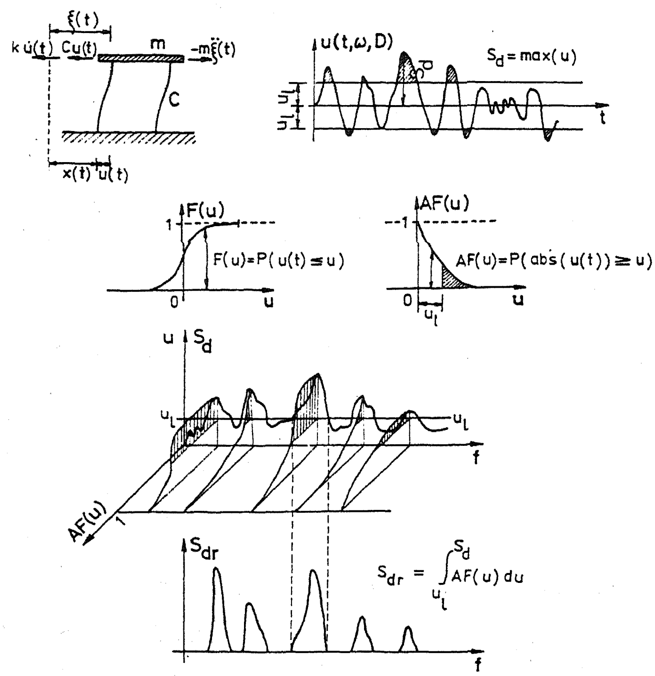


Fig. 3. Illustration of additional spectral characteristics

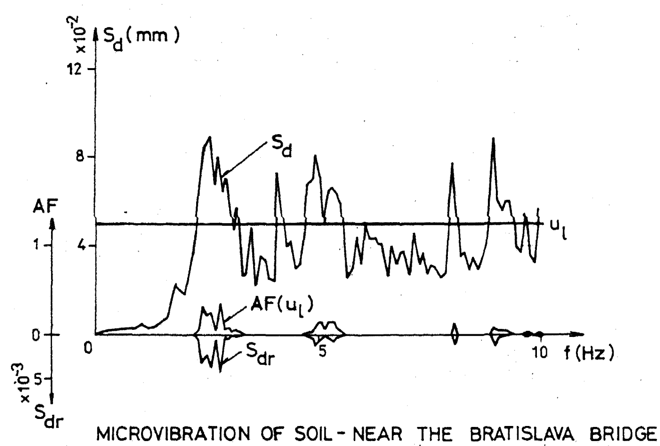


Fig. 4. Example of absolute distribution function $AF(u_l)$ and reduced rest response spectrum S_{dr}

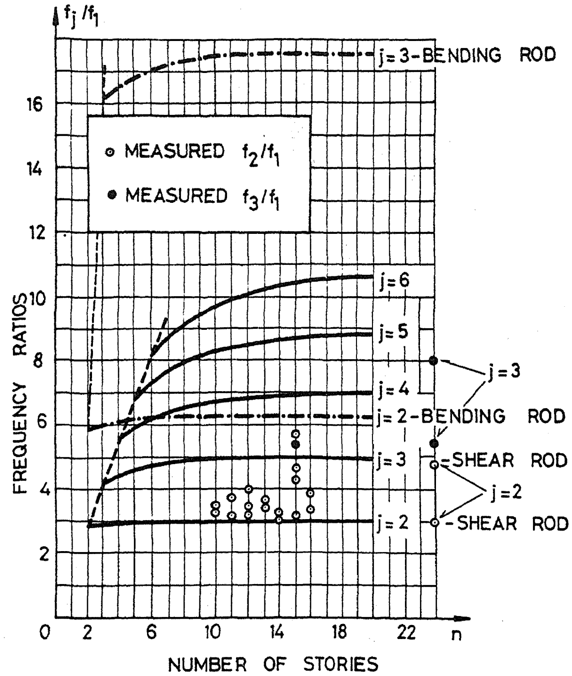


Fig. 5. Experimental frequency ratios for building structures

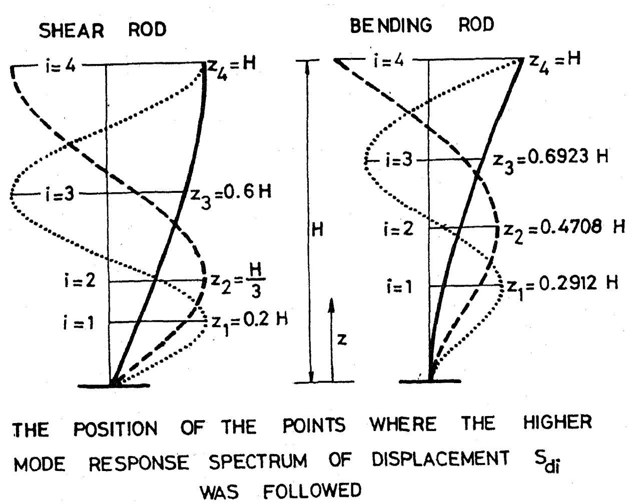
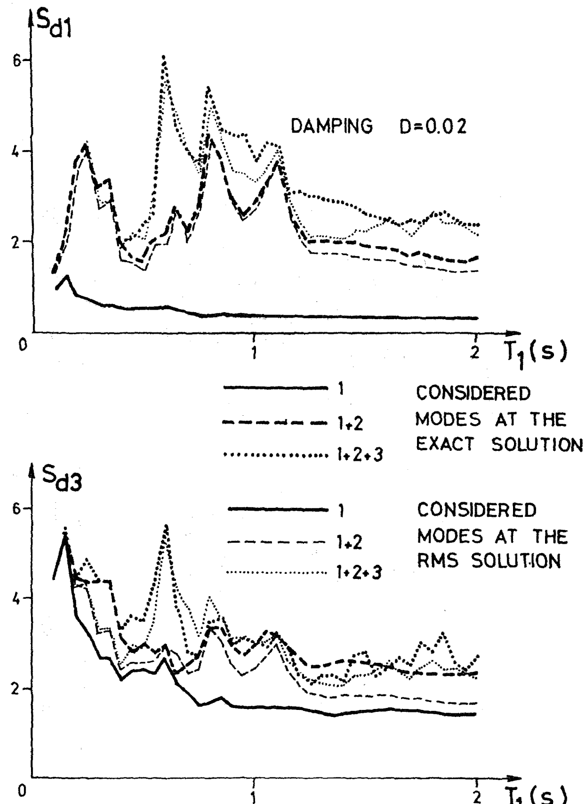
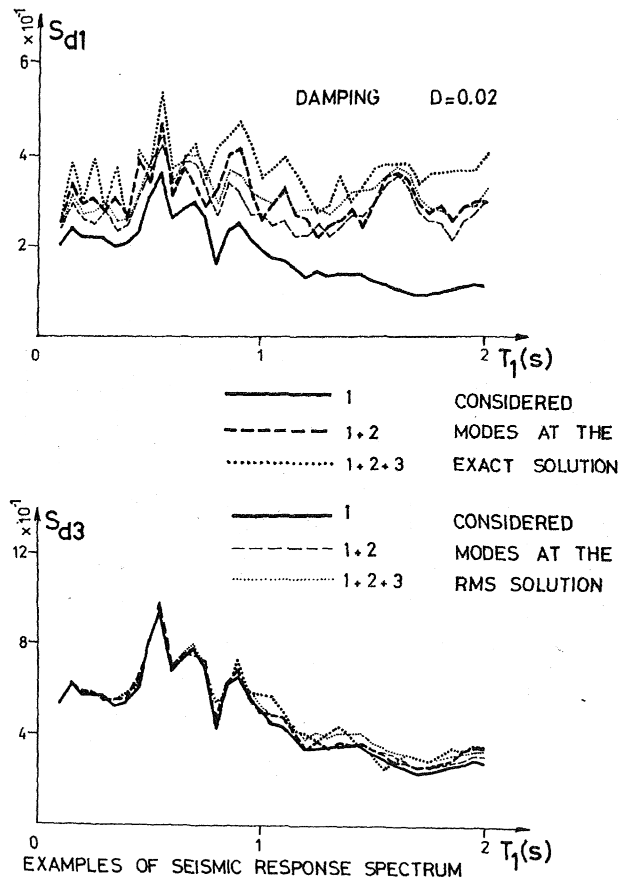


Fig. 6.



EXAMPLES OF SEISMIC RESPONSE SPECTRUM
FOR BENDING ROD

Fig. 7.



EXAMPLES OF SEISMIC RESPONSE SPECTRUM
FOR SHEAR ROD

Fig. 8.