I -684

SEISMIC DESIGN INPUT FOR RIGID-BLOCK SECONDARY SYSTEMS

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INTRODUCTION: Seismic Design for nonstructural elements to mitigate property losses and life-safety hazards has become an important issue for designers and the manufacturers. In many cases, the monetary value of the damage associated with the nonstructural elements exceeds the value of the damage to the primary structural components. There are several techniques in order to determine design response, such as, time history, response spectrum and random vibration approaches. Conventionally, for the design of light equipment, nonstructural components and other secondary systems, seismic input is often defined in the form of floor response spectra (FRS). So far, absolute acceleration response has been commonly used as floor response characteristics and design input for equipment. It is valid and sufficient to determine the dynamic qualifications of machinery and piping systems. However, in the case of rigid block like systems are slightly different. Since their overturning behavior, rocking parameters and energy input attributable to damage are so much related with absolute velocity response. Due to the absolute velocity character of response of interest, the standard FRS methods can not handle this problem. Hereby , in this work FRS is obtained analytically by using a probabilistic technique and used as criteria in the dynamic safety of systems.

THEORY AND ANALYSIS: By modelling an earthquake as a stationary random process, a relation can be derived between its power spectral density function (PSDF) and response spectrum (RS). From base design RS , consistent PSDF can be generated by iteration for the base of the structure. Then making use of standard random vibration theory, PSDF for points of interest in the structure can be obtained by appropriate multiplication of transfer functions with the derived base PSDF. Finally, RS for the points of interest are obtained using the inverse form of the relationship between a PSDF and a RS. In Fig.1, the overall design procedures and existing methods are shown. First step in the analysis is to get dynamic characteristics of primary structure by using modal analysis. Assuming that earthquake motion is a zero mean stationary Gaussian random process, it is possible to characterize the event statistically, by only the mean and standard deviation. The PSDF for the acceleration $\ddot{u}_k(t)$ is obtained by taking the Fourier transform of the autocorrelation function at the floor level k on which the equipment is attached.

$$S_{\ddot{u}_k}(\omega)=\sum_m\sum_n \phi_{km}\phi_{kn}\left[\omega_m^2\omega_n^2+2i\omega_m\omega_n(\omega_n\xi_m-\omega_m\xi_n)+4\xi_m\omega_m\xi_n\omega_n\omega^2\right]H_m^*(\omega)H_n(\omega)S_{Q_mQ_n}(\omega) \quad (1)$$

where $[S_{Q_mQ_n}(\omega)]_{r*r}=[P]_{r*1}[S_{a_g}(\omega)][P]_{1*r}^T$ (2)

PSDF of the oscillator absolute acceleration response $S_o(\omega,\omega_o)$

$$S_o(\omega,\omega_o)=H_o(\omega,\omega_o)H_o^*(\omega,\omega_o)S_{\ddot{u}_k}(\omega) \quad (3)$$

Assuming that earthquake motion is a zero mean stationary Gaussian random process and the response spectrum is related to the standard deviation of the oscillator velocity response

$$\sigma^2(\omega_o)=RMS-(E[\dot{x}])=E[\dot{x}^2]=\int_{-\infty}^{\infty}S_{\dot{x}}(\omega)d\omega=\int_{-\infty}^{\infty}\frac{1}{\omega^2}S_{\ddot{x}}(\omega)d\omega=\int_{-\infty}^{\infty}\frac{1}{\omega^2}S_o(\omega,\omega_o)d\omega \quad (4)$$

Then absolute velocity response spectrum can be expressed as

$$R(\omega_o)=F(\omega_o)\sigma(\omega_o) \quad (5)$$

where $F_o(\omega_o)=\sqrt{\left[-2\ \ln\left\{-\left(\frac{\pi}{T}\right)\left(\frac{\sigma}{\dot{\sigma}}\right)\ln(1-p)\right\}\right]}$, $\varepsilon=\sqrt{\left[1-\left(\frac{\dot{\sigma}^2}{\sigma\ddot{\sigma}}\right)^2\right]}$ = error check (6)

Fo is an amplitude factor, while T is effective time duration and p is excedence probability. Approximate transformation from design RS to PSDF is defined as an iterative procedure (Ref.1).

$$S(\omega_o)=\frac{2\xi_o}{\pi\omega_o}R^2(\omega_o)\left\{-2\ln[-\left(\frac{\pi}{\omega_oT}\right)\ln(1-p)]\right\}^{-1} \quad (7)$$

APPLICATION: To show the efficiency and the applicability of the method, five story building modelled as a shear type was used. Kobe Eq. records are applied as a seismic ground input. Besides, structural damping parameter, 0.05 and as for equipment 0.01 values are employed. After egien analysis the periods of the structure was found as follows; 1.89, 0.65, 0.42, 0.33,0.29. The analytic results can be shown below by Fig 2. We can see that the oscillatdr pèaks well coincides with the structural natural periods. Then as a next step, the response spectrum curves easily determine the related design parameters. Such as for rigid block structures θ_c can be defined by using this equation

$$\theta_c = \frac{S_v}{\sqrt{gR}}\sqrt{\frac{WR^2}{gI_o}}$$

CONCLUDING REMARKS: In this study a response spectrum method is obtained using random vibration theory in order to detrmine the seismic safety and qualifications of rigid block like secondry systems. Since the overturnings of rigid block like secondary system so much related with abs. velocity response spectrum.

References:

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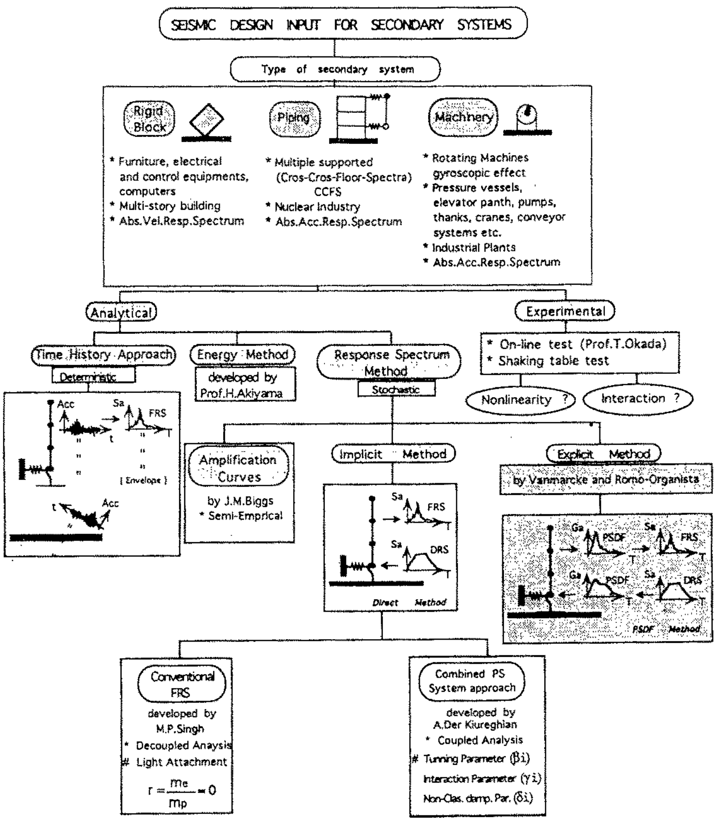

Fig.1: Overall view of seismic design processes.

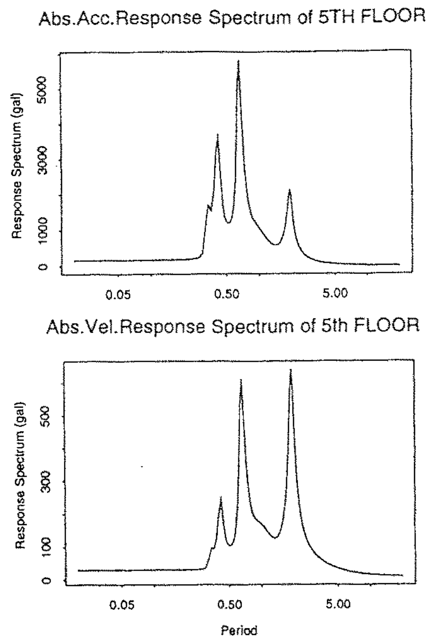

Fig.2: Secondary system Response Spectrum.