Effect of Damping Ratio on Rigid Response Coefficient for Modal Response Combination of Non-Classically Damped Structures

Using classical damping for non-classically damped systems like nuclear power plant piping systems supported by stiff structures, coupled building piping or equipment and soil structure interaction system of structures, may lead to inaccurate calculation of responses. In high frequency region of the spectrum modal responses are rigid and combines algebraically irrespective of whether the modes are near or far away. United States Nuclear Regulatory Committee, USNRC 1.92, rev3 (2012) recommends the Gupta method for the modal combination of the responses which contains a rigid and damped periodic part. The empirical expressions for rigid response coefficient are based on a straight-line fit between a key frequency f_1 and a rigid frequency f_r which is independent of damping. The modal response combination of modal responses of non-classically damped structures involves modal correlation coefficients based on relative displacement-based spectrum and relative velocity-based spectrums. In previous studies, the effect of damping on the rigid response coefficient for non-classically damped systems is expressed as a parabolic variation from the straight-line fit based on 12 earthquakes. All the relevant parameters required for the modal response combination of non-classically damped systems whose response contains a rigid as well as periodic part are expressed in terms of empirical relations based on these earthquakes. The relative velocity-based parameters required for the modal response combination of non-classically damped structures are expressed in terms of relative displacement-based parameters. Consideration of parameters based on an average of 12 earthquakes has its own limitations. Further the recent studies show that rigid frequency also varies according to the damping ratio. The spectral curve with a higher damping ratio becomes rigid at a lower frequency when compared to another spectral curve with a higher damping ratio. Similar results are observed for rigid response coefficient based on a relative velocity-based spectrum. Therefore, it is proposed to develop an expression for rigid response coefficients based on the numerical studies using 40 earthquake ground motions which can be used for different damping ratios for the modal response combination of non-classically damped structures. The corresponding key frequencies, rigid frequencies and cross correlation coefficients will be studied in detail.

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