MODAL DYNAMIC ANALYSIS OF LINEAR ELASTIC SYSTEMS WITH SPECIFIED DISPLACEMENT TIME HISTORIES

A. W. CHAN

Stone & Webster Engineering Corporation,
P.O. Box 2325, Boston, Massachusetts 02107, U.S.A.

SUMMARY

In the dynamic analysis of secondary systems (subsystems), or branch pipings, it is customary to use, as input, the attachment point displacement or acceleration time histories generated in the primary system dynamic analysis. Alternately, the response spectra at the attachment points can be used. Dynamicists are familiar with the use of response spectra and acceleration time histories. Although displacement time histories pose no new analytical problems, they are rarely used because most large scale modal dynamic analysis computer programs do not accept them as inputs. Modal dynamic analysis, as presently used for force-time history analysis, is ill suited for this purpose. Substantial logic modification is required to accept displacement inputs.

When the subsystem is multisupported, present spectral or acceleration time history procedures are not entirely satisfactory, particularly when the support motions are distinct. These problems are common in the seismic analysis of nuclear power plant equipments or pipings which are supported at different elevations. Similar situations arise in the LOCA dynamic analysis of major equipment, equipment supports, and branch pipings where most of the subsystem support points are grounded, except the few attachment points to the primary system which is undergoing severe LOCA responses. Since the classical modal dynamic analysis computer programs are not capable of distinguishing various support points as independent grounds, the analyst is again without an effective tool unless he modifies his computer software.

This paper presents a procedure for the dynamic analysis of linear elastic systems with specified displacement time histories using the classical modal analysis computer programs without computer software modifications. Since the procedure is applicable to subsystems with any number of supports, it also provides a solution to the more common problem of multisupported subsystem seismic analysis if the displacements are used instead of accelerations. The proposal to use displacements instead of accelerations is not new, but few analysts can implement the concept since they do not have the necessary computer software.

Based on the equations of motions, this paper shows that the exact procedure for modal dynamic analysis with displacement time history inputs is equivalent to grounding all the dynamic degrees of freedom where displacements are specified, and applying appropriate forcing functions to adjacent mass points. Based on this observation, a simplified approximate procedure is developed. In the approximate method, the same dynamic degrees of freedom are connected to ground by relatively stiff simple springs. Instead of applying the displacement time histories, force time histories, proportional to the corresponding displacement time histories by the added spring constants, are applied. Limits on the minimum and maximum stiffnesses of these springs are provided. The accuracy and validity of this method can be verified by comparing the computed displacement time histories to the specified time histories. Thus, by a simple modification of his mathematical model, the analyst is able to obtain the dynamic response of a subsystem subjected to specified displacement time histories with the use of the classical modal dynamic analysis computer programs.