THE RESPONSE OF SIMPLE STIFFNESS DEGRADING STRUCTURES

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SYNOPSIS

The response of six different yielding and stiffness degrading systems to an ensemble of six earthquakes is examined. Average response spectra are given for each system for periods in the range of 0.4 to 4.0 sec and ductilities ranging from 0.6 to 8.0. The response spectra are used to define equivalent linear system parameters for both the simple yielding and stiffness degrading systems.

INTRODUCTION

Most structures are designed to undergo some degree of yielding during a severe earthquake. Often this yielding is such that the hysteresis loops associated with successive cycles of loading show a progressive decrease in both stiffness and energy dissipation. This may be the case, for example, in reinforced concrete structures. Such structures are commonly referred to as deteriorating or stiffness degrading.

Previous investigators have found that the earthquake response of a stiffness degrading system differs significantly from that of a linear system [1,2,3]. However, the qualitative and quantitative nature of these differences has not yet been fully explored. The purpose of the present investigation is to provide additional insight into the earthquake response of this important class of systems.

STRUCTURAL MODEL

It is assumed that the equation of motion of the structure or a particular mode of the structure can be written in the form

$$\ddot{x} + 2\zeta\omega_0\dot{x} + \omega_0^2 f[x(t)]/k_0 = a(t)$$

where x is the generalized relative displacement, ζ is the fraction of viscous damping, ω_0 is the natural frequency, $f[x(t)]$ is the generalized restoring force, k_0 is the nominal stiffness, and $a(t)$ is the excitation acceleration. In what follows, it is assumed that $\zeta = 2\%$.

The generalized restoring force $f(x)$ is assumed to arise from the combined action of 3 different types of physically describable elements. These are: an elastic element (E-type element), an elasto-plastic element (Y-type element) and an element which exhibits both cracking and crushing like behavior (C-type element). Physical analogs of these elements are indicated in Fig. 1 along with the force-deflection diagram for one cycle of loading from a virgin state. The E and Y-type elements are frequently used in analysis of nondeteriorating structures. The effects of deterioration come from the inclusion of the C-type element. When this element is loaded in a tensile direction, it slips or "cracks" at a generalized force level f_{c_1}. When the element is loaded in a compressive sense, it yields or "crushes" at a generalized force level f_{c_2}. The similarity of this type of behavior to that observed in concrete is apparent. It is easily seen that the cyclic energy dissipation of the C-type element decreases sharply after the first loading excursion to an amplitude greater than that required for compressive failure. Two such elements are used in a back-to-back configuration to model the initially symmetric force-displacement diagrams considered herein. The details of the model are given in reference [3].

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