CHAPTER I

INTRODUCTION

In a finite element analysis of a large or complex structure, the number of degrees of freedom involved may be too large to be handled by the digital computer available. In such a case it is possible to carry out the analysis by using the substructuring technique in which the number of degrees of freedom of the original system is reduced to a relatively smaller one. The fundamental theory for the static analysis of structures using substructuring technique was presented by Przemieniecki (18). Rubinstein (19) proposed a means to improve the computational efficiency of this method. Basically, the structural system is considered as an assemblage of substructures inter-connected at boundary nodes with internal coordinates condensed prior to the assembly process. The usefulness of this technique is that it enables large structural systems to be solved easily on relatively small to medium incore capacity computers without having to resort to special techniques.

The problem of computer storage requirement and expense is even more serious in the free vibration analysis of a complex structure, which often leads to a large eigenvalue problem. To reduce the size of the resulting eigenvalue problem, Guyan (6) and Irons (9) proposed a method which is known as eigenvalue economization and has been widely used. In this method the kinetic and strain energies of the structure are obtained in terms of the master degrees of freedom by adopting the same displacement transformation matrix as in the static condensation process to relate the slave coordinates to the master coordinates. A major drawback of this method is that the masters must be chosen properly, otherwise poor results would be obtained. To improve the accuracy of the eigenvalue economization method Henshell and Ong (7) proposed an automatic technique for selecting the optimum variables to be kept as masters. Leung (10) developed an exact method of dynamic condensation which takes into account the effect of the slave coordinates on the master coordinates exactly. The formulation for substructures was also presented. The accuracy of this method can therefore be achieved for any choice of masters except in some rare cases of partial vibration. A simplified method of mass condensation suitable for tall building analyses and very useful in a design office was proposed by Lukkunaprasit and Alam (11). The method is based on assuming some simple displacement shape function over each substructure so that the kinetic energies of the substructures can be obtained without stiffness coupling.

Two other approaches suitable for free vibration analyses of large structural systems should also be mentioned here, although they are not employed in this study. The subspace iteration method was developed by Bathe and Wilson (2) to solve large eigen problems by directly calculating only a few lowest eigenvalues and eigenvectors required using the Ritz analysis and simultaneous inverse iteration. In another approach known as the component mode method (7) the free vibration behavior of a large system is synthesized from the free vibration behavior of the individual components.

Very few studies have been done to incorporate the substructuring technique in an elastic-plastic finite element analysis. One such application by Armen was described in a paper by Noor, et al. (17) in which the substructure is divided into two sets of substructures, one that behaves elastically throughout the load history and the other that may undergo plastic deformations. This method is too restrictive to be used in general because in most practical situations, a distinct separation of the elastic and elastic-plastic regions may not exist. Anand and Shaw (1) employed the substructuring technique in conjunction with the mesh grading scheme in an elastic-plastic analysis. The solution of the equilibrium equations is obtained by the incremental technique in which the structure stiffness matrix is recalculated at every load increment by using the appropriate plastic stiffness matrices for the yielding elements. Consequently the displacement transformation matrix relating the slave and master coordinates of each substructure is changed at every time step, and the reduced stiffness and mass matrices have to be re-evaluated. This would render such a solution scheme inefficient.

In this study a formulation which overcomes the above mentioned difficulty is presented for the static and dynamic analysis of an elastic-viscoplastic system with substructures. The constitutive model employed by Lukkunaprasit and Kelly (12) is adopted in a stress resultant formulation for analyzing planar frames. The formulation eliminates the need to modify the reduced stiffness matrix of the yielding substructure, which reduces the time consuming out-of-core readings and writings. Examples of elastic-perfectly plastic plane frames subjected to static and dynamic loadings are given to illustrate the accuracy in predicting the static collapse load and the dynamic response. Small displacement is assumed and shear deformation is neglected.