CHAPTER V

CONCLUSIONS AND REMARKS

An efficient and accurate numerical technique has been developed for estimating the flexural buckling load of two-dimensional, axially-loaded, skeleton structures with consideration of shear deformation, elastic lateral restraints and inelastic material behavior. The well-known principle of stationary total potential energy has been utilized to derive the variational formulation and the standard Rayleigh-Ritz approximation scheme has been adopted to construct a discretized eigenvalue problem. The capability of the proposed technique has been enhanced by supplying the automatic adaptivity to the finite element approximation via the successive improvement of the assumed buckling shape. The shape functions, used to form the trial functions for each element, have been derived from an exact function form of the buckling shape obtained directly by solving the differential equations. With such special development, the final shape functions possess two attractive features: (i) they contain an adaptive parameter involving the axial load of each element and (ii) they can represent an exact buckling shape of each element if the axial load is identical to the exact buckling load. A proper iterative procedure has been implemented along with the use of such special features of the shape functions to successively improve the buckling load estimation. The power method and the Rayleigh quotient technique have been used to determine the minimum eigenvalue and the corresponding eigenvector.

From extensive numerical experiments on various structures, it has been found that only a few adaptive steps to update the assumed buckling shapes are required to achieve the converged buckling load for a sufficiently small, specified tolerance. As compared with reliable benchmark solutions, the proposed technique has proven to yield highly accurate results comparable to exact solutions without any mesh refinement. In addition, by using the converged eigenvector obtained from the eigen-hunt in the previous step as an initial guess vector in the power method and Rayleigh quotient routine for computing the minimum eigenvalue, less number of iterations is required in the subsequent adaptive steps. In addition, the proposed technique can also accurately predict the buckling load of structures that are braced against the lateral movement and may experience switch of the buckling modes.

A proposed computational procedure provides an attractive alternative to other available methods (e.g. analytical techniques, standard finite element method, etc.) for flexural buckling analysis of structures. Since it yields highly accurate numerical solutions comparable to the analytical solution for a broad class of structures, one direct application is to use this technique either to generate benchmark solutions for comparison purposes or as a computational tool for performing some parametric studies. Due to the automatic adaptivity embedded and no mesh refinement needed, meshing effort required for a large scale structure can be significantly reduced. Another application is to use this technique to correctly estimate the effective length factor of columns in both sway and non-sway multi-story frames. It has been found very often in various practical situations that alignment charts predict very inaccurate effective length factor. The accurate estimated effective length factor is essential in the design of members in compression and members in combined flexure and compression.

As a final remark, the proposed technique still possesses certain limitations and requires further investigations. For instance, it is not directly applicable to structures with members of varying cross sections, structures subjected to the distributed axial load, and structures with significant influence of the axial deformation. Also, structures consisting of members with singly-symmetric or non-symmetric cross section in which the flexural-torsional buckling is dominated cannot be treated.