Journal of Pressure Vessel Technology

Book Review

Structural Analysis, by J. P. Liable, Holt Rinehart and Winston, New York, N.Y., 1985, 901 pp.

This is a "peach" of a book. The author starts with the basics of structural analysis and progresses to the more complicated and up-to-date Finite Element Analysis (FEA). As stated by the author, "While adequately preparing our engineers for the modern workplace where computer-based methodology is commonplace . . . . too often, structural analysis appears to . . . be a collection of dissociated methodologies . . . . The text frequently reinforces the fundamental principle emphasizing the role that each concept plays in a given technique." The author starts out with a big concept of what structural analysis contains. He does justice to most of them. The text is lucid, full of illustrative examples, and reads like a novel.

The book consists of 11 chapters, 3 appendices, a large number of problems to be worked out, and a good set of references.

Chapter 1 introduces structural engineering, discusses modeling, linear material behavior and an excellent section on 7 types of live loads. This follows with the thought of uncertainty plus probability of failure and structural safety. Chapter 2 continues with the basic equilibrium equations, determinant and indeterminate. It concludes with the determination of unknowns in a structure. Chapter 3 speaks about the equilibrium, compatibility and force displacement relations for a structure. This follows with an introduction to matrices, the basic stiffness method, and force flexibility method. Chapter 4 continues with the classical truss analysis. The definition and modeling of structural trusses, member forces and sign conventions plus method of joints.

Chapter 5 stresses the matrix analysis of trusses. Beginning with the geometric description of a truss (joint and member continuity), we journey ahead and discuss direction cosines, automated construction of statics and load matrix, multiple load cases plus compatibility and force displacement relations for truss structures. We pick up speed and cover the basic stiffness method, analysis of plane and three-dimensional trusses. Comments are made concerning the good and bad points of basic and element stiffness method plus that of the flexibility method for indeterminate trusses.

The next chapter reports on internal equilibrium of beams, frames and arches. Initiating this topic is the sign convention for axial shear and bending action. We then encounter orthogonal transformation of concentrated and distributed loans plus determination of axial shear and bending solution by direct application of equilibrium and differential relationships for shear and bending. This follows with shear and bending diagrams employing the differential and integral relations for the load, stress and moment plus superposition of moment diagram. We continue with the equilibrium of single and three-dimensional hinged arches and approximate analysis of indeterminate planar beams and frames.

Chapter 7, one of the most lengthiest focuses upon force displacement relations, i.e., geometric and energy methods. The beam bending theory and constitutive laws for beam bending and equilibrium open the chapter. This proceeds into the relationship between moments and temperature curvatures plus differential equations of beam bending. This leads us into the important techniques of moment area and conjugate beam methods. The various constituents of work and energy deformation; i.e., internal and external, real work and virtual work are put in a prominent light. Next, we study the internal complimentary work for structural members and then follow with the displacement of two and three-dimensional structures, flexibility matrix for frame members. Continuing, the expressions for strain energy in linear structural members plus principles of stationary potential energy and minimum potential energy completes this section. The next important topics are Castigliano's first and second theory, Engesser's theorem and complimentary potential energy. The chapter concludes with comments on the energy principle and the reciprocal theorems. An excellent, well-laid out chapter!

Chapter 8, another lengthy chapter, covers classic methods of indeterminate analysis. The general steps of formulation of flexibility method, the consistent deformation of one degree of freedom indeterminate structures using Castigliano's theorem and displacement tables are derived and studied. The multi-degree indeterminate structure are solved by Castigliano's theorem. This leads to the solution of matrix flexibility method employing Castigliano's theorem. We apply this to the frame. The program for member flexibility matrices, extended statics matrix and solution algorithms are clearly outlined. We next encounter fixed end actions and then study the stiffness approach with direct applications to continuous beams using iterative solutions of the stiffness equations. Moment distribution is exhibited including unknown joint translation with side sway and sloping members. The chapter concludes with a brief discussion of the slope deflection method.

Chapter 9 continues with the direct stiffness method. Previously, the basic information was introduced in Chapters 3 and 5. The direct stiffness method is most efficient and forms three matrix relations at the element or member load. The structural stiffness matrix is formed in place by applying equilibrium and compatibility to the structure as a whole. The frame member stiffness relations are derived by consistent deformation and then repeated by the energy method (Catigliano's theorem). Both are shown to form the same structural stiffness matrix as derived in previous chapter. The properties of the stiffness matrices; i.e., equilibrium, rigid body motion, singularity, symmetry are obtained. We follow with orthogonal transformations in matrix form for the local and global coordinate systems. This includes end load and forces. Proceeding further, member stiffness matrices in global coordinates are dealt with, i.e., joint equilibrium and equivalent joint loads for member loadings. The various special end conditions, i.e., spring supports, inclined supports are then formulated in terms of stiffness matrices. Illustrative examples show how the above can be employed in the direct stiffness method. The chapter concludes with some aspects of computer implementation. The symbols used in the full storage mode are shown with explanation of input control, geometric data and various assignments to load and structural stiffness matrices with direct solution of the equation. This is applied to large structural systems where the usable portion of the structure stiffness matrix is employed. The reviewer likes the latter section of this chapter since it conveys to the reader the various loops and switching processes embedded in a full size computer program. A good chapter!

Chapter 10 focuses upon the important topics of influence diagrams, moving loads and approximate numerical methods. Initially the influence diagrams are explained and constructed by virtual work for indeterminate and determinate structures. The author applies it to trusses with extension to the full power of the Muller-Breslau principle. Moving ahead, we encounter the idea of moving loads at varying positions for determining the maximum response at these specified locations. The chapter concludes with numerical approximation of differential relations applied to determinate and indeterminate beams with variable cross section plus Simpson's rule for numerical integration and least-squares relations for minimization.

The final chapter studies FEA. We recount the impact of the direct stiffness method, formulation of the stiffness matrix by least square method in solving the differential equation and by the energy method in the previous chapter. The assumed displacement field, shape function, formulation of an axial member and beam element shape function are considered. This leads to plane stress triangle and the potential energy approach in formulating the beam and axial stiffness matrix. The derivation of the linear triangular element stiffness and stress matrices, equivalent nodal loads and comments concerning equilibrium plane stress appears on the horizon. We continue with a brief section on modeling, mesh generation plus pre- and post-processing. The chapter concludes with a short discussion of Galerkin's method (weighted residuals).

Appendix A explains matrix mathematics. Appendix B contains a number of subroutines in BASIC and FORTRAN and were previously described in Chapter 9. Appendix C contains tables of areas and centroids for simple and general curves plus units and conversion factors.

In summary, this is an excellent book. Although repetitive at times, the author makes good use of the continuity of topics. The reviewer would have preferred seeing sections on transfer matrix and its relationship to direct stiffness method. Macauley's method for numerical methods and table of nomenclature for the various symbols would be of help to the reader. In addition, little mention is made of shear deformation and its place in the stiffness matrix. Hardly any mention is made of isoparametric shape functions and their respective elements in two and three dimensions. The latter is a very important factor in FEA. Nevertheless, the reviewer does recommend this book to those interested in obtaining a good basic formulation of FEA.

H. Saunders
Scotia, NY 12302