Applying Nonlinear Analysis to Learn the Fundamentals of Structural Stability

Course Overview – By using nonlinear structural analysis software as the basis for a virtual laboratory, students will explore and learn the fundamentals of structural stability. Per European terminology, methods of analysis reviewed and employed in this course include linear buckling analysis (LBA) as well as geometric nonlinear analysis (GNA), material nonlinear analysis (MNA), and geometric and material nonlinear analysis (GMNA), and their counterparts that include initial imperfections (GNIA, MNIA, and GMNIA). The stability of members, such as columns and beams, and systems are explored.

Lecturer: Ronald D. Ziemian, PhD, PE
Professor, Bucknell University, Lewisburg, PA USA

Software: MASTAN2 (available at www.mastan2.com at no cost)

Lecture 1 – An Introduction to Elastic and Inelastic Analyses
After reviewing the finite element method as means for analyzing two- and three-dimensional frames and trusses, a concentrated plasticity (plastic hinge) model will be introduced as a means for accounting for material nonlinear behavior. Students will employ first-order elastic and inelastic analyses of a simple structural system to comprehend basic concepts. The impact of axial force on the plastic strength of members will be demonstrated.

Lecture 2 – Geometric Nonlinear Analysis
The basic concepts of Lecture 1 will expanded to include geometric nonlinear behavior. Using a similar hands-on approach, second-order elastic behavior will be explored, which will then be modified to include material nonlinear behavior. Next, an explanation and investigation of elastic and inelastic critical load (bifurcation by eigenvalue) analyses will be completed. The lecture will conclude by studying a two-dimensional frame to illustrate the first- and second-order elastic and inelastic analysis capabilities reviewed.

Lectures 3 and 4 – Behavior of Compression Members
This lecture will focus on fully understanding the behavior compression members, such as columns in building or chord and web members in a truss bridge. Using the analysis capabilities learned in Lectures 1 and 2, a hands-on approach will be used to systematically retract the assumptions related to Euler buckling. The impact of factors such a material yielding, residual stresses, initial out-of-straightness, and support conditions will be explored.

Lectures 5 and 6 – Behavior of Flexural Members
This lecture will focus on understanding the behavior flexural members, such as beams in a building or girders in bridge. Continuing with a hands-on approach, the

strength limit states of beams, including full yielding and in/elastic lateral torsional buckling, will be explored. The impact of factors such a material yielding, residual stresses, initial out-of-straightness, lateral bracing, and moment gradient will be studied.

Lecture 7 – Behavior of Beam-Columns and Structural Systems

With the basics now in hand, this lecture will explore the behavior of members and systems with members subject to the combined effects of compression and flexure. Students will compare hand methods for approximating geometric nonlinear effects with results obtained using rigorous second-order computational analysis. The lecture will conclude with an overview on how some international specifications permit the use of advanced methods of nonlinear analysis (GMNIA) to design steel structures.

About the Speaker

Ron Ziemian is a Professor of Civil and Environmental Engineering at Bucknell University in Lewisburg, PA, USA. He received his BSCE, MENG, and PhD degrees from Cornell University. In addition to authoring papers and completing research in the design and analysis of steel and aluminum structures, Dr. Ziemian is co-author of the textbook *Matrix Structural Analysis* (Wiley, 2000) and the editor for the 6th edition of the *Guide to Stability Design Criteria for Metal Structures* (Wiley, 2010). He is currently chair of the American Institute of Steel Construction's Task Committee 10 on Frame Stability, and he recently completed his terms as chair of the Structural Stability Research Council and chair of AISC's Task Group on Inelastic Analysis and Design. He serves on the AISC and Aluminum Association Specification Committees and is active with the Steel Joist Institute. Dr. Ziemian, with W. McGuire and G. Deierlein, were awarded the ASCE Norman Medal (1994) for their paper on employing advanced methods of inelastic analysis in the limit states design of steel structures, and he was the recipient of the AISC Special Achievement Award (2006) for his innovative development of the advanced structural analysis MASTAN2 software and his key role in its use to develop the fully-revised 2005 AISC Specification provisions for stability analysis and design of steel structures. In April 2013, Dr. Ziemian received the ASCE Shortridge Hardesty Award for his "substantial accomplishments in research, service, and teaching, as well as advancing practice in the field of structural stability." He has also received Bucknell University's *Presidential Award for Teaching Excellence (2000)*, and in 2010 was named a Bucknell University Presidential Professor.