Continuing Education Course #421
Structural Nonlinearity
Part 2 - Analysis Methods

1. Recursion is:
- a. the tendency of a distorted structure to return to its unloaded/undistorted state
- b. when something is defined in terms of itself.
- c. when a circle is referenced in column geometry
- d. the last bit of resistance before a column buckles due to combined bending and axial compression

2. Which of the following is incorrect? A 1st-order analysis (single iteration of linear stiffness analysis) can:
- a. serve as a validity check of a structural model before adding nonlinearity
- b. serve as a comparison against later nonlinear model results
- c. not typically produce nonlinear results
- d. solve some types of nonlinear boundary conditions

3. There is only one way that nonlinearity can be precisely analyzed using a 1st-order analysis, which is:
- a. analyzing roughly discretizing members that change shape over their length by stepping the section properties
- b. analyzing a structural system that contains phase-type nonlinearities that do not get triggered/engaged for the applied loads
- c. using a geometric stiffness matrix after-the-fact to analyze axial+flexure geometrically nonlinear behavior
- d. making the structure highly indeterminate and providing redundancy

4. There are two different nonlinearities/nonlinear effects that can be effectively analyzed using a single linear stiffness analysis by way of reasonably accurate approximate methods. These include:
- a. gap supports and gap members
- b. members that change shape over their length, and axial+flexure P-delta effects (geometric nonlinearity)
- c. material nonlinearity, and initial stress/load states
- d. directional members and directional supports

5. Since most structural analysis software only considers the distorted geometry at joints or nodes when analyzing geometric nonlinearity:
- a. all members of a structural model should be discretized into several sub-members when analyzing for any type of geometric nonlinearity
- b. all columns of a structural model should be discretized into several sub-members when analyzing for any type of geometric nonlinearity
- c. all beams of a structural model should be discretized into several sub-members when analyzing for geometrically nonlinear effects that include transverse member deflections
- d. all members of a structural model that are axially loaded should be discretized into several sub-members when analyzing for geometrically nonlinear effects that include transverse member deflections

6. Using the geometric stiffness matrix to adjust the overall structural stiffness after a single linear analysis can solve, with reasonable accuracy:

○ a. Geometric nonlinearity; axial member shortening/elongation only
○ b. Geometric nonlinearity; large deflections/deformations only
○ c. Geometric nonlinearity; P-delta effects only
○ d. Geometric nonlinearity; Snap-through only

7. Kinematics can be summarized as:
○ a. parametric stretching of flexural and tensile members
○ b. finding a final equilibrium state by solving a stiffness matrix that is recursive
○ c. the tendency of a deflected/displaced structure to return to its undeflected/displaced condition
○ d. considering individual snapshots of structural movement without regarding actual motion and dynamics

8. Numerical analyses:
○ a. use numbers in the stiffness matrix instead of variables (x, L, P, etc)
○ b. solve problems without closed-form solutions by slightly changing variables until the change in output narrows and converges on a tolerance
○ c. are technically approximate methods as opposed to exact, though results of 2nd order analyses are regarded "as correct as is practical" in the structural engineering industry
○ d. A & C
○ e. B & C

9. Two different advanced SAS (structural analysis software) packages have been validated and are tasked with analysis of a 3D, multistory, steel moment frame building structure including geometrically nonlinear P-delta effects. 2nd-order analyses are run with each using the exact same dimensions, loads, and material & section properties. The two software packages get very similar results but one has 0.3% higher column moments and deflections. Which is correct?
○ a. The software package with the lower results is correct
○ b. The most expensive software package is correct
○ c. They are both "as correct as is practical"
○ d. Both incorrect; geometric nonlinearity cannot be analyzed without using 3rd-order software

10. The Newton-Raphson method is frequently used by software solvers to:
○ a. modulate an analysis variable by following along a curve
○ b. derive stiffness expressions for members that are nonlinear by shape
○ c. approximate constant spring rates for springs with non-uniform stiffness
○ d. to check if phase-type nonlinearities are active

11. A beam is a member, web crippling is a form of local instability,
○ a. and plastic behavior is a form of inelastic behavior
○ b. and brittle fracture is a form of inelastic behavior
○ c. and nonlinear elasticity is a form of inelastic behavior
○ d. all of the above

12. The difference between analyses that acknowledge and analyses that anticipate ductile yielding-type material nonlinearity can be summarized as:
○ a. using an elasto-plastic stress-strain relationship as opposed to a detailed stress-strain relationship or detailed backbone curves that explicitly define post-yielding material response, respectively
○ b. using stress-based analysis calculations as opposed to displacement-based analysis calculations, respectively
○ c. using 1D-line elements as opposed to using 2D-area or 3D-volume elements, respectively
○ d. letting software stop analysis at the point of yielding by not changing default settings, as opposed to changing the default software settings, respectively

13. Which of the following can capture local effects in structural analysis, such as an irregularly placed load like a concentrated force applied at the flange-edge of an I-beam?

○ a. 1D-line beam elements
○ b. 1D-line truss elements
○ c. 2D-area plate elements
○ d. detailed stress-strain relationships

14. If a structural system has deformed to the extent that material yielding occurs, then _____ will almost surely occur.
○ a. pushover
○ b. geometric nonlinearity
○ c. rupture or crushing
○ d. large deflections

15. The difference in analyzing nonlinear structural systems with 2nd-order analyses and simulation-type analyses is that:
○ a. 2nd-order analyses are faster
○ b. 2nd-order analyses load the structure suddenly and instantaneously and then modulates variables to converge on a solution, while simulation-type analyses use load ramping to incrementally load the structure
○ c. 2nd-order analyses cannot perform dynamic analyses while simulation-type analyses can only explicitly regard time in dynamic analyses
○ d. 2nd-order analysis provides an exact solution while simulation is an approximation

16. Why could a simulation analysis of a structure have nearly the same distorted shape after the 6th analysis iteration as a 2nd-order analysis of the same exact structure after the 1st analysis iteration?
○ a. simulation considers geometric nonlinearity at each analysis step, so distorted shapes evolve gradually
○ b. simulation is uses more analysis iterations than 2nd-order analyses to result in higher precision
○ c. simulation is typically used for mechanical engineering so it prioritizes thermodynamic calculations before structural calculations
○ d. simulation purposefully uses more iterations to result in smoother animations

17. 2nd-order and 3rd-order analyses are both iterative nonlinear analysis methods. The difference between the two analysis methods is that:
○ a. 2nd-order analyses can only use 2D planar members and elements with 3 DOFs while 3rd-order analysis can use 3D spatial members and elements with 6 DOFs
○ b. 2nd-order analyses use the second derivative of member slope, 3rd-order analyses use the third derivative
○ c. 2nd-order analyses iterate linear stiffness analyses, 3rd-order analyses iterate nonlinear analyses that use nonlinear beam theory including nonlinear curvature and axial strain
○ d. 2nd-order analyses iterate linear stiffness analyses, 3rd-order analyses iterate 2nd-order analyses using fractal math

18. Match the nonlinearities to the least sophisticated analysis method that can solve them. 1= nonuniform supports and geometrically nonlinear axial deformations, 2=geometrically nonlinear P-delta effects, 3= phase-type nonlinearities, 4=large deflections. J=2nd-order analysis, K=a few linear analyses, L=3rd-order analysis, M=linear stiffness analysis with geometric stiffness matrix
○ a. 1J, 2K, 3L, 4M
○ b. 1K, 2J, 3M, 4L
○ c. 1J, 2M, 3K, 4L
○ d. 1M, 2L, 3J, 4K
○ e. 1L, 2K, 3J, 4M

19. Which condition would require more iterations to converge when analyzing for geometric nonlinearity using a 2nd-order, kinematic analysis?

○ a. a flexible structural system
○ b. a stiff structural system
○ c. neither, the stiffness of a structural system does not affect the number of iterations needed to converge

20. Benchmarks are:
○ a. revisited structural problems from history that help verify analysis methods
○ b. the limitations of software for analyzing nonlinearity
○ c. names for the different activity states of phase-type nonlinearities
○ d. associated with surveying and has no place in discussions of structural analysis

21. A quick approximation of geometrically nonlinear P-δ and P-Δ effects using linear analysis results can:
○ a. be made using software provided by the committees that write codes and material standards
○ b. be made using a magnification factor based on the ratio of axial compression to the critical buckling compression
○ c. never be made without expecting large errors
○ d. only be made if shear deformations are included in the linear analysis

22. If websites or advertisements for analysis software generically list "nonlinear analysis" as a feature or ability:
○ a. it means that the software can analyze material nonlinearity, at a minimum
○ b. it means that only gap supports can be analyzed
○ c. it means that only directional members can be analyzed
○ d. it means that only nonlinear springs can be analyzed
○ e. it means that more information should be sought out by asking specific questions, watching example demonstrations, and/or reading the user's manual