Continuing Education Course #405
Structural Nonlinearity
Part 1 - Defining Nonlinearity

1. A structural system can be said to be nonlinear if:
- ○ a. it is highly indeterminate
- ○ b. it has a stiffness matrix or load vector that is not constant
- ○ c. it has more than three degrees-of-freedom
- ○ d. it is composed of a brittle, non-yielding material

2. Which of the following is not a fundamental assumption of linear structural analyses:
- ○ a. supports are always reactive and constant, and equally in opposite directions
- ○ b. members are straight, uniform in material and cross-section over their length, and react equally in opposite directions
- ○ c. the length along deflected members (length of elastic curve) equals the undeflected length
- ○ d. forces act in member reference frames and change their vector direction according to distorted structure geometry
- ○ e. the structure is unloaded and stress and strain-free before being loaded

3. Time can be considered a pseudo-variable:
- ○ a. in dynamic analyses that expressly includes motion and accelerations
- ○ b. in kinematics as a way to look forward at individual snapshots of static structural response and movement
- ○ c. if the structure is critically damped
- ○ d. only in historic buildings or bridges

4. _____ describes a material that does not have a linear or near-linear stress-strain relationship.
- ○ a. directionality
- ○ b. stress stiffening
- ○ c. nonlinear elasticity
- ○ d. nonprismatic

5. A translational spring support with a constant "k" stiffness can be linearly analyzed. A support with translational spring(s) would be considered nonlinear if:
- ○ a. the spring has a constant stiffness ("k" in force/length) and a gap between the member and the tip of the spring
- ○ b. the spring has a linear stiffness (progressive, "k" as a function of displacement)
- ○ c. the spring has a constant stiffness ("k") and a frictionless bumper that the member can contact after a short displacement that prevents further member translation
- ○ d. all of the above

6. A structural member is said to be nonlinear by shape, or have physical nonlinearity if:
- ○ a. a section property changes with a squared, cubic, or trigonometric function over the member length
- ○ b. a section property changes in any way but a stepped, discontinuous manner over the member length
- ○ c. the member curves in plan or in elevation

○ d. the stress-strain relationship (modulus of elasticity) smoothly changes over the length of the member
○ e. all of the above

7. In which of the following are both listed conditions/effects structurally nonlinear?
○ a. nonuniform boundary conditions, internal member releases
○ b. linearly tapered members, elastic supports with constant stiffness
○ c. P-δ effects, directional members
○ d. initial stress states, indeterminate trusses

8. A single directional member or directional support can render a determinate (indeterminate to the 0th degree) structure unstable, and N+1 directional nonlinearities could render a structure that is indeterminate to the Nth degree as internally unstable:
○ a. TRUE
○ b. FALSE

9. The two key ingredients for geometrically nonlinear effects are having a structure and/or members that are _____ and having a structural system that behaves and reacts differently in a distorted (displaced, rotated, deflected, sloped) position than it does in its initial, unloaded geometry.
○ a. symmetric
○ b. hollow
○ c. nonprismatic
○ d. flexible

10. Unshored composite construction where initially placed steel beams are used to support a concrete pour that will later become a stressed and composite part of the beams is:
○ a. an example of forces that change over time nonlinearity
○ b. a special case of initial load/stress state nonlinearity
○ c. an example of a geometric nonlinearity effect
○ d. a linear structural system

11. Plastic hinge formation in a member of a structural frame is an example of material nonlinearity that changes the shape of the member, and can result in what two types of lingering nonlinearities for any future analyses of a member that is partially permanently deformed? --> Nonlinearity by shape and _____.
○ a. initial stress state
○ b. snap-through
○ c. gap member
○ d. contact

12. How is the analysis of curved members (nonlinearity by shape) related to geometrically nonlinear P-delta effects in columns?
○ a. it is not related
○ b. P-delta effects are the residual stresses that occur due to the rolling fabrication process of curved metal columns
○ c. the columns undergoing P-delta effects must be held in a distorted/deflected (curved) shape while being analyzed
○ d. they both are phase-type nonlinearities

13. _____ nonlinearities should be considered, while nonlinearities _____ should be included in the structural analyses.
○ a. All | whose effects are non-negligible and consequential
○ b. Phase-type | that are easy to analyze
○ c. Material | other than material nonlinearity
○ d. All | that involve active frictional resistance

14. Friction is rarely actively analyzed as a nonlinearity within a structural system because:
- a. friction can result in having a zero in the diagonal of the stiffness matrix
- b. frictional resistance alone is rarely relied on to resist applied forces or to provide support reactions
- c. kinetic friction coefficients are not readily available
- d. structural engineering materials all have very high friction coefficients and can reliably resist large forces

15. As a guideline, "small deflections" no longer apply when:
- a. members yield and go plastic
- b. members transversely deflect more than approximately half their depth
- c. P-δ effects are non-zero
- d. a directional member is disengaged

16. Cable structures where cables are transversely loaded are:
- a. easy to analyze because there's no bending forces to contend with
- b. materially nonlinear
- c. composed of directional member(s) and are highly geometrically nonlinear
- d. typically linearly analyzed

17. As a guideline, "small deflections" no longer apply when:
- a. members yield and go plastic
- b. members transversely deflect more than approximately half their depth
- c. P-small-delta effects are non-zero
- d. a directional member is disengaged

18. Performing a nonlinear analysis when no nonlinearities are present or engaged can:
- a. be wasteful and inefficient, but still provide valid results
- b. produce highly erroneous results
- c. hide problems with a structural system that would have been discovered using a linear analysis
- d. provide a more efficient structural design due to the reduced nonlinear response

19. If a nonlinear structural system with the nonlinearity engaged is loaded with a force P, and the deflection at the loaded point is determined as 2.00 inches using a nonlinear analysis, then the deflection found using a nonlinear analysis under force 2P will be:
- a. equal to 4.00 inches
- b. 3.00 inches
- c. 5.00 inches
- d. not equal to 4.00 inches

20. Why is it important to know if there could be multiple concurrently acting nonlinearities present in one structural system?
- a. results must be combined after the structural system is analyzed multiple times with only one nonlinearity present in the structural system for each analysis
- b. results from separate nonlinear analyses cannot be combined and superimposed so if several types of nonlinearity are present and consequential then they must all be analyzed concurrently
- c. nonlinearities cannot be combined and there cannot be multiple nonlinearities present in the same structural system so there must be early planning decisions on which nonlinearities have to be avoided or removed