Definitions:

1- Monotonic loading;
2- Cyclic loading;
3- Isotropic;
4- Isotropic material;
5- Orthotropic material;
6- Anisotropic material;
7- Homogeneous material;
8- Heterogeneous material
9- Constitutive Relationship (the relation between principle stresses and principle strains);
10- Uniaxial stress;
11- Biaxial stress;
12- Tangent modulus of elasticity;
13- Secant modulus of elasticity;
14- Smeared cracks;
15- Smeared reinforcement;
16- Discrete cracks;
17- Discrete reinforcement;
18- Microscopic;
19- Macroscopic;
20- Micro crack;
21- Perfect bond;
22- Strain softening in compression;
23- What is the meaning of "Linear Analysis"?;
24- What is the meaning of "Nonlinear Analysis"?;
25- What are the types of "Nonlinearity"?;
26- What are the factors affecting the nonlinear behavior of R.C elements?'
27- From where the differences in the nonlinear analysis of R.C come?'
28- Why we have to study "Nonlinear Analysis"?
29- What is the importance of "Nonlinear Analysis"?'

State the importance - function and purpose of the nonlinear analysis of R.C elements?

Importance function and purpose of the nonlinear analysis of R.C elements are:

1- To understands the actual behavior of R.C structures;
2- To get information that can't be easily measured from experimental studies;
3- Make parametric studies to save cost and time;
4- Monitoring the failure modes (failure mechanism) in R.C structure like flexure failure-shear failure;
5- To represent or modeling the concrete and steel in R.C fields;
6- Modeling the structure in realistic modeling of material and geometry to take material and geometry nonlinearity in the analysis of R.C structures;
7- To get the internal strains which are difficult to measure by using the strain gauge externally.

The basic assumptions considered throughout the nonlinear analysis of the R.C plane frames:

- The mathematical formulation is based on the following assumptions:
  1- Plane section remains plane after deformation (i.e. linear strain distribution and shear deformation is ignored);
  2- The cross section of each element is symmetric with respect to an axis which coincides with the loading plane (i.e. the torsional moment is neglected);
  3- The mechanical properties of concrete and steel reinforcement are well defied;
  4- Concrete in tension should be taken into consideration ;
  5- Elastic modulus are defined according as secant or tangent.

The typed of nonlinearity are:

1- Geometric nonlinearity;
2- Material nonlinearity.

The causes and factors leading to the difference in the nonlinear analysis of R.C structures:

1- The difference in material modeling ;
2- The difference in finite element formulation;
3- Increase in the no of iterations required for satisfying the convergence conditions;
4- The difference in the no of layers;
5- The poor state of the art in constituent modeling of cracked R.C.

Tension stiffening:

1- After concrete cracked in tension, the concrete between adjacent cracks is still capable of resisting some tensile stresses which is carried by steel reinforcement at crack location.
2- The capability of concrete in tension to carry tensile stresses after cracking.
3- The participation of concrete in tension in carrying the tensile stress between cracks.

Strain hardening:

Strain hardening is the increase of steel stress after yielding or the ascending branch of steel stress-strain after yielding.

Factors affecting the nonlinear behavior of R.C elements:

- The low tensile strength and accompanying tensile cracking of concrete at relatively low stress is one of the major factors causing nonlinear behavior of R.C composite;

What is the major factors causing nonlinear behavior of R.C elements?

-The low tensile strength and accompanying tensile cracks of concrete at relatively low stress is one of the major factors causing nonlinear behavior of reinforced concrete elements;

- Codes consider concrete as linear, elastic, homogeneous, isotropic material, while it is heterogeneous material;
- Codes consider the reinforcing steel as linear, elastic, homogeneous, isotropic material, while it is heterogeneous material;
- Concrete behave as a nonlinear material at high stress and its properties in tension is completely difference the properties in compression.

From where the differences in the nonlinear analysis of R.C come?

1- Poor state of the art in constitutive modeling of cracked reinforced concrete;
2- Error in material idealizations;
3- Error in finite element formulations;

Compression softening:

- After the peak stress is reached, the stress drops and crakes parallel to the direction of loading become visible in the concrete while the strains increases until failure. This is called the compression softening which mean that increasing in strain and decreasing in compression stress.
-

Strain hardening:

- The increasing in stresses is accompanied by increasing in strains. This action occurred at the plastic region. The actual stress increases continuously. I.e. when steel is strained beyond the yield point, more stress to produce additional plastic deformation and the steel seems to behave stronger and difficult to deform i.e. steel become stronger as the strain increases.

Loading techniques:

There are three types of loading techniques:

1- Iterative (this method can evaluate the max. load point, but can't draw the load deflection curves);
2- Incremental (with this method del load is applied in increments – using this method, you can draw the load- displacement curve);
3- Incremental – Iterative (has the advantages of both the previous methods but it is difficult and take more time to get convergence).

Secant Modulus and its use:

It is the slope of the straight line passing through the original point of the stress strain curve and the point (ε and σ) at the curve; $E_{secant} = \sigma/\varepsilon$ it is used for ascending and descending branches in the stress - strain curve.

Tangent Modulus and its use:

It is the slope of the tangent of stress strain curve at the point of loading. This slope is +ve in ascending branch and –ve at the descending branch . so it is used in ascending branch to avoid calculation failure (-ve value at the diagonal of the stiffness matrix)