Banha University
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Computation of Nonlinear (STR602)

For Master of Engineering Sciences

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"Nonlinear Analysis of Reinforced Concrete Structures"
Definitions

1-Monotonic loading

In these tests the loading is one direction, an increasing load is applied to the specimen to identify its mechanicals properties.

2- Cyclic loading

In these tests the loading is applied in Changeable form, using hesitated load patterns.

3- Isotropic materials

Properties are the same in all directions, likes glass and metals.

4- Anisotropic materials

Properties change with direction along the object, like wood and composites.

5- Orthotropic material

Orthotropic materials have different properties in three equally perpendicular directions.

6- Homogeneous mixture

It is a mixture where the components are uniformly distributed throughout the mixture, like alloys.

7- Heterogeneous mixture

It is a mixture where the components of the mixture are not uniform or have different properties, like Concrete.

8- Uniaxial stress

It is a one dimensional state of stress in which stresses act along one direction only.

9- Biaxial stress

It is a two dimensional state of stress in which stresses act along two directions.

10- Tangent Modulus of elasticity

It is the slope of a line tangent to the stress-strain curve at a point of interest.

11- Secant Modulus of elasticity

It is the slope of the straight line passing through the original point of the stress strain curve and a point on the curve.

12- Micro cracks

It refers to very small cracks that form in concrete but are not visible to the naked eye.

13- Perfect bond

Perfect bond between concrete and reinforcement steel represent the interaction and transfer of forces between steel and concrete.

14- 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.

15- Strain hardening:

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

16- Tension stiffening:

- 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.
- The capability of concrete in tension to carry tensile stresses after cracking.
- The participation of concrete in tension in carrying the tensile stress between cracks.

17- Linear Analysis

Deals with the concrete in linear case and consider the concrete homogeneous material.

18- Non-Linear Analysis

Deals with the actual behavior of materials, show the concrete in nonlinear case and take in consideration the compressive and tensile strength of concrete.

19- Types of nonlinearity

Geometric nonlinearity & Material nonlinearity.

20- Importance function and purpose of the nonlinear analysis of R.C elements

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

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

The mathematical formulation is based on the following assumptions:

- Plane section remains plane after deformation (i.e. linear strain distribution and shear deformation is ignored);
- 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);
- The mechanical properties of concrete and steel reinforcement are well defied;
- Concrete in tension should be taken into consideration;
- Elastic modulus is defined according as secant or tangent.

22- The major factors causing nonlinear behavior of R.C elements?

- The low tensile strength and accompanying tensile cracks of concrete at relatively low stress.
- Codes consider concrete 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.

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

- The difference in material modeling;
- The difference in finite element formulation;
- Increase in the number of iterations required for satisfying the convergence conditions;
- The difference in the number of layers;
- The poor state of the art in constituent modeling of cracked R.C.

24- Loading techniques:

There are three types of loading techniques:

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