BENHA UNIVERSITY
SHOUBRA FACULTY OF ENGINEERING
CIVIL ENGINEERING DEPARTEMENT
Master of Engineering Sciences
Code: STR602

Final Term Exam

Computation of Nonlinear Analysis

مادة: الطرق الحسابية للتحليل اللاخطي

إمتحان الفصل الدراسي الاول دراسات عليا

٢٠١٧-٢٠١٨

دكتور المادة

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BENHA UNIVERSITY
SHOUBRA FACULTY OF ENGINEERING
CIVIL ENGINEERING DEPARTEMENT
Master of Science (M.Sc)
Code: STR602

Final 1st Term Exam

Saturday 23/12/2017
Computation of Nonlinear Analysis
Duration: 3.0 hours
No. of questions: 2

Total Mark: 60 Marks | **Closed Book Exam** | **The Exam consists of two pages**

*** Answer all the following questions**
***Systematic arrangement of calculations and clear neat sketches are essential.**

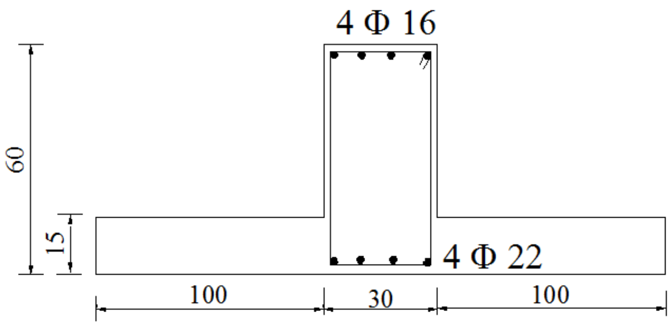
<u>Question (1): Write short note about the followings:</u> **(20 Marks)** **[ILO's: a1, b1, b2]**

(1) Linear analysis.
(2) Non-linear analysis.
(3) Types of nonlinearity.
(4) Monotonic loading
(5) Cyclic Loading
(6) Compression softening.
(7) Strain hardening.
(8) Tension stiffening;
(9) Importance function and purpose of the nonlinear analysis of R.C elements.
(10) The basic assumptions considered throughout the nonlinear analysis of the R.C plane frames.
(11) Loading techniques;
(12) Tangent modulus of elasticity.
(13) Secant modulus of elasticity.

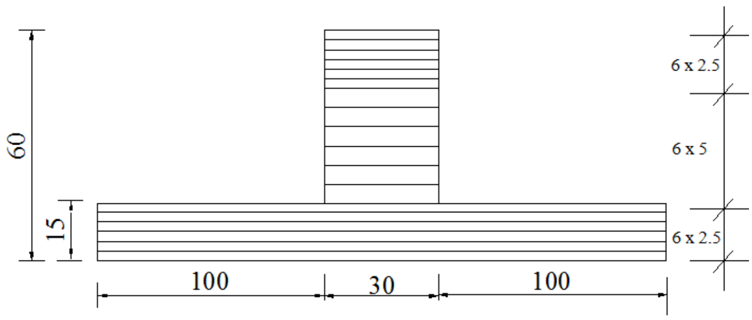
<u>Question (2)</u> **(40 Marks)** **[ILO's: a1, b1, b2, c1]**

For the given section shown in Figure 1, the axial strain at mid height of the section $\boldsymbol{\epsilon_0 = -0.0003}$ and the slope $\boldsymbol{\varphi = -0.0001}$ (d`= d`` = 2.5 cm). Using the given stress-strain curves for steel and concrete in tension and compression, it is required to:

(a) Calculate and draw the strain distribution;
(b) Calculate and draw the stress distribution;
(c) Calculate axial, coupling and flexural stiffness's (A,B and D) using the secant modulus of elasticity;
(d) Calculate section capacity (M and N);



Beam Section
(d` = d`` = 2.5 cm)



Layered System

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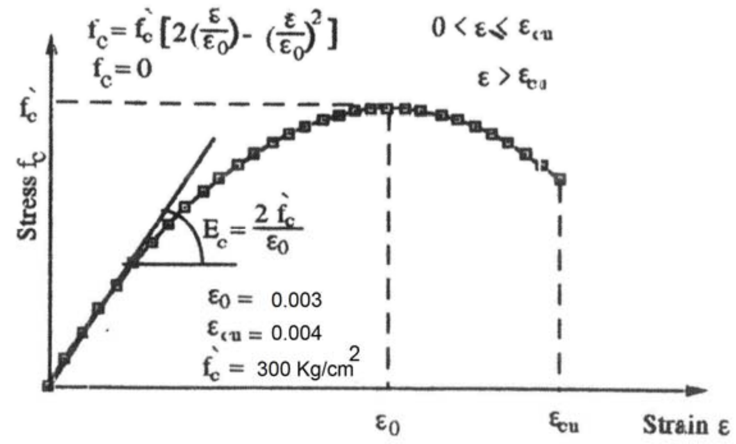
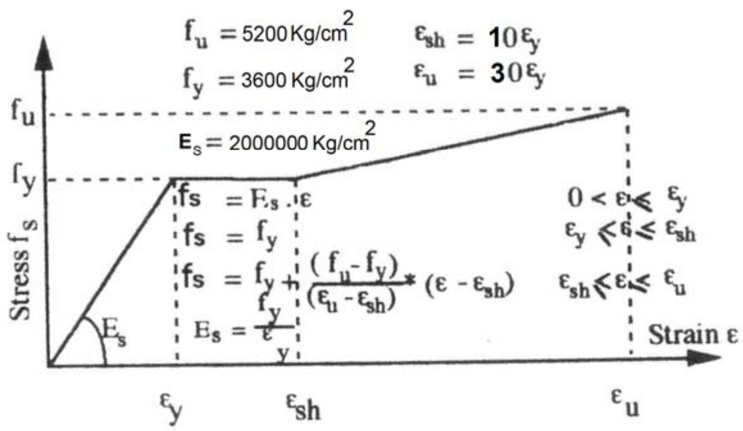
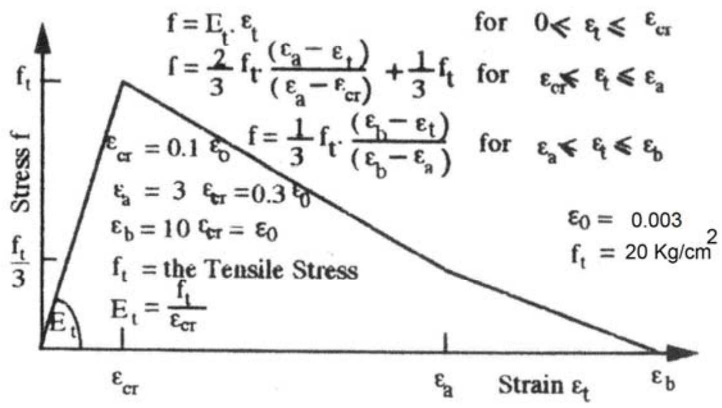


Concrete Stress-Strain Curve in Compression



Trilinear Stress-Strain Cirve for Steel Reinforcement in Tension and Compression



Trilinear Model for Concrete in Tension

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Total Mark: 60 Marks **Model Answer**

Question (1): Write short note about the followings (20 Marks) **[ILO's: a1, b1, b2]**

(1) Linear Analysis:

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

(2) 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.

(3) Types of nonlinearity:

Geometric nonlinearity & Material nonlinearity.

(4) Monotonic loading

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

(5) Cyclic loading

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

(6) 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.

(7) Strain hardening:

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

(8) Tension stiffening:

(a) 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.

(b) The capability of concrete in tension to carry tensile stresses after cracking.

(c) The participation of concrete in tension in carrying the tensile stress between cracks.

(9) Importance function and purpose of the nonlinear analysis of R.C elements:

(a) To understands the actual behavior of R.C structures;

(b) To get information that can't be easily measured from experimental studies;

(c) Make parametric studies to save cost and time;

(d) Observing the failure modes (failure mechanism) in R.C structure like flexure failure, shear failure;

(e) To represent or modeling the concrete and steel in R.C fields;

(f) Modeling the structure in realistic modeling of material and geometry to take material and geometry nonlinearity in the analysis of R.C structures;

(g) To get the internal strains which are difficult to measure by using externally strain gauge.

(10) The basic assumptions considered throughout the nonlinear analysis of the R.C plane frames.

The mathematical formulation is based on the following assumptions

(a) Plane section remains plane after deformation (i.e. linear strain distribution and shear deformation is ignored);

(b) 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);

(c) The mechanical properties of concrete and steel reinforcement are well defied;

(d) Concrete in tension should be taken into consideration ;

(e) Elastic modulus is defined according as secant or tangent.

(11) Loading techniques:

There are three types of loading techniques:

(a) Iterative: this method can evaluate the max. load point, but can't draw the load deflection curves;

(b) Incremental: with this method del load is applied in increments – using this method, we can draw the load- displacement curve;

(c) Incremental – Iterative: has the advantage of both the previous two methods but it is difficult and takes more time to get convergence.

(12) Tangent Modulus of elasticity

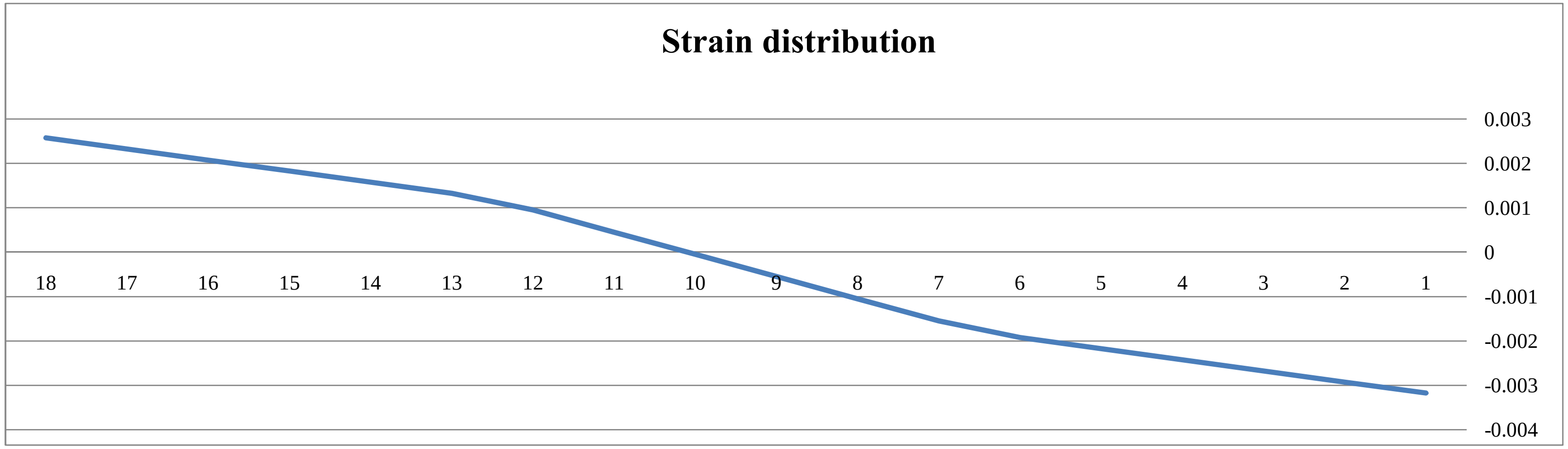
It is the slope of a line tangent to the stress-strain curve at a point of interest.

(13) Secant Modulus of elasticity

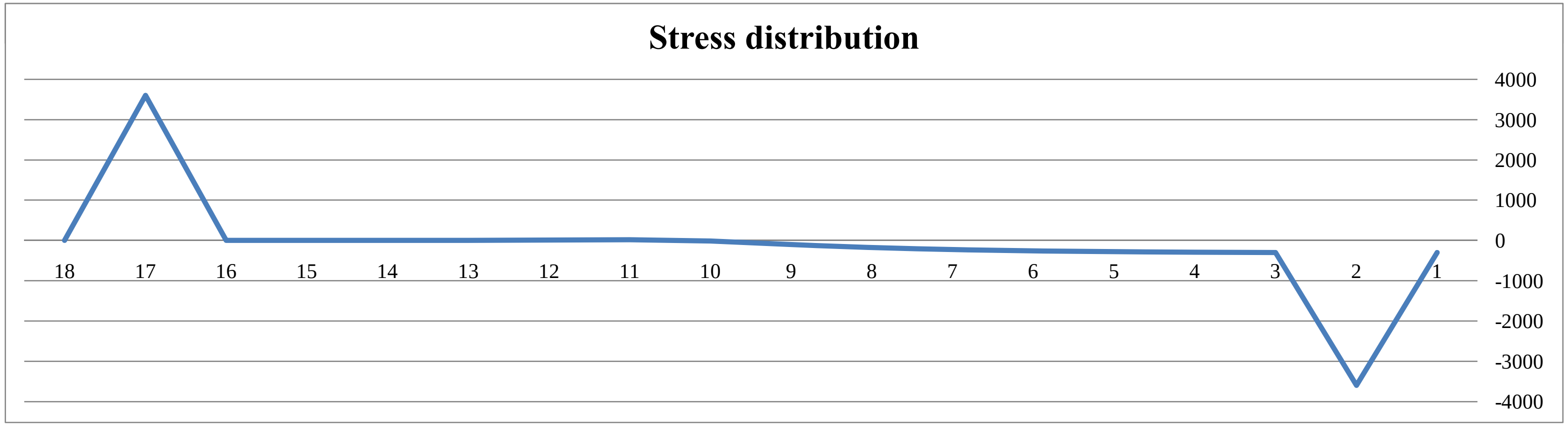
It is the slope of the straight line passing through the original point of the stress strain curve and a point on the curve.

Question (2) (40 Marks) [ILO's: a1, b1 b2]

a) Strain distribution



b) Stress distribution



Axial stiffness (A) , Coupling stiffness (B) & Flexural stiffness (D)

comp. concrete given		
Fc' =	300	Kg/cm2
Fy_{st}	2400	Kg/cm2
$\epsilon_{0=}$	0.003	
$\epsilon_{cu=}$	0.004	

Tension concrete given		
Fcu =	300	Kg/cm2
Ft =	20	Kg/cm3
$\epsilon_{0=}$	0.003	
$\epsilon_{cr=}$	0.0003	
Et	66666.667	Kg/cm2

Steel given		
St 37	360/520	
Fy	3600	Kg/cm2
Fu	5200	Kg/cm2
Es	2000000	Kg/cm2
$\epsilon_{y=}$	0.0018	
$\epsilon_{u=}$	0.054	
$\epsilon_{sh=}$	0.018	

$\epsilon_{cr=}$	0.0003
$\epsilon_{a=}$	0.0009
$\epsilon_{b=}$	0.003
Et	66666.66667

axial strain at mid height $\epsilon_{0=}$	-0.0003
slope =	-0.0001

b=	230	cm	t=	60	cm	As=	6.084	cm2
						As'=	3.218	cm2

layer no .	layer type	T_l (CM)	b_l (CM)	z_l (CM)	ϵ_l	status	F_l (Kg/CM2)	E secant (Kg/CM2)	A secant (cm2)	B secant (Kg.CM)	D secant (Kg.CM2)	N.F secant (Kg)	B.M secant (Kg.CM)
1	concrete	2.5	230	-28.75	-0.003175	c-comp	-298.9791667	94166.66667	54145833.33	-1556692708	44754915365	-171913.0208	4942499.349
2	steel	2.5	6.083	-26.25	-0.002925	steel	-3600	1230769.231	18716923.08	-491319230.8	12897129808	-54747	1437108.75
3	concrete	2.5	230	-23.75	-0.002675	c-comp	-296.4791667	110833.3333	63729166.67	-1513567708	35947233073	-170475.5208	4048793.62
4	concrete	2.5	230	-21.25	-0.002425	c-comp	-288.9791667	119166.6667	68520833.33	-1456067708	30941438802	-166163.0208	3530964.193
5	concrete	2.5	230	-18.75	-0.002175	c-comp	-277.3125	127500	73312500	-1374609375	25773925781	-159454.6875	2989775.391
6	concrete	2.5	230	-16.25	-0.001925	c-comp	-261.4791667	135833.3333	78104166.67	-1269192708	20624381510	-150350.5208	2443195.964
7	concrete	5	30	-12.5	-0.001550	c-comp	-229.9166667	148333.3333	22250000	-278125000	3476562500	-34487.5	431093.75
8	concrete	5	30	-7.5	-0.001050	c-comp	-173.25	165000	24750000	-185625000	1392187500	-25987.5	194906.25
9	concrete	5	30	-2.5	-0.000550	c-comp	-99.91666667	181666.6667	27250000	-68125000	170312500	-14987.5	37468.75
10	concrete	5	30	2.5	-0.000050	c-comp	-9.916666667	198333.3333	29750000	74375000	185937500	-1487.5	-3718.75
11	concrete	5	30	7.5	0.000450	c-ten	16.66666667	37037.03704	5555555.556	41666666.67	312500000	2500	18750
12	concrete	5	30	12.5	0.000950	c-ten	6.507936508	6850.459482	1027568.922	12844611.53	160557644.1	976.1904762	12202.38095
13	concrete	2.5	30	16.25	0.001325	c-ten	5.317460317	4013.177598	300988.3199	4891060.198	79479728.21	398.8095238	6480.654762
14	concrete	2.5	30	18.75	0.001575	c-ten	4.523809524	2872.260015	215419.5011	4039115.646	75733418.37	339.2857143	6361.607143
15	concrete	2.5	30	21.25	0.001825	c-ten	3.73015873	2043.922592	153294.1944	3257501.631	69221909.65	279.7619048	5944.940476
16	concrete	2.5	30	23.75	0.002075	c-ten	2.936507937	1415.184548	106138.8411	2520797.476	59868940.05	220.2380952	5230.654762
17	steel	2.5	3.217	26.25	0.002325	steel	3600	1548387.097	12452903.23	326888709.7	8580828629	28953	760016.25
18	concrete	2.5	30	28.75	0.002575	c-ten	1.349206349	523.9636308	39297.27231	1129796.579	32481651.64	101.1904762	2909.22619
									ΣA=	ΣB=	ΣD=	ΣN.F=	ΣB.M=
	Σt=	60							480380588.9	-7721711180	1.85535E+11	-916285.2946	20869982.98

C) ***A=*** ***480380588.9*** ***B=*** ***-7721711180*** ***D=*** ***1.85535E+11***

d) ***N=*** ***-916285.2946*** ***M=*** ***20869982.98***