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

الحل النموذجي لإمتحان الفصل الدراسي الثاني
دراسات عليا

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دكتور المادة
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Final Term Exam
Saturday 03/06/2017
Computation of Nonlinear Analysis
Duration: 3.0 hours
No. of questions: 2

Total Mark: 60 Marks **Model Answer**

<u>Question (1):</u> <u>Discuss the following items</u> (30 Marks) [ILO's: a3, b2, b3, d4]

(1) <u>Compression softening:</u>

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.

(2) <u>Strain hardening:</u>

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

(3) <u>Tension stiffening:</u>

(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.

(4) <u>Linear Analysis:</u>

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

(5) <u>Non-Linear Analysis:</u>

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

(6) <u>Types of nonlinearity:</u>

Geometric nonlinearity & Material nonlinearity.

(7) <u>Importance function and purpose of the nonlinear analysis of R.C elements:</u>

(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.

(8) <u>The basic assumptions considered throughout the nonlinear analysis of the R.C plane frames:</u>

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.

(9) <u>The major factors causing nonlinear behavior of R.C elements:</u>

(a) The low tensile strength and accompanying tensile cracks of concrete at relatively low stress.

(b) Codes consider concrete as linear, elastic, homogeneous, isotropic material, while it is heterogeneous material;

(c) Concrete behave as a nonlinear material at high stress and its properties in tension is completely difference the properties in compression.

(10) <u>The causes and factors leading to the difference in the nonlinear analysis of R.C structures:</u>

(a) The difference in material modeling ;

(b) The difference in finite element formulation;

(c) Increase in the number of iterations required for satisfying the convergence conditions;

(d) The difference in the number of layers;

(e) The poor state of the art in constituent modeling of cracked R.C.

(11) <u>Loading techniques:</u>

There are three types of loading techniques:

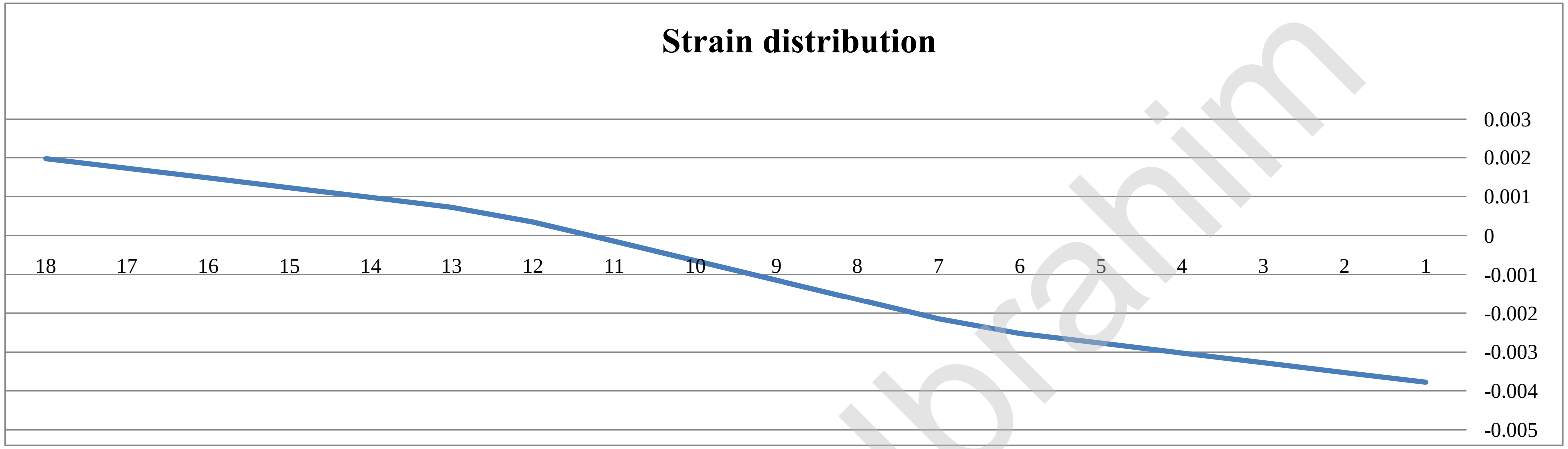
(a) Iterative: this method can evaluate the max. load point, but can’t draw the load deflection curves;

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

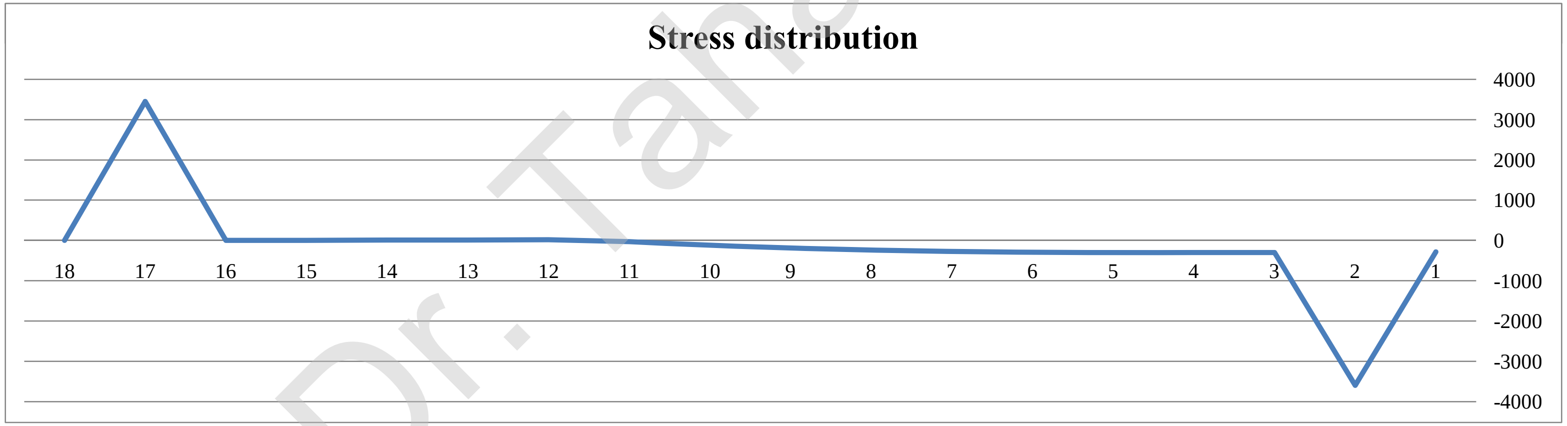
(c) Incremental – Iterative: has the advantage of both the previous two methods but it is difficult and takes more time to get convergence.

Question (2) **(30 Marks)** **[ILO's: a3, b2, b3, d4]**

a) Strain distribution



b) Stress distribution



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

comp. concrete given		
Fc' =	300	Kg/cm2
Fyst	2400	Kg/cm2
ϵ_{0}=	0.003	
ϵ_{cu}=	0.004	

Tension concrete given		
Fcu =	300	Kg/cm2
Ft =	20	Kg/cm3
ϵ_{0}=	0.003	
ϵ_{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
ϵ_y=	0.0018	
ϵ_u=	0.054	
ϵ_{sh}=	0.018	

ϵ_{cr}=	0.0003
ϵ_a=	0.0009
ϵ_b=	0.003
Et	66666.66667

axial strain at mid height ϵ_0=	-0.0009
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	-0.003775	c-comp	-279.9791667	74166.66667	42645833.33	-1226067708	35249446615	-160988.0208	4628405.599
2	steel	2.5	6.083	-26.25	-0.003525	steel	-3600	1021276.596	15531063.83	-407690425.5	10701873670	-54747	1437108.75
3	concrete	2.5	230	-23.75	-0.003275	c-comp	-297.4791667	90833.33333	52229166.67	-1240442708	29460514323	-171050.5208	4062449.87
4	concrete	2.5	230	-21.25	-0.003025	c-comp	-299.9791667	99166.66667	57020833.33	-1211692708	25748470052	-172488.0208	3665370.443
5	concrete	2.5	230	-18.75	-0.002775	c-comp	-298.3125	107500	61812500	-1158984375	21730957031	-171529.6875	3216181.641
6	concrete	2.5	230	-16.25	-0.002525	c-comp	-292.4791667	115833.3333	66604166.67	-1082317708	17587662760	-168175.5208	2732852.214
7	concrete	5	30	-12.5	-0.002150	c-comp	-275.9166667	128333.3333	19250000	-240625000	3007812500	-41387.5	517343.75
8	concrete	5	30	-7.5	-0.001650	c-comp	-239.25	145000	21750000	-163125000	1223437500	-35887.5	269156.25
9	concrete	5	30	-2.5	-0.001150	c-comp	-185.9166667	161666.6667	24250000	-60625000	151562500	-27887.5	69718.75
10	concrete	5	30	2.5	-0.000650	c-comp	-115.9166667	178333.3333	26750000	66875000	167187500	-17387.5	-43468.75
11	concrete	5	30	7.5	-0.000150	c-comp	-29.25	195000	29250000	219375000	1645312500	-4387.5	-32906.25
12	concrete	5	30	12.5	0.000350	c-ten	18.88888889	53968.25397	8095238.095	101190476.2	1264880952	2833.333333	35416.66667
13	concrete	2.5	30	16.25	0.000725	c-ten	10.55555556	14559.38697	1091954.023	17744252.87	288344109.2	791.6666667	12864.58333
14	concrete	2.5	30	18.75	0.000975	c-ten	6.428571429	6593.406593	494505.4945	9271978.022	173849587.9	482.1428571	9040.178571
15	concrete	2.5	30	21.25	0.001225	c-ten	5.634920635	4599.935212	344995.1409	7331146.744	155786868.3	422.6190476	8980.654762
16	concrete	2.5	30	23.75	0.001475	c-ten	4.841269841	3282.216842	246166.2631	5846448.749	138853157.8	363.0952381	8623.511905
17	steel	2.5	3.217	26.25	0.001725	steel	3450	2000000	16085000	422231250	11083570313	27746.625	728348.9063
18	concrete	2.5	30	28.75	0.001975	c-ten	3.253968254	1647.578863	123568.4147	3552591.923	102137017.8	244.047619	7016.369048
									ΣA=	ΣB=	ΣD=	ΣN.F=	ΣB.M=
	Σt=	60							443574991.3	-5938152489	1.59882E+11	-993032.7411	21332503.14

C) **A= 443574991.3** **B= -5938152489** **D= 1.59882E+11**

d) **N= -993032.7411** **M= 21332503.14**