BENHA UNIVERSITY
SHOUBRA FACULTY OF ENGINEERING
CIVIL ENGINEERING DEPARTEMENT

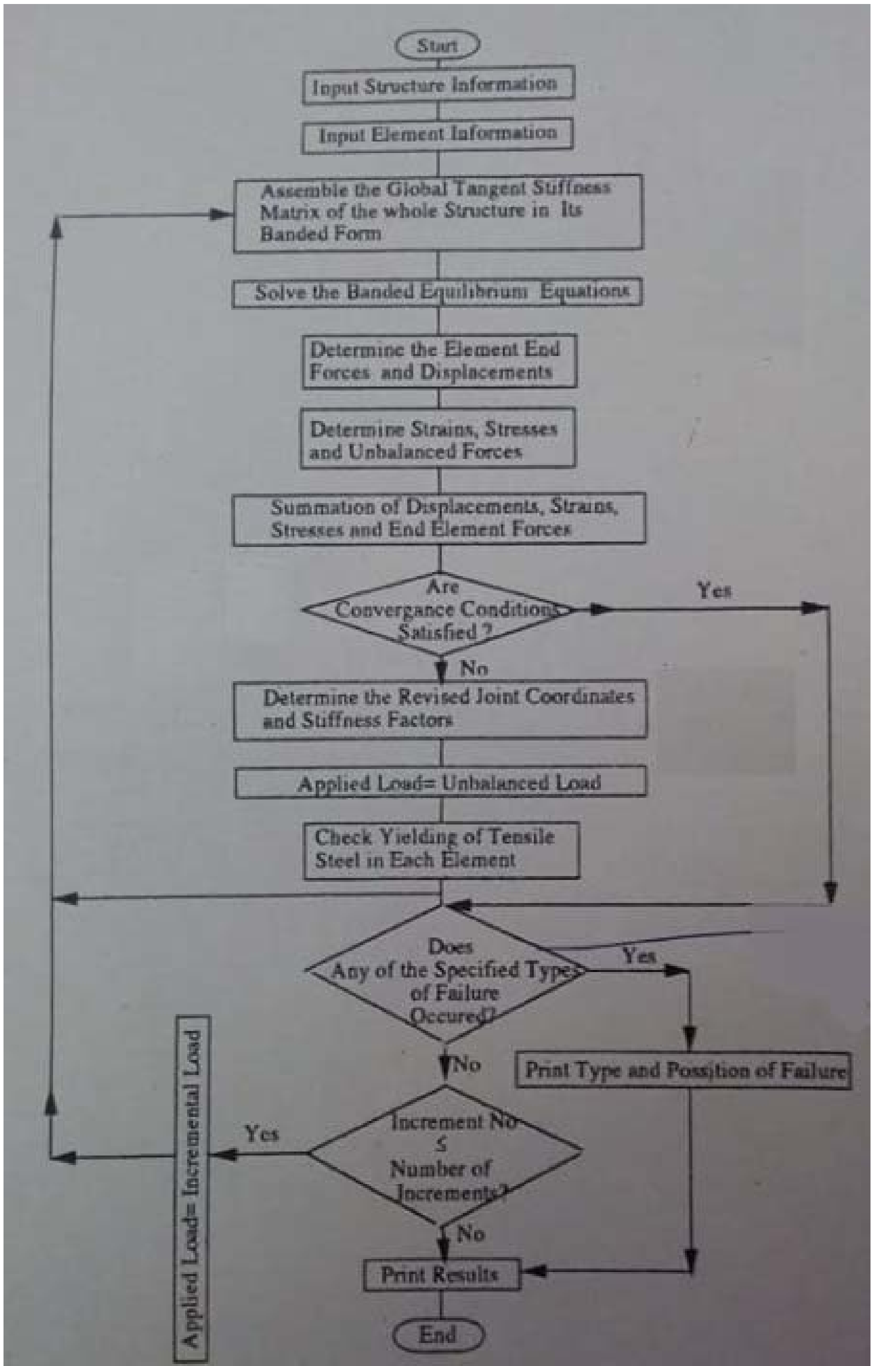
Final 1st Term Exam
Saturday 18/01/2020
Computation of Nonlinear Analysis

Master of Science & Engineering (M.Sc)
Code: STR602

Duration: 3.0 hours
No. of questions: 3

Total Mark: 60 Marks **Model Answer**

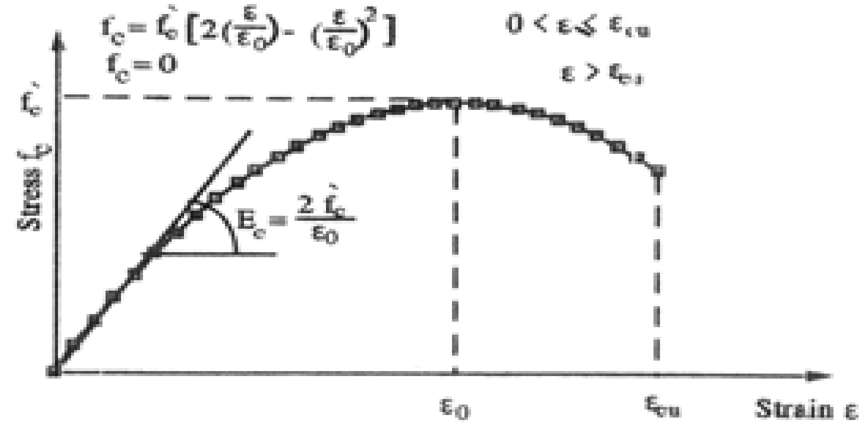
Question (1):



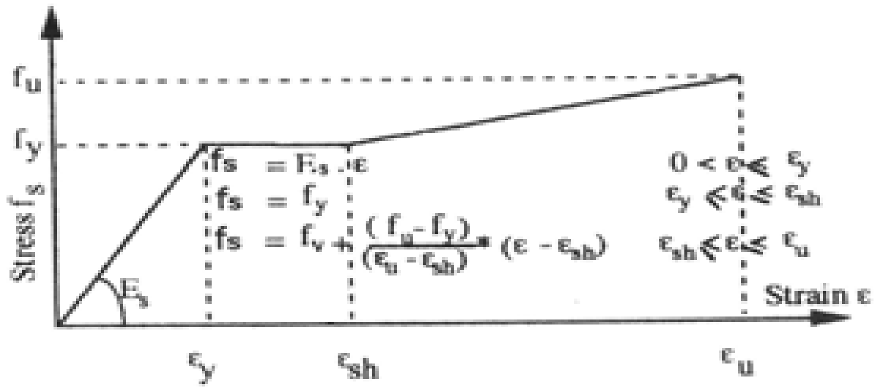
Flow Chart for the Plane Frame Program

Question (2): **Write short note about the followings**

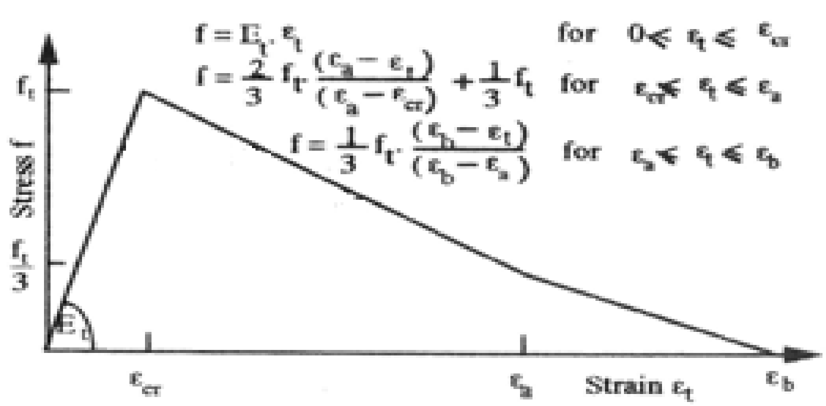
(1) , (2) , (3)



Concrete Stress-Strain Curve in Compression



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



Trilinear Model for Concrete in Tension

(4) Linear Analysis:

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

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.

Types of nonlinearity:

Geometric nonlinearity & Material nonlinearity.

(5) Monotonic loading

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

Cyclic loading

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

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.

(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.

Strain hardening:

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

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.

(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>Tangent Modulus of elasticity</u>

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

<u>Secant Modulus of elasticity</u>

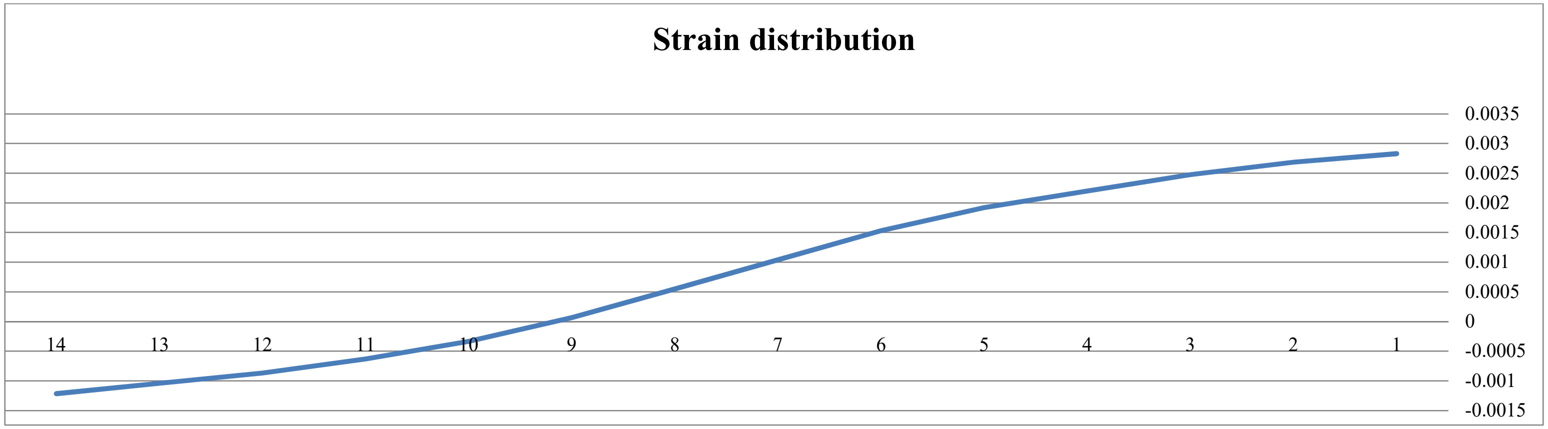
It is the slope of the straight line passing through the original point of the stress strain curve and a point on the curve.

(10) <u>From where the differences in the nonlinear analysis of R.C come?</u>

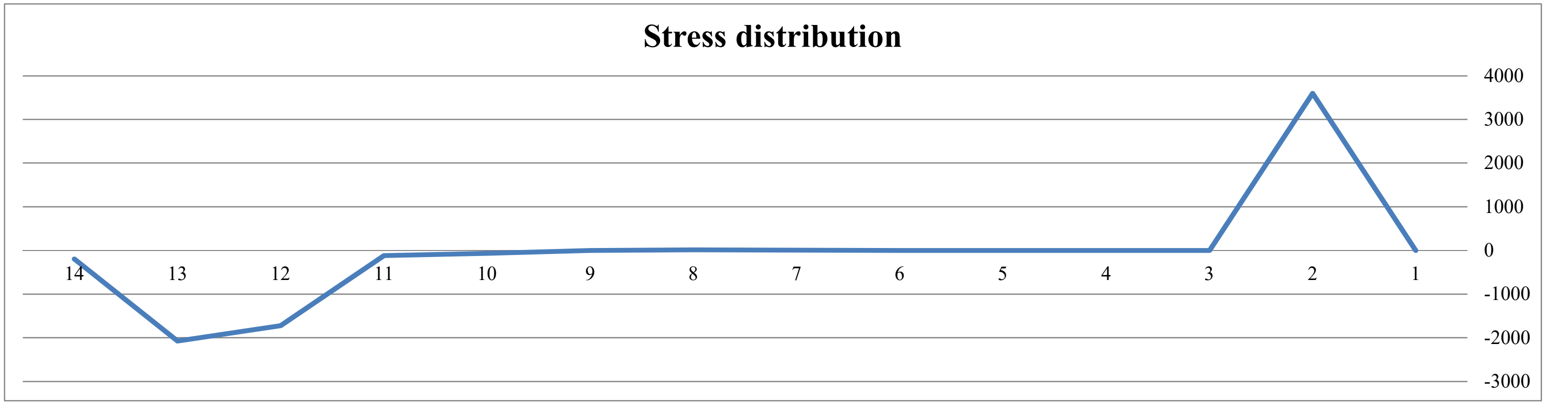
1- Poor state of the art in constitutive modeling of cracked reinforced concrete;
2- Error in material idealizations;
3- Error in finite element formulations;

Q3- 1

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

24.55

9.82

axial strain at mid height ϵ_{0}=	0.0008
slope =	-0.00007

b=	var.	cm	t=	60	cm	As=	34.37	cm2
						As'=	19.64	cm2

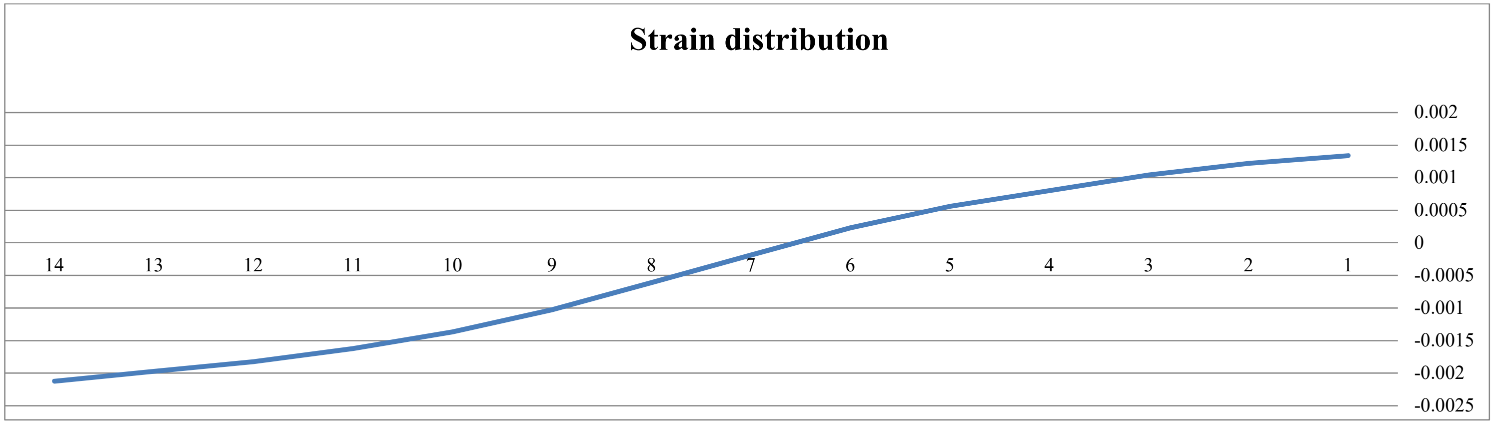
layer no .	layer type	Ti (CM)	bi (CM)	zi (CM)	ϵ_i	status	Fi (Kg/CM2)	E secant (Kg/CM2)	A secant (cm2)	B secant (Kg.CM)	D secant (Kg.CM2)	N.F secant (Kg)	B.M secant (Kg.CM)
1	concrete	2	40	29	0.002830	c-ten	0.53968254	190.7005441	15256.04352	442425.2622	12830332.6	43.17460317	1252.063492
2	steel	2	9.82	27	0.002690	steel	3600	1338289.963	26284014.87	709668401.5	19161046840	70704	1909008
3	concrete	4	40	24	0.002480	c-ten	1.650793651	665.6426011	106502.8162	2556067.588	61345622.12	264.1269841	6339.047619
4	concrete	4	40	20	0.002200	c-ten	2.53968254	1154.401154	184704.1847	3694083.694	73881673.88	406.3492063	8126.984127
5	concrete	4	40	16	0.001920	c-ten	3.428571429	1785.714286	285714.2857	4571428.571	73142857.14	548.5714286	8777.142857
6	concrete	7	40	10.5	0.001535	c-ten	4.650793651	3029.832997	848353.2392	8907709.012	93530944.63	1302.222222	13673.33333
7	concrete	7	40	3.5	0.001045	c-ten	6.206349206	5939.09015	1662945.242	5820308.347	20371079.21	1737.777778	6082.222222
8	concrete	7	40	-3.5	0.000555	c-ten	14.33333333	25825.82583	7231231.231	-25309309.31	88582582.58	4013.333333	-14046.66667
9	concrete	7	40	-10.5	0.000065	c-ten	4.333333333	66666.66667	18666666.67	-196000000	2058000000	1213.333333	-12740
10	concrete	4.25	100	-16.125	-0.000329	c-comp	-62.14744792	189041.6667	80342708.33	-1295526172	20890359521	-26412.66536	425904.229
11	concrete	4.25	100	-20.375	-0.000626	c-comp	-112.1770313	179125	76128125	-1551110547	31603877393	-47675.23828	971382.98
12	steel	2.5	3.928	-23.75	-0.000863	steel	-1725	2000000	19640000	-466450000	11078187500	-16939.5	402313.125
13	steel	2.5	9.82	-26.25	-0.001038	steel	-2075	2000000	49100000	-1288875000	33832968750	-50941.25	1337207.813
14	concrete	2.5	100	-28.75	-0.001213	c-comp	-193.4947917	159583.3333	39895833.33	-1147005208	32976399740	-48373.69792	1390743.815
	Σt=	60							ΣA=	ΣB=	ΣD=	ΣN.F=	ΣB.M=
									320392055.2	-5234615812	1.52025E+11	-110109.4627	6454024.089

C) ***A=*** ***320392055.2*** ***B=*** ***-5234615812*** ***D=*** ***1.52025E+11***

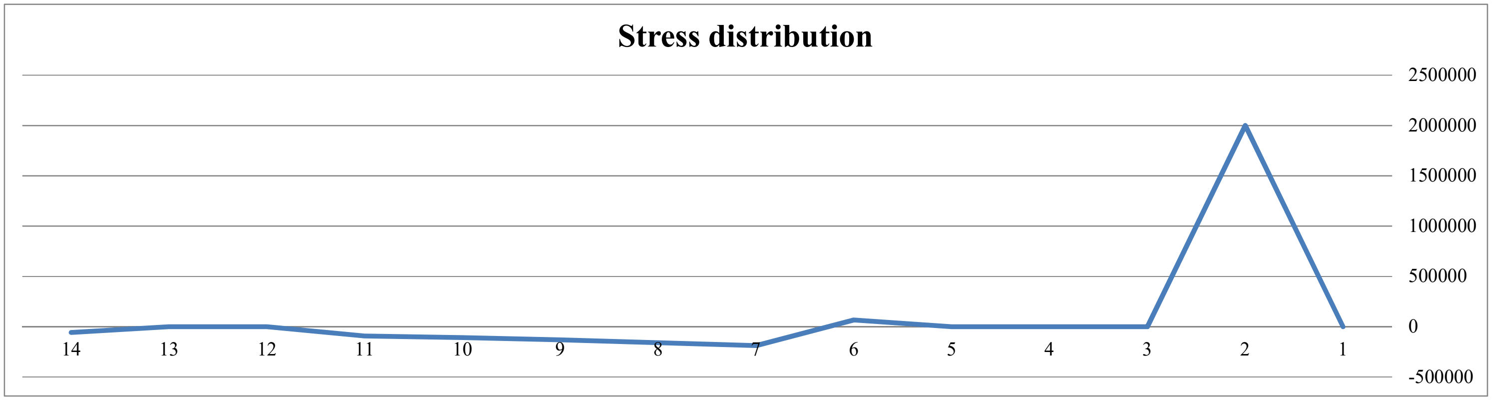
d) ***N=*** ***-110109.4627*** ***M=*** ***6454024.089***

Q3- 2

a) Strain distribution



b) Stress distribution



M & N

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

Tension concrete given		
F_{cu} =	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

15.7

6.28

axial strain at mid height ϵ_0=	-0.0004
slope =	0.00006

b=	var.	cm	t=	60	cm	As=		cm2
						As'=	12.56	cm2

layer no .	layer type	T_I (CM)	b_I (CM)	z_I (CM)	ϵ_I	status	F_I (Kg/CM2)	E tangent (Kg/CM2)	N.F secant (Kg)	B.M secant (Kg.CM)
1	concrete	2	40	-29	0.001340	c-ten	0	0	0	0
2	steel	2	7.85	-27	0.001220	steel	2000000	1639344262	31400000	-847800000
3	steel	4	1.57	-24	0.001040	c-ten	0	0	0	0
4	concrete	4	40	-20	0.000800	c-ten	0	0	0	0
5	concrete	4	40	-16	0.000560	c-ten	0	0	0	0
6	concrete	7	40	-10.5	0.000230	c-ten	66666.66667	289855072.5	18666666.67	-196000000
7	concrete	7	40	-3.5	-0.000190	c-comp	-187333.3333	985964912.3	-52453333.33	183586666.7
8	concrete	7	40	3.5	-0.000610	c-comp	-159333.3333	261202185.8	-44613333.33	-156146666.7
9	concrete	7	40	10.5	-0.001030	c-comp	-131333.3333	127508090.6	-36773333.33	-386120000
10	concrete	4.25	100	16.125	-0.001368	c-comp	-108833.3333	79585618.53	-46254166.67	-745848437.5
11	concrete	4.25	100	20.375	-0.001623	c-comp	-91833.33333	56599897.28	-39029166.67	-795219270.8
12	concrete	2.5	100	23.75	-0.001825	steel	0	0	0	0
13	steel	2.5	5.024	26.25	-0.001975	steel	0	0	0	0
14	concrete	2.5	100	28.75	-0.002125	c-comp	-58333.33333	27450980.39	-14583333.33	-419270833.3
	Σt=	60							ΣN.F= -183640000	ΣB.M= -3362818542

b) ***N=*** ***-183640000*** ***M=*** ***-3362818542***