BUILDING DESIGN USING

ELECTRONIC DIGITAL COMPUTER

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Summary:

A Program has been developed for building design. General building comprises, slabs, simple beams, continuous beams, and columns. Input to the program describes arbitrary statical system. Output provides dimensions of different components, required area of steel, volume of concrete, and weight of reinforcements. Hence, the program can be used for the following purposes:

1- design a new structure.
2- review the design of an existing structure.
3- economical study of buildings.

The program sticts to Egyptian specification as close as possible.

The program is written in Fortran IV language.

Introduction:

If it is required to solve a problem, a question may be arised whether to use a computer or not. The answer has to depend on the nature of the problem, i.e. mainly on the following factors:

1- amount of exact calculations.
2- repitition of the problem.

If one of the above factors is increased, computer should be used. As a matter of fact, building design is a repetitive problem, i.e. the same proceudure of calculations has to be carried out periodically, only the numerical data being different for different configurations.

In such a case, a computer program may be written in a form of a standard general program (Package), and the analysis of the individual case merely involves transformation of the designer's drawing board into computer input medium.

Computers can be used to solve problems of structural analysis. An extension to the analysis is to design a structure for a given allowable stresses. The presented program is an attempt to intoroduce a standard program for building design, which can be applied to different inpute. In making preliminary studies, structural engineers often prepare cost estimates, using different column spacings, and beam arrangements. Hence, it is possible to get the most economical choice.

Building design, in this program, is carried out according to the elastic theory.

I. Method of solution:

A: Slabs:

Program differentiates between one way slab, and two way slab according to their dimensions. Initial slab thickness is assumed equal to 10cm, and then corrected according to the bending moment. Numbers and diameters of steel bars are calculated in the two directions. Weight of steel and volume of concrete are also obtained.

The following boundary conditions are considered:

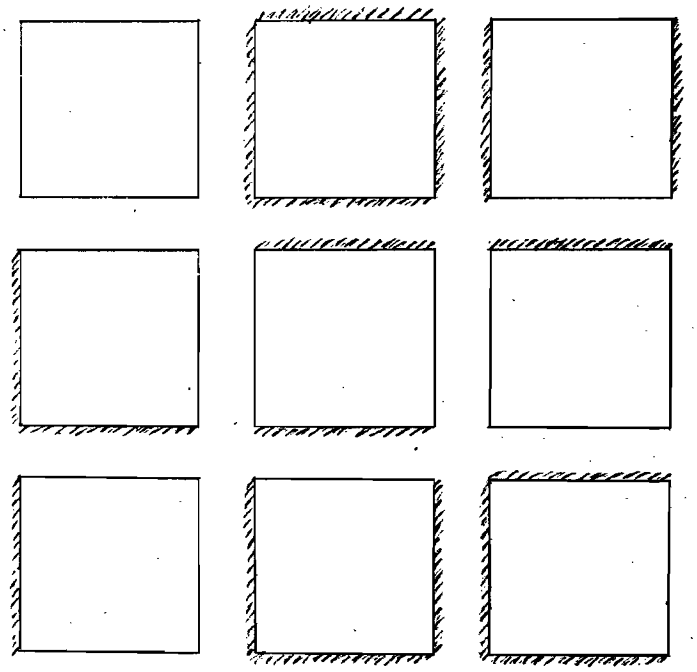


Fig. 1

B: Secondary beams:

The maximum positive bending moment is calculated by means a subroutine which also calculates reactions. Neighbouring slabs transform loads to simple beams according to their codes as follows:

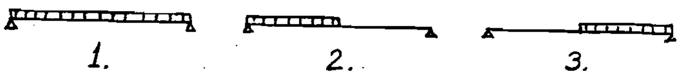


Fig. 2

Concentrated loads are also considered. The mentioned subroutine calculates bending moment at different stations beginning from 0.2 span till 0.8 span. The maximum positive bending moment is obtained as the maximum value at these stations. The depth is obtained from the maximum positive bending moment as a tee section. The corresponding area of steel is determined. Weight of steel and volume of concrete are also presented.

C: Continuous beams:

The analysis of the continuous beams is performed by the equilibrium method (stiffness matrix). The continuous beam is condidred as a linear skeletal structure. Loads from neighbouring slabs and cross beams are transformed to main bemas. Slope-deflection method is applied to obtain the stiffness matrix. The matrix is solved for rotations at the joints. Hence the connecting moments are obtained. Solution of the equations follows the band matrix alogrithm. Calculation of maximum positive bending moment for each span followss the same procedure as that of simple beams. Constant depth and breadth are assumed all over the continuous beams. Depth is obtained according to the maximum negative beinding moment. Area of steel is calculated for each span according to the maximum negative and maximum positive bending moment. Volume of concrete and weight of steel are also calculated for each continuous beam.

D: Diagonal tension check for beams:

The ordinarly used equation for diagonal tension is used to get diagonal tensile stresses. If these stresses exceed the allowable limits, diagonal reinforcements will be introduced in the form of inclined stirrups.

The following choices are considered:

1- number of branches of each stirrup n = 2
2- area of steal As = 0.5 cm^2 which corresponds to Ø 8mm.
3- allowable diagonal tensile stess q = 6 Kg/cm^2

The following equations are used:

$$q = \frac{Q}{.87\ b\ d}, \quad S = \frac{.87\ n\ As\ fs\ d}{Q.}\sqrt{2}$$

Where:

Q = maximum shearing force.
fs= allowable steal stress.
d = depth of beam.
b = breadth of beam.
S = maximum spacing of inclined stirrups at maximum shearing force.

E: Columns

As mentioned before the subroutine for calculating the maximum positive bending moment, also calculates column loads P by accumulating shearing forces from different beams.

The following known equation is used for design of columns as concentracally loaded.

$$Ac = \frac{P}{1.15\ fc_0} \qquad \text{for} \quad \frac{As}{Ac} = 0.01$$

Where

Ac = required area of concrete.
As = required area of steel.
fc_0= allowable concrete stress.

The effect of buckling is taken into consideration, hence the required area of concrete is modified according to the following:

$$Ac = \frac{P}{1.15\ fc\ w}$$

where w is a reduction factor that depends on column length and breadth and given by E.S.S. tables.

II. Input:

Input to the program describes exactly the statical system, i.e. the following are fed to the program as an example of input cards:

1. First card:

   15 8 5 3 3

   Where

Number of joints	= 15
number of slabs	= 8
number of simple beams	= 5
number of continuous beams	= 3
number of storys	= 3

2. Second card

   50 1400 60. 1400 50. 300 400 3.

   Where

allowable concrte stress for slabs	= 50 kg/cm2
allowable steal stress for slabs	= 1400 kg/cm2
allowable concrete stress for beams	= 60 kg/cm2
alloable steal stress for slabs	= 1400 kg/cm2
allowable concrete stress for slabs	= 50 kg/cm2
live load	= 300 kg/cm2
dead load	= 400 kg/cm2
height of wall	= 300 m

3. Third group of cards:

   3. 4. 1

   Where

x - coordinate of a joint	= 3.
Y - coordinate of a joint	= 4.
I C	= 1

IC = 1 if a column exists at this joint, other value for IC indicates that there is no column at this point. Every joint has the same format i.e. the number of this group of cards equal to the number of joints.

4. Fourth card

   107 208...........

   where

designation of the first slab	= 107
designation of the second "	= 208

It is meant designation, the two numbers connecting a diagonal of the slab.
The number of slab designations equal to number of slabs.

5. Fifth card

   5 6 8 2.......

   where

   designation of first slab boundary conditions = 5

   designation of second slab boundary conditions = 6

For designation of slab boundary conditions refer to Fig.1

6. Sixth group of cards:

   205 1 1 2 204 1 206 1 3

   Where

designation of the simple beam	=	205
designation of direction	=	1
designation of wall existance	=	1
number of connecting slabs	=	2
first connecting slab	=	204
designation of first slab	=	1
second connecting slab	=	206
designation of second slab	=	1
point of concentrated load	=	3

Designation of a simple beam is the number of jounts forming the beam i.e. the above beam connects joints 2,5

Designation of the direction equal to zero if the beam is in the x-direction, and equal to 1 for the y- direction.

Designation of slabs connected to the beam as explained before.

7. Seventh group of cards: (Continuous beams)

5	0	1		
507	1	609	1	8

Where

first card	number of spans	= 5
	designation of direction	= 0
	designation of wall	= 1

Second card

designation of span	=	607
number of connecting slabs	=	1
connecting slab	=	609
designation of slab	=	1
point of concentrated load	=	8

For each continuous beam the first card indicates the number of spans, the second card is repeated for each span. The above first card and second cards are performed for each continuous beam.

II. Output

Slabs:

1. designation of slab : SLABNO
2. thicknes of slab : T.
3. number of steel bars in X-direction : N B A
4. diamter of steel bars in X-direction: D B A
5. number of steel bars in y-direction : N B B
6. diameter of steel bars in y-direction: D B B
7. weight of steel/unit area in X-direc.: W S T A
8. weight of steel/unit area in y-direc.: W S T B
9. total w. of steel up to the relevant state : W S T T.
10. total volume of concrete up to the relevant stage : V C O N

Secondary beams:

1. designation of secondry beam : S.B.No
2. maximum positive bending moment : P B M.
3. breadth : B.
4. depth : D.
5. shear stress at the first joint : Q1.
6. shear stress at the second joint : Q2.
7. spacing of inclined stirrups at the first joint. : S1.
8. spacing of inclined stirrups at the second joint : S2.
9. area of steel : AS.
10. weight of steel in the secondary beam : W S T
11. total w. of steel up to the relevant stage: W S T T
12. total volume of concrete up to the revlant stage : V C O N.

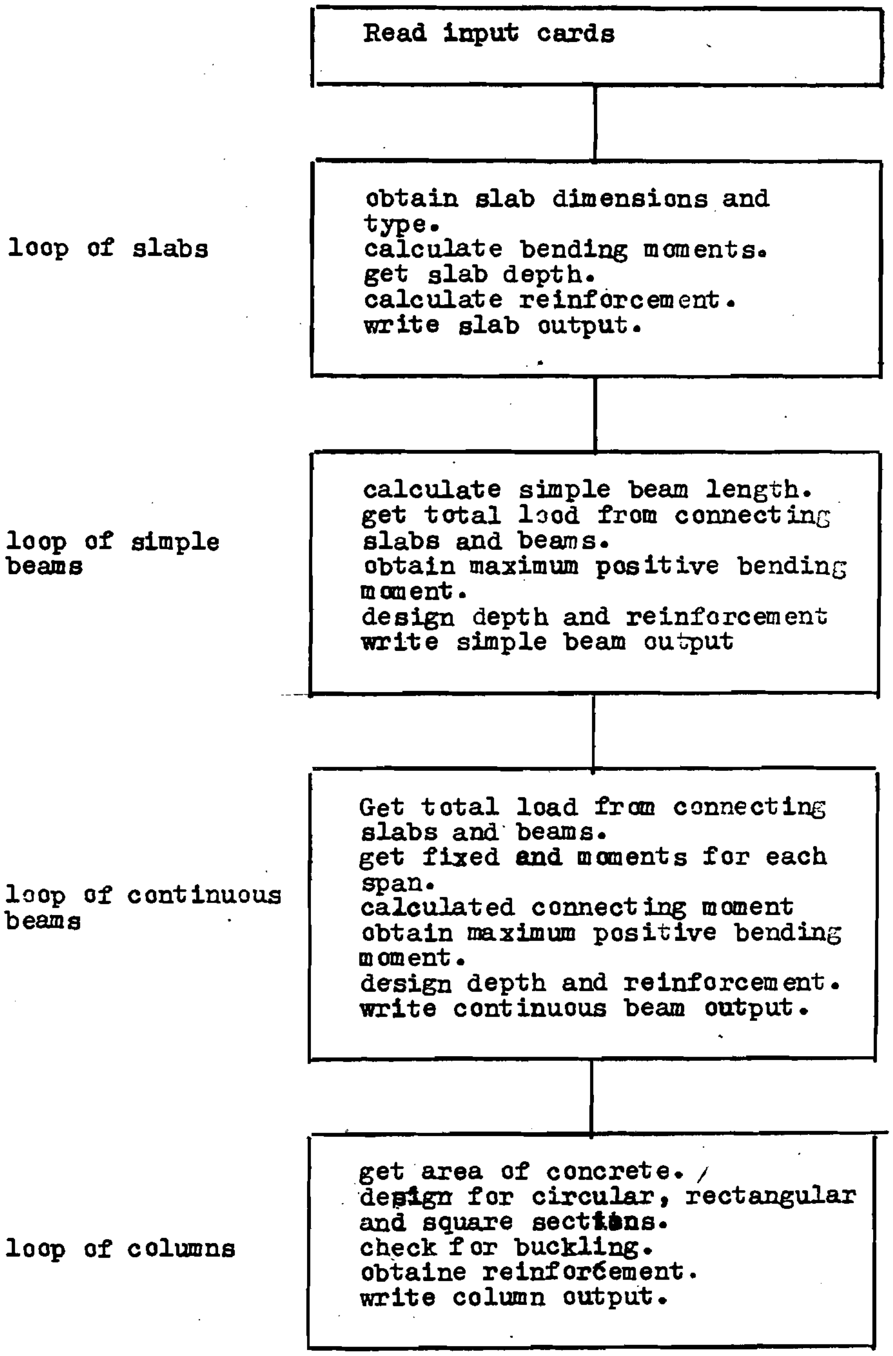
Continuous beams:

1. span number of the continuous beam : SPANNO
2. maximum positive bending moment of the span :PBM
3. connecting moment at the first joint : BM1
4. connecting moment at the second joint : BM2
5. breadth : B
6. depth : D
7. shear stress at the first joint : Q1
8. shear stress at the secdond joint : Q2
9. spacing of inclined stirrups at the first joint : S1.
10. spacing of inclined stirrups at the second joint : S2.
11. area of steel at the first joint : AS1
12. area of steel at the seaond joint : AS2
13. weight of steel in the span : WST
14. total weight of steel up to relevant stage : WSTT
15. total volume of concrete up to the relevant stage: VCON

Columns:

1. designation of the column joint : JNO
2. column load : SF.
3. concerete area for square section : ACS
4. steel area for square section : ASS
5. langth of square side : BS
6. concrete area for circular section : ACC
7. steel area for circular section : ASC
8. diameter of column : BC
9. concrete area for rectangular section : ACR
10. steel area for rectangular section : ASR
11. breadth of rectanguler section : BR.
12. weight of steel in the column : WST.
13. total weight of steel up to the relevant stage : WSTT.
14. total volume of concrete up to the relevant stage: VCON

V. Block diagram:



III- Results:

Results:

The attached drawing is solved, and the annexed output is for that building. The following parameters are included:

1. number of joints : 76
2. number of slabs : 45
3. number of simple beams : 6
4. number of continuous beams : 26
5. number of columns : 56
6. number of storys : 3

Total mill time taken for this problem = 56 seconds

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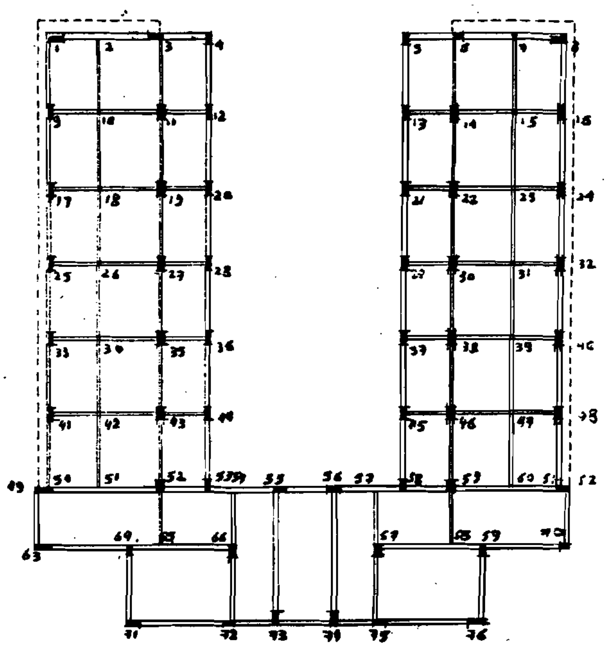

DESIGN OF SLABS

SLABNO	T	NBA	DBA	NBB	DBB	WSTA	WSTB	WSTT	VCON
110	8.	6	8.	5	8.	3.08	2.57	56.47	0.80
211	8.	5	10.	5	8.	4.01	2.57	141.97	1.84
312	8.	6	8.	5	8.	3.08	2.57	198.44	2.64
514	8.	6	8.	5	8.	3.08	2.57	254.91	3.44

DESIGN OF SECONDARY BEAMS

S.B.NO	PBM	B	D	Q1	Q2	S1	S2	AS	WST	WSTT	VCON
4963	0.179E 04	25.	25.	4.4	4.4	20.0	20.0	9.40	31.57	3549.85	46.51
6471	0.379E 04	25.	55.	3.2	3.2	20.0	20.0	6.62	29.68	3579.52	47.06
5573	0.136E 05	12.	85.	8.8	8.8	13.3	13.3	14.29	112.03	3691.56	47.78
5674	0.144E 05	12.	85.	9.3	9.3	12.6	12.6	15.07	118.15	3809.70	48.49
6976	0.372E 04	25.	55.	3.1	3.1	20.0	20.0	6.50	29.11	3838.81	49.04
6270	0.179E 04	25.	25.	4.4	4.4	20.0	20.0	9.40	31.57	3870.38	49.23

DESIGN OF CONTINUOUS BEAMS

SPANNO	PBM	BM1	BM2	B	D	Q1	Q2	S1	S2	AS1	AS2	WST	WSTT	VCON
109	0.261E 04	0.000E 00	-.355E 04	25.	55.	2.8	4.2	20.0	20.0	0.00	4.55	20.39	3890.77	49.78
917	0.113E 04	-.355E 04	-.258E 04	25.	55.	3.7	3.3	20.0	20.0	5.30	1.97	23.74	3914.51	50.33
1725	0.145E 04	-.258E 04	-.290E 04	25.	55.	3.4	3.6	20.0	20.0	3.85	2.53	17.26	3931.77	50.88
2533	0.145E 04	-.290E 04	-.258E 04	25.	55.	3.6	3.4	20.0	20.0	4.34	2.53	19.42	3951.19	51.43
3341	0.113E 04	-.258E 04	-.355E 04	25.	55.	3.3	3.7	20.0	20.0	3.85	1.97	17.26	3968.46	51.98
4150	0.261E 04	-.355E 04	0.000E 00	25.	55.	4.2	2.8	20.0	20.0	5.30	4.55	23.74	3992.20	52.53
210	0.252E 04	0.000E 00	-.343E 04	12.	55.	5.6	8.6	20.0	13.6	0.00	4.40	19.73	4011.93	52.79
1018	0.109E 04	-.343E 04	-.250E 04	12.	55.	7.5	6.7	15.6	17.5	5.13	1.91	22.97	4034.90	53.06
1826	0.140E 04	-.250E 04	-.281E 04	12.	55.	6.9	7.2	16.8	16.2	3.73	2.45	16.71	4051.61	53.32
2634	0.140E 04	-.281E 04	-.250E 04	12.	55.	7.2	6.9	16.2	16.8	4.20	2.45	18.80	4070.40	53.58
3442	0.109E 04	-.250E 04	-.343E 04	12.	55.	6.7	7.5	17.5	15.6	3.73	1.91	16.71	4087.11	53.85
4251	0.252E 04	-.343E 04	-.298E-07	12.	55.	8.6	5.6	13.6	20.0	5.13	4.40	22.97	4110.09	54.11

DESIGN OF COLUMNS STORY NO= 3

JNO	SF	ACS	ASS	BS	ACC	ASC	BC	ACR	ASR	BR	WST	WSTT	VCON
0.000E 00	0.768E 06												
1	8671.2	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	6469.09	94.71
3	16264.4	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	6487.09	94.90
4	2264.3	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	6505.09	95.08
5	2264.3	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	6523.09	95.27
6	16264.4	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	6541.09	95.46
8	8671.2	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	6559.09	95.65
9	16378.9	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	6577.09	95.83

DESIGN OF COLUMNS STORY NO= 2

JNO	SF	ACS	ASS	BS	ACC	ASC	BC	ACR	ASR	BR	WST	WSTT	VCON
0.769E 06	0.768E 06												
1	17342.4	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	14936.17	210.23
3	32528.8	628.6	6.29	25.0	628.6	6.29	30.0	628.6	6.29	25.0	18.10	14954.28	210.42
4	4528.6	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	14972.28	210.61
5	4528.6	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	14990.28	210.79
6	32528.8	628.6	6.29	25.0	628.6	6.29	30.0	628.6	6.29	25.0	18.10	15008.38	210.98
8	17342.4	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	15026.38	211.17
9	32757.9	633.0	6.33	25.0	633.0	6.33	30.0	633.0	6.33	25.0	18.23	15044.61	211.36

DESIGN OF COLUMNS STORY NO= 1

JNO	SF	ACS	ASS	BS	ACC	ASC	BC	ACR	ASR	BR	WST	WSTT	VCON
0.231E 07	0.768E 06												
1	26013.6	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	48102.58	665.00
3	48793.3	942.9	9.43	35.0	942.9	9.43	35.0	942.9	9.43	40.0	27.15	48129.74	665.28
4	6792.8	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	48147.74	665.47
5	6792.8	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	48165.74	665.66
6	48793.3	942.9	9.43	35.0	942.9	9.43	35.0	942.9	9.43	40.0	27.15	48192.89	665.94
8	26013.6	625.0	6.25	25.0	625.0	6.25	30.0	625.0	6.25	25.0	18.00	48210.89	666.13
9	49136.8	949.5	9.50	35.0	949.5	9.50	35.0	949.5	9.50	40.0	27.35	48238.24	666.41
11	74225.3	1634.3	14.34	40.0	1634.3	14.34	45.0	1634.3	14.34	60.0	41.31	48279.54	666.84