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Welcome back to **INSIDE BUILD-MASTER !**

Mat foundation or **Raft Slab** is commonly used where the base soil has a low bearing capacity or the column loads are so large, that the conventional spread footings overlap each other, as in the case of multi storied buildings.

Since mat foundations require both positive and negative steel at top and bottom of the slab, use of **spread footings** is **more economical** as compared with the cost of mat foundations. It is therefore preferred to use spread footings wherever possible.

Mat foundation is useful for the buildings with deep **basements** both to spread the column loads to a more uniform pressure distribution and also to provide the floor slab for the basement. It also helps as a water barrier for basements below Ground water table. Mat foundations are also used where settlement of foundation is a problem.

Common types of mat foundations are (i) Flat Plate, (ii) Flat Plate with Inverted Beams (iii) Flat Plate with Pedestals and (iv) Flat Plate with Rock Anchors. There are many methods to design a mat foundation. However two main methods of designing it with the computer programs are **Finite Element Method (FEM)** and **Finite Grid Method (FGM)**.

Many programs are available now a day to do the Finite Element Analysis. However FEM output is very difficult to interpret. Concentrated Loads and Moments can be added easily but the nodal static check is difficult. Similarly vertical force summation is not easy since element node shears are difficult to compute, since Moments are obtained on a unit width basis in FEM.

J. E. Bowles, the author of book 'Foundation Analysis and Design' **does Not recommend** the use of **FEM for mat and plate problems**. There are many situations where FEM is particularly suited, however FGM is preferred for the more direct solution of foundation engineering problems.

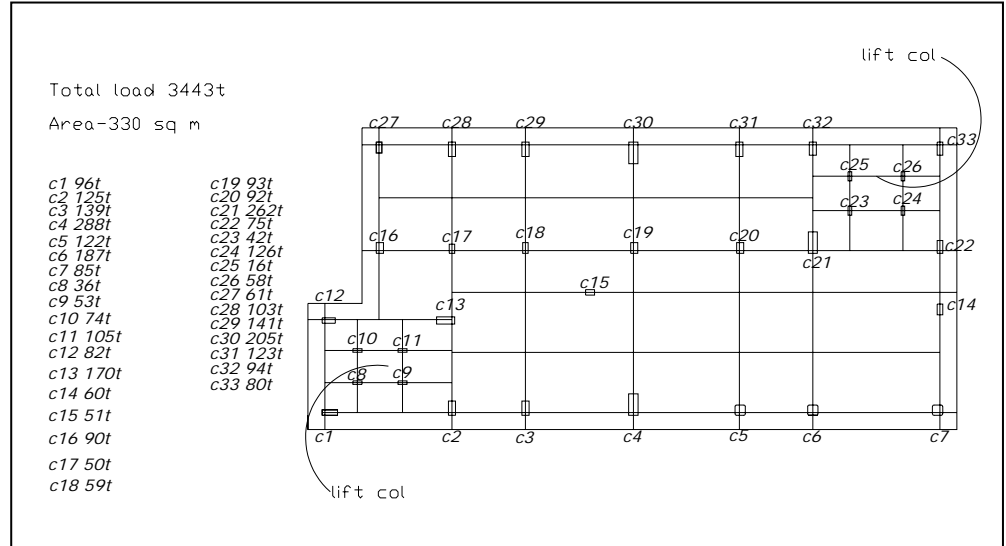
The procedure of idealizing **Raft Slab** or **Mat Foundation** with **Build-Master** using FGM method as per the above book is described here in brief.

Idealizing Raft Slab with Build-Master

A Raft slab actually provided for a GR+7 storied building is taken here as an example.

Analysis & design of (building) superstructure was first carried out with **Build-Master** and **Column Reactions** at the Foundation level were obtained.

Following are the forces read from .FOT file.



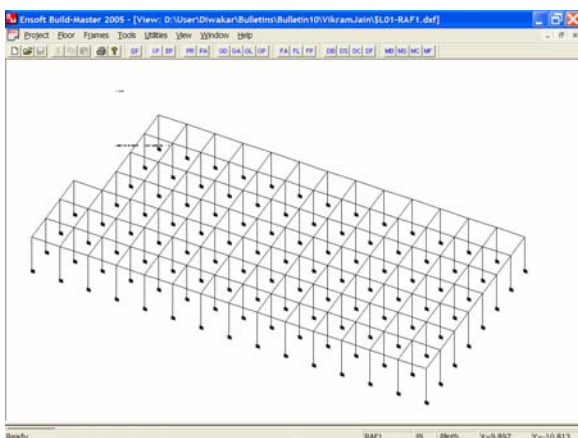
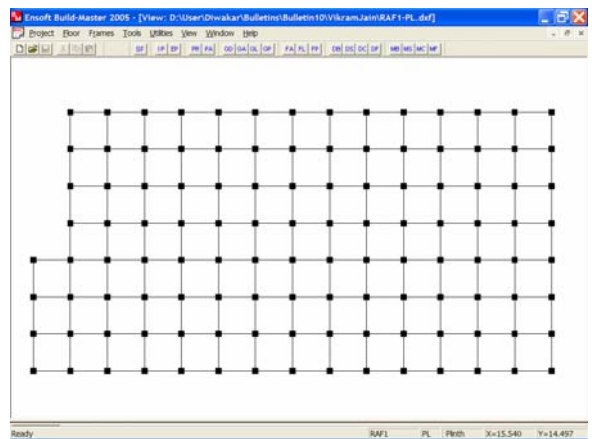
Raft Slab is idealized as a separate structure with **Slab resting on Soil**. Reactions of Columns of the Building above are applied as **External Loads** on this Slab at the Positions of the Columns as shown in the above Figure. **Soil** is idealized as **Springs** at equal intervals. Stiffness of the soil is assigned to these springs. Springs are assumed fixed at their base. Soil is a soft / flexible material, it can withstand only compressive force, (can not take tension). Spring also have stiffnes only in one direction along its axis. If we do not allow tension to come in springs in this model, Springs represent the soil appropriately. When the analysis is done of this model, the recations of the springs represent the bearing pressure of the Soil. This pressure at all portions of the slab shall be less than the bearing capacity of soil.

This **Raft Slab model** is idealized as a single storey structure is **Build-Master**. **Slab** is idealized as equidistant **Grid of Beams**. Width of Beams is assumed to be half the spacing between them, so that the self-weight of beams is equal to self-weight of the slab. **Columns** are placed at every intersection of Grid Beams to represent Springs. Equivalent Stiffness of the soil is assigned to these columns. **Loads** of the actual Columns of the Building are applied as Point Loads on the Grid Beams at the Locations of the actual Columns.

Start a new **Building Project** in Build-Master with Number of Levels equal to 1 and Storey height below Plinth = 3.0 Mt. Draw a mesh of **Beams** with equal spacing of 2mt x 2mt on both the sides. Assume Beam Width = 1mt (Half the Beam Spacing) and Beam Depth = Raft Slab Thickness.

Slabs generated by Build-Master between this mesh of beams are to be ignored. To do this all these slabs are made of Zero Thickness with Zero Superimposed Dead Load and Live Load on it.

Add **Columns** at every intersection of the Grid Beams. Calculate the size of Column to be assigned, such that the stiffness of the Columns will be equal to that of Soil Springs, as shown below:



Modulus of sub grade K_s for Clayey soil is 20000 to 60000 KN/Mt³ . (Refer Foundation Analysis and Design by J. E. Bowels)

For Min. Value of K_s (20000 KN/mt³) i.e. 2000 T/ mt³, Stiffness of Soil for 2m x 2m Grid = 8000T/mt.

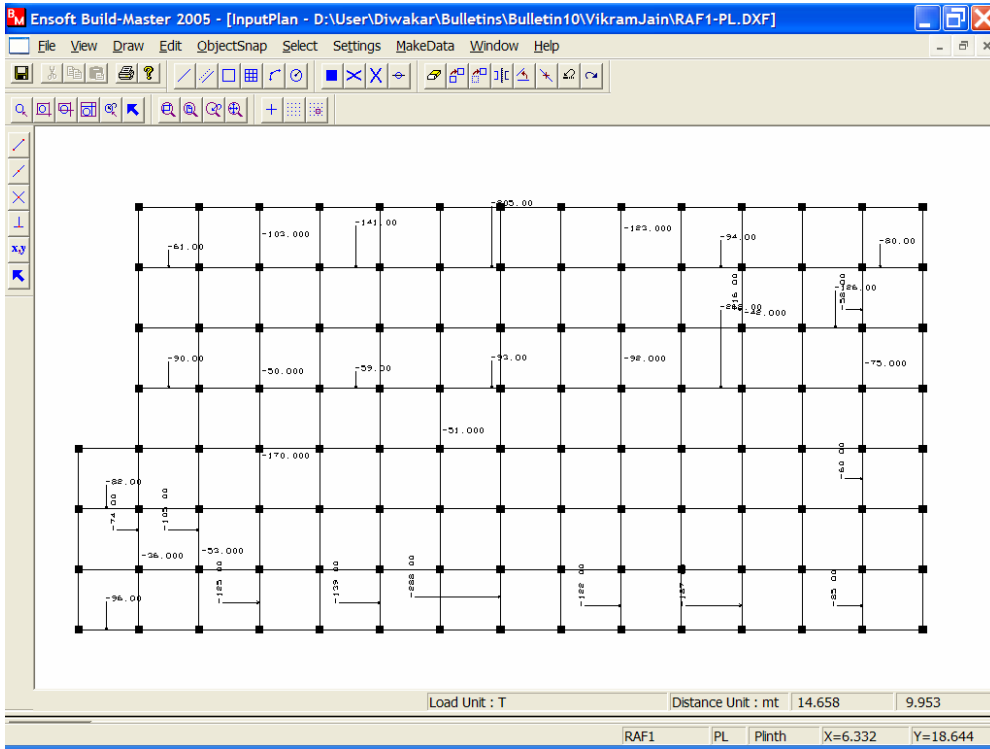
This shall be equal to Stiffness of RCC Column, i.e. = AE / L Where L is Length of the Column, A is Area of Column.

For L = 3 mt, E of Concrete = 2200000 T/ mt²,

Area required for Column = $8000 * L / E = 0.011 \text{ mt}^2$.

Hence Size of Square Columns required = $\text{Sqrt}(0.011) = 0.1\text{mt}$

Thus Columns of 100 mm x 100 mm size are added at all grid intersections.



Add **Point Loads** on these Beams at the Actual Column Position using **Input Plan**.

Make **Space Frame** of single storey. Value of Moment of Inertia of Columns Shall be made Zero / Negligible, Since Soil Springs cannot take moments. This can be done using Edit Frame Data File option.

Carry out Frame Analysis and Proceed for Design of Beams.

Design of Beams will give us Area of Steel. If beam widths are entered as 1 mt., it will be the Area of Steel required per Mt. width of the slab.

Check that any of the Support Reaction of Columns has gone in Tension. Since Soil cannot have tension, it will be equivalent to the loss of contact of Slab and the soil. Remove the spring (column) at these locations and reanalyze the Frame till there is no tension in the springs, any where in the raft. Redesign Beams to get Area of Reinf. Steel.

Raft Slab Analysis Results With 600 mm Thickness

S103	S104	S105	S106	S107	S108	S109	S110	S111	S112	S113	S114	S115	S116	
6.690	20.510	27.000	29.280	27.090	29.240	35.360	23.650	21.270	19.930	15.780	13.360	17.670	0.920	
S89	S90	S91	S92	S93	S94	S95	S96	S97	S98	S99	S100	S101	S102	
30.680	50.040	66.220	68.040	68.670	67.360	94.180	60.520	71.090	68.760	72.660	65.080	77.980	39.070	
S75	S76	S77	S78	S79	S80	S81	S82	S83	S84	S85	S86	S87	S88	
30.050	45.010	48.600	49.000	48.070	52.820	62.960	52.130	62.570	85.360	103.820	100.680	103.250	42.330	
S61	S62	S63	S64	S65	S66	S67	S68	S69	S70	S71	S72	S73	S74	
38.540	51.060	45.430	37.580	36.710	41.680	52.850	39.270	62.150	97.200	118.250	79.360	75.060	27.310	
S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
13.770	50.660	62.110	56.870	34.290	25.190	36.330	30.400	20.920	27.310	45.790	52.500	42.970	43.700	13.380
S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43	S44	S45
52.070	98.810	112.570	108.290	50.810	28.750	35.330	38.030	25.030	17.040	22.160	27.150	28.950	32.340	8.780
S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
54.280	101.210	116.310	102.750	63.650	61.700	71.580	107.110	65.840	50.720	47.600	64.390	47.780	40.640	13.260
S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
53.670	71.950	62.430	66.700	49.720	64.100	76.660	111.060	76.710	67.630	64.240	88.180	60.850	48.600	15.300

Reactions of the Springs obtained for Raft Slab with 600 mm thickness of Beams, are Shown above. It is seen that the Value of Spring Reactions S8 and S23 are 111.06 T and 107.11 T at the position below the Maximum Column Load of C4 as 288 T Load. Thus we see that the Load gets distributed due to the provision of raft slab.

Distribution of the Column Loads on the soil will depend on the thickness of the Raft Slab and also the stiffness of the soil. Raft Slab shall be redesigned with different thickness to check the load distribution pattern.

Although every care is taken to provide the correct information in this bulletin, **Ensoft Systems PL** is **not** responsible for any errors, mistakes, wrong interpretation in or as a result of the usage of it.

Raft Slab Analysis With 450 mm Thickness

S103	S104	S105	S106	S107	S108	S109	S110	S111	S112	S113	S114	S115	S116	
3.430	15.960	19.940	22.650	18.510	19.720	30.900	14.710	15.990	15.330	8.870	3.510	14.690	1.340	
S89	S90	S91	S92	S93	S94	S95	S96	S97	S98	S99	S100	S101	S102	
32.390	54.720	77.880	78.250	78.830	69.470	123.190	57.500	81.470	68.920	72.730	54.690	89.820	37.030	
S75	S76	S77	S78	S79	S80	S81	S82	S83	S84	S85	S86	S87	S88	
25.010	40.280	41.430	42.850	40.160	43.420	59.690	39.260	51.510	78.660	104.880	100.070	121.940	32.190	
S61	S62	S63	S64	S65	S66	S67	S68	S69	S70	S71	S72	S73	S74	
38.580	50.860	40.530	33.180	34.660	39.040	59.970	31.230	65.510	112.670	144.320	68.240	79.890	17.150	
S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
4.890	41.720	49.850	48.540	24.470	18.030	39.190	26.080	11.580	19.130	40.590	44.950	28.960	43.770	8.660
S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43	S44	S45
51.420	109.370	121.250	128.640	41.290	14.410	24.760	27.960	13.160	4.620	10.000	13.160	17.170	33.090	6.820
S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
44.340	107.080	125.650	111.810	57.760	64.840	71.960	138.530	66.940	53.330	46.130	75.710	44.680	44.400	12.540
S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
54.870	69.460	44.150	62.910	38.610	63.870	65.910	122.790	64.880	64.470	55.670	100.380	52.700	49.860	10.360

Reactions of the Springs obtained for the same Raft Slab with 450 mm thickness of the Slab, are Shown above. It is seen that the Value of Spring Reaction has increased to 138.53 T instead of 107.11 T value obtained with 600 mm thickness. Values of Spring Reactions can also be compared at various internal points of the Raft Slab.

It is seen above that Thicker Raft Slabs Spread Column Loads to a larger areas of the Soil below and Show more Uniform distribution of total Column Loads. Slab with Lesser Thickness behaves more flexible and does Not spread the Column Loads.

Contributory Area of each Spring is 2 mt x 2 mt i.e. 4 mt². There fore value of Bearing pressure below each Spring will be equal to the Spring Reaction divided by Contributory Area. Maximum value of Bearing pressure shall be less than the bearing capacity of the soil.

Vertical Deflection value of the Spring Support shall be checked against allowable value of deflection of the Raft Slabs. Thus we see that Raft Slabs can be easily idealized and designed with Finite Grid Method. We hope that the information provided will be useful to you.

See you soon in the next issue of INSIDE BUILD-MASTER.

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ENSOFT SYSTEMS PVT. LTD.
 C-509, Bhaveshwar Plaza, LBS Marg
 Ghatkopar (West), MUMBAI - 400086.
 Tel: 25008866, Fax: (022) 25003505

Website : www.ensoftindia.com

E-mail : support@ensoftindia.com