International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 11, November-2018

PILED- RAFT FOUNDATION FOR HIGH RISE INDUSTRIAL STRUCTURE

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Abstract ---The design of high rise building for industrial structure with piled raft foundation on clayey soil in UPSIDC industrial area, sandila city, hardoi district. The higher load transfer buildings which are lies on loose soil. They cannot design with shallow foundation. It is necessary to provide deep foundation .in present area combination of shallow and deep (piled-raft) foundation is used. Piled raft foundation is adopted to reduce the total and differential settlement of foundation. In the present study, analysis of piled raft foundation is done by "plate on spring" approach in which the raft is represented by an elastic plate while the soil and piles are modelled as bed of equivalent spring at nodal points and intersecting spring respectively. The stiffness of pile is estimated by procedure given by Hazarika and Ramaswamy(2000). For the estimation of soil stiffness a method by de-beer and martens (1975) is employed for sand. For clays the same is estimated using immediate and e-log p curve. Software for the analysis of raft using finite difference method, estimation of stiffness for soil and pile and structural design of raft and pile is developed in SAFE software. Using this software a typical case study is analysed and results are presented. Effect of coefficient of subgrade reaction of soil and pile stiffness on the settlement, bending moment, shear force and punching shear values of raft are studied.

Key words: piled-raft foundation, bending moment, SAFE software

I.INTRODUCTION

Raft foundation is a structure which support an arrangement of number of columns in a row(s) to transmit load to the soil by means of continuous slab. It has an advantage of reducing differential settlement as concrete slab resists differential movements between the loading positions. They are often required on soft or loose soils with low bearing capacity as they can spread the loads over a larger area. Pile foundation is used when surface soil is unsuitable for shallow foundation, and a firm stratum is so deep that it cannot be reached economically by shallow foundation. A pile foundation generally much more expensive than a shallow foundation. It should be adopted only when a shallow foundation is not feasible.

To overcome this issue, concept of piled raft foundation was developed.Piled raft foundations provide an economical foundation option for circumstances where the Performance of the raft alone does not satisfy the design requirements. A pile raft foundation is concept in which total load coming from super structure is partly shared by raft by through its contact with soil and the remaining load is shared by piles through skin friction. A piled raft foundation is economical as compared to the pile foundation because piles in the case do not have to penetrate to the full depth of clay layer but it can be terminated at higher elevation. Piled raft foundations have been used successfully in Germany and other place where thick clay deposits exist over large depth.

II.LITERATURE REVIEW

Pile raft foundation are composite geotechnical structures which are characterized by their capability of sharing loads between their respective foundation components, i.e. piles and raft. They are particularly suitable in supporting major structures with concentrated loads in highly compressible ground. Pile raft foundations are required when the soil is very weak, highly compressive over large depth and in the presence of high water table. It is also use to resist horizontal forces in addition to vertical concentrated load to resist uplift pressure.

Davis and Paulo's (1972) developed the concept of piled raft foundation, which was further described by many authors, including Burl et al (1977), Cooke (1986), chow and Randolph (1994), ta and small (1996), kin et al(2001), Paulo's (2001) etc. Mandolin (1936) analysed the behaviour of piled raft system based on elastic solutions. A boundary element procedure to predict the settlement of piles and piles groups has been developed by Paulo's and Davis

(1968) and Paulo's (1972) based on the interaction between the single piles with rigid circular pile cap. Raft flexibility has been considered by Haim and lee (1978) by combining the finite element method for the raft with the interaction factor procedure for the pile group. The stress distribution along the piles shaft and beneath the raft could not be obtained by these approximate methods.

To overcome this rigorous study using three dimension finite element has been presented by ottaviani (1975), but the analysis was valid for maximum 15 members of piles. Later a hybrid finite element –elastic continuum method was developed by Haim and lee (1978) considering 6x6 piled raft. Further Griffiths et al (1991) developed a hybrid finite element continuum- load transfer approach to specially minimize the amount of computations and increase the number of piles (more than 200piles) in the analysis. The effect of pile-cap-soil interaction, load carried by the raft and the effect of the additional pile support on absolute and differential have further been discussed by Randolph and Real (2003).

III. SOIL INVESTIGATION AND SOIL RESULTS

Soil investigation represent method of determining physical properties of soil at construction site. This procedure is done with the aim of establishing whether soil is safe and solid for construction. The entire process of soil investigation entails different steps and methods. However, there are several methods like inspection, test pits and boring. Inspection is the first step and entails the examination of the site. After wards test pits are dug with the aim of collecting samples. For a more detailed analysis, borehole are made, which enables gathering the information on soil/rock strata, soil properties, and ground waters. In the present industrial area to know the soil conditions four bore hole are dug from that bore holes soil is taken and conduct tests**.** The results of lab tests and bore holes 1, 2, 3 and 4 indicate that the strata at the site is found to comprise of cohesive soil only and next standard penetration test is conducted in clayey region. The S.P.T. values obtained in the clayey layer region present as per bore-log charts enclosed are found to range from 6 to 30 indicating 'Medium' to 'Very Stiff' consistency. The other tests conducted on soil are sieve analysis, atterberg tests, moisture content test, specific gravity, and shear test is conducted. The water table at a depth of 5.00 metre below ground level has been adopted for calculation purposes. The soil result are

- Depth of foundation below ground level (m) = 2.50
- Length of footing (m) = 44.00
- Width of footing (m) = 25.00
- Water Table below ground level assumed (m) = - 5.00
- Cohesion (Kg/sqcm.) = 0.5
- Angle of Internal Friction (Ø) = 6°
- Density above foundation level (gms/cc) = 1.97
- Density below foundation level (gms/cc) = 1.97
- Overburden (tonne/sqm.) = 4.92
- Void Ratio (eo) = 0.605
- Net Safe Bearing Capacity (tonne/sqm.) = 14.46
- Settlement produced (mm) = 249.80
- Safe Allowable Pressure (tonne/sqm.) = 6.15
- Settlement produced for safe allowable pressure (mm) = 125.00

as in Sl. No. 13 and within safe permissible limit as per IS: 1904-1986

IV. STRUCTURAL DESIGN OF RAFT AND PILE FOUNDATION

A raft foundation usually consist of a concrete slab with consist thickness throughout its plan area, through other forms such as slab thickened under column. In fact the isolated footing are essentially flat slabs. The slab directly subjected to action of concentrated column loads, it is treated as structure critical in punching shear mode as the footing. If the column is small and the column load is larger substantially thick slab will be necessary to resist punching shear around the column. Flat slab means a reinforced concrete slab with or without drops, supported generally without beams, by columns with or without flared column heads.

The pile is a small diameter column, which are driven or cast into ground by suitable means. The piles may be subjected to vertical loads, horizontal loads or both, they are very useful and economical in transferring load through the poor soil or water to a suitable bearing stratum by means of end bearing. A pile can be designed as structural member in accordance with IS: 2911:1985 (part 1 section 1, 2, 3, and 4). Loads from superstructure is transferred to the piles through pile cap. The load then start getting distributed through skin friction and bearing and finally reach the toe. Thus, a pile should adequate strength to sustain the design load and satisfy the design criteria as a reinforced concrete column.

The numerical analysis of the piled raft foundation has been carried out using SAFE 2016.The analysis is done with the preliminary data provided. SAFE model has been done by considering Plant North upward Direction (Along Z axis). The Analysis is carried out for all load combinations including Sustained load with Wind and Earthquake. Calculations and design of foundations are based on related codes, IS 2911 (part 1 to 4) -1985(for pile foundations), and IS 1904-1985. The analysis of the sub structure, maximum shear forces, bending moments, are computed and compared for all cases.

A. Material properties of concrete

Compressive strength of concrete (Fck) = C30
Young's modulus of concrete (Ec) = 27386.12 N/mm^2
Poisson ratio = 0.2

B. Material properties of steel

Young's modulus of steel (Es) = 200000 N/mm^2
Yield strength of steel = 400N/mm^2
Ultimate strength of steel = 500N/mm^2

C. Raft data

Thickness of slab = 750mm
Length of slab = 44m
Width of slab = 25m

D.Pile data

Diameter of pile = 300mm
Length of pile = 17m

E. Soil property

Sub grade modulus = 20000KN/m^3

G. Raft analysis

The following stresses are tabulated for Critical Load Combinations.

			Shear		Membrane			Bending Moment		
	Plate	L/C	SQX (local) N/mm2	SQY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	MxkNm/m	My kNm/m	MxykNm/m
Max Qx	3734	216 1.5DL+1.5LL+1.5EO+1.5PO	2.3	-2.0	0.0	0.0	0.0	-518.7	-510.9	0.7
Min Qx	3073	216 1.5DL+1.5LL+1.5EO+1.5PO	-2.1	2.3	0.0	0.0	0.0	-486.5	-509.5	-21.9
Max Qy	3073	216 1.5DL+1.5LL+1.5EO+1.5PO	-2.1	2.3	0.0	0.0	0.0	-486.5	-509.5	-21.9
Min Qy	2863	216 1.5DL+1.5LL+1.5EO+1.5PO	-1.0	-2.0	0.0	0.0	0.0	-317.6	-316.6	-3.6
Max Sx	5676	214 0.9DL+0.9EE+0.9PE+1.5WL –Z	0.0	0.0	0.2	-0.2	0.0	1.7	11.5	3.0
Min Sx	5678	214 0.9DL+0.9EE+0.9PE+1.5WL –Z	0.0	0.0	-0.2	0.2	0.0	3.3	3.5	3.2
Max Sy	3294	250 1.5DL+1.5EO+1.5PO+1.5EQ –Z	0.6	-1.1	0.0	0.2	-0.1	-150.4	-70.8	-125.8

Min Sy	5127	214 0.9DL+0.9EE+0.9PE+1.5WL –Z	0.0	0.0	0.2	-0.2	0.0	9.2	1.8	2.5
Max Sxy	3513	274 0.9DL+0.9EO+0.9PO+1.5EQ –Z	-0.9	0.8	0.0	-0.2	0.1	-211.9	-371.4	66.7
Min Sxy	3513	249 1.5DL+1.5EO+1.5PO+1.5EQ +Z	-0.9	0.6	0.0	0.2	-0.1	-259.1	-84.1	-83.6
Max Mx	3518	216 1.5DL+1.5LL+1.5EO+1.5PO	0.5	0.6	0.0	0.0	0.0	295.6	43.1	42.3
Min Mx	3503	248 1.5DL+1.5EO+1.5PO+1.5EQ –X	-1.5	-1.3	-0.1	0.0	0.0	-579.9	-435.1	-63.3
Max My	3555	216 1.5DL+1.5LL+1.5EO+1.5PO	0.4	-0.3	0.0	0.0	0.0	154.6	370.7	24.3
Min My	3504	266 1.2DL+1.2LL+1.2EO+1.2PO +1.2EQ -Z+1.2TL +VE	1.9	2.0	0.0	-0.1	-0.1	-437.5	-567.8	2.0
Max Mxy	3515	216 1.5DL+1.5LL+1.5EO+1.5PO	0.5	0.6	0.0	0.0	0.0	-71.7	-99.1	141.4
Min Mxy	1122	216 1.5DL+1.5LL+1.5EO+1.5PO	-0.4	0.3	0.0	0.0	0.0	20.7	-69.1	-161.5

Since loads are highly unsymmetrical and maximum shear stress obtained from the analysis are **2.3N/mm^2** in both the horizontal directions (X and Y) which is more than the maximum allowable nominal shear stress of **2.2 N/mm^2**(*for M30 mix as per I.S. 456, Table no 24*) thus it is advised to maintain the raft thickness to 750mm uniformly.

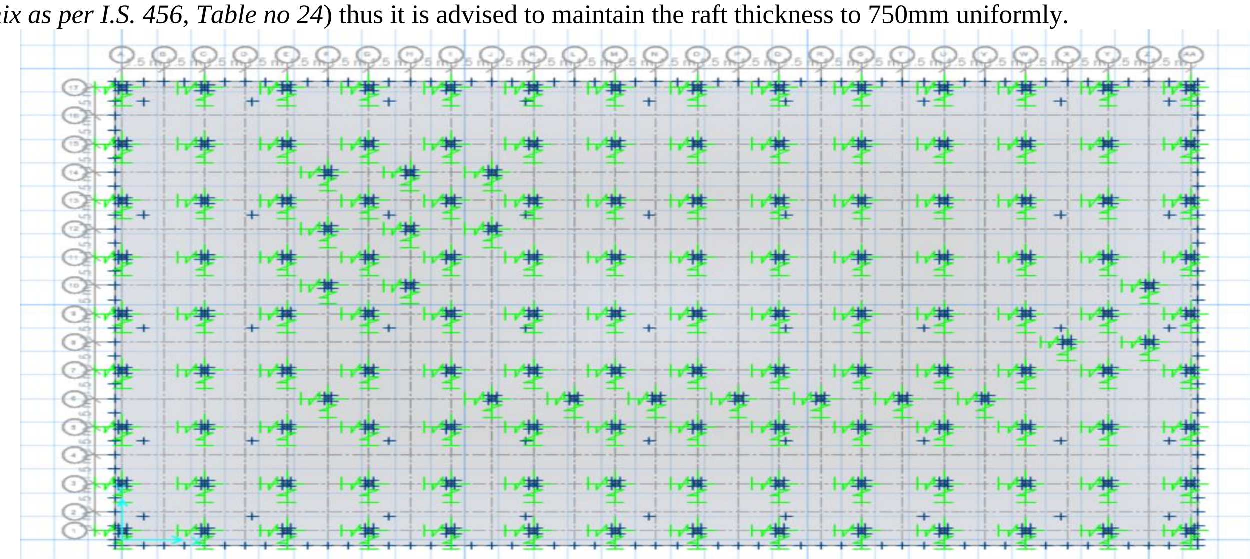

Figure1: Two dimensional view of piled raft foundation

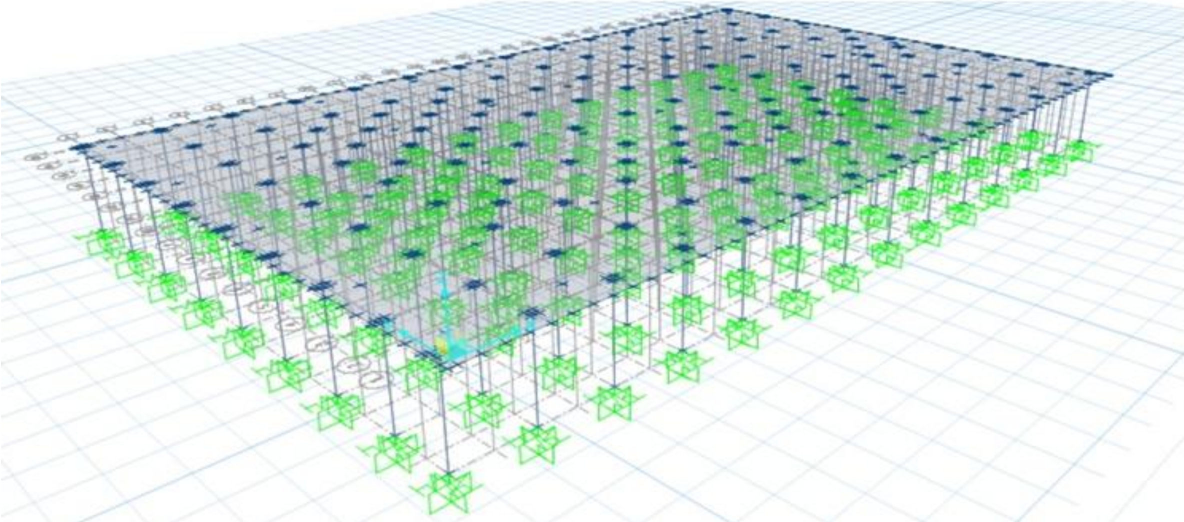

Figure2: Three dimensional view of piled raft foundation

V. RESULT AND DISCUSSION

Detailed analysis of pile raft foundation has been carried out considering the effect of interaction for all the load cases. In this report two load combinations (115 & 168) had been presented considering the effect of supporting soil media.

A. For Load Combination 115 (1.0DL+1.0LL+1.0EO+1.0PO)

			Horizontal	Vertical	Horizontal
Direction	Node	L/C	Fx KN	Fz KN	Fy KN
Max Fx	1171	115	0.02	677.665	0.002
Min Fx	1250	115	-0.02	601.748	0
Max Fy	2690	115	-0.005	**736.093**	-0.003
Min Fy	5243	115	-0.005	493.88	-0.015
Max Fz	1202	115	0.004	630.583	0.015
Min Fz	5225	115	0	662.963	-0.023
Max Mx	1171	115	0.02	677.665	0.002
Min Mx	1171	115	0.02	677.665	0.002
Max My	1171	115	0.02	677.665	0.002
Min My	1171	115	0.02	677.665	0.002
Max Mz	1171	115	0.02	677.665	0.002
Min Mz	1171	115	0.02	677.665	0.002

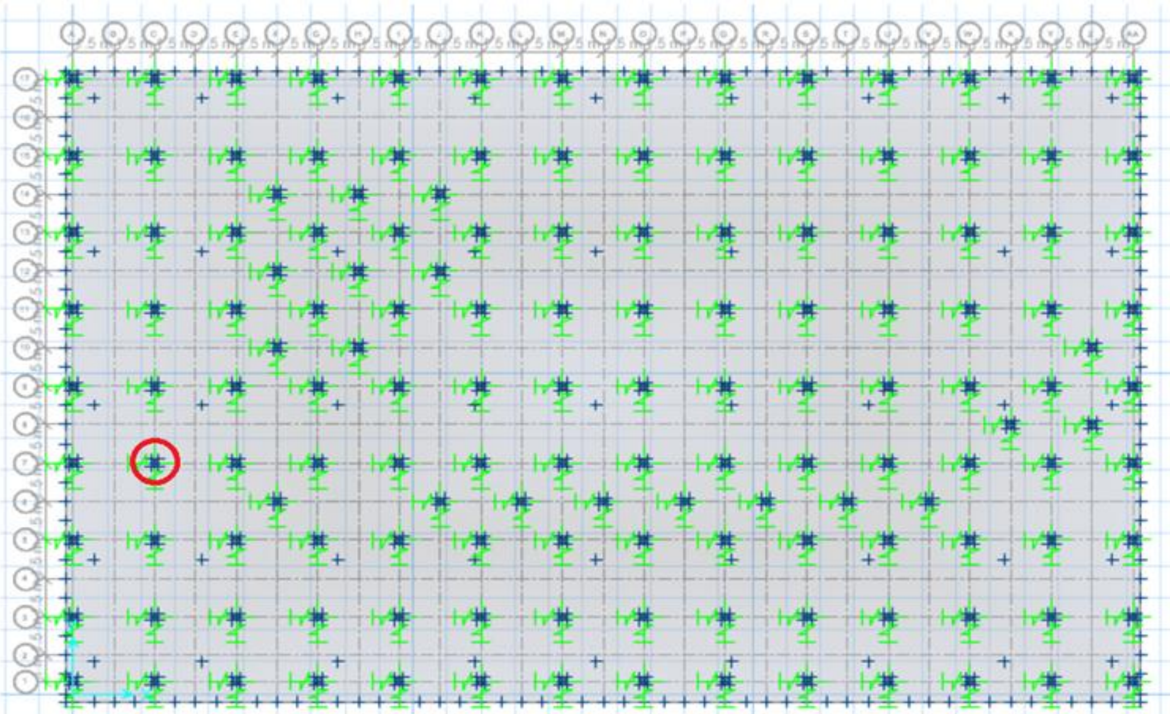

Figure 3: Node 2690 (Pile reaction 736 KN) exceed maximum capacity

B. For Load Combination 168(1.0DL+1.0LL+1.0EO+1.0PO+1.0EQ -X+1.0TL –VE)

			Horizontal	Vertical	Horizontal
Direction	Node	L/C	FxkN	FzkN	FykN
Max Fx	1171	168	18.929	**780.195**	-1.218
Min Fx	5237	168	17.475	544.029	0.937
Max Fy	2104	168	18.576	**808.442**	-1.218
Min Fy	5243	168	17.477	396.319	1.116
Max Fz	3209	168	18.176	546.071	1.13
Min Fz	1600	168	18.766	**789.323**	-1.22
Max Mx	1171	168	18.929	**780.195**	-1.218
Min Mx	1171	168	18.929	**780.195**	-1.218
Max My	1171	168	18.929	**780.195**	-1.218
Min My	1171	168	18.929	**780.195**	-1.218
Max Mz	1171	168	18.929	**780.195**	-1.218
Min Mz	1171	168	18.929	**780.195**	-1.218

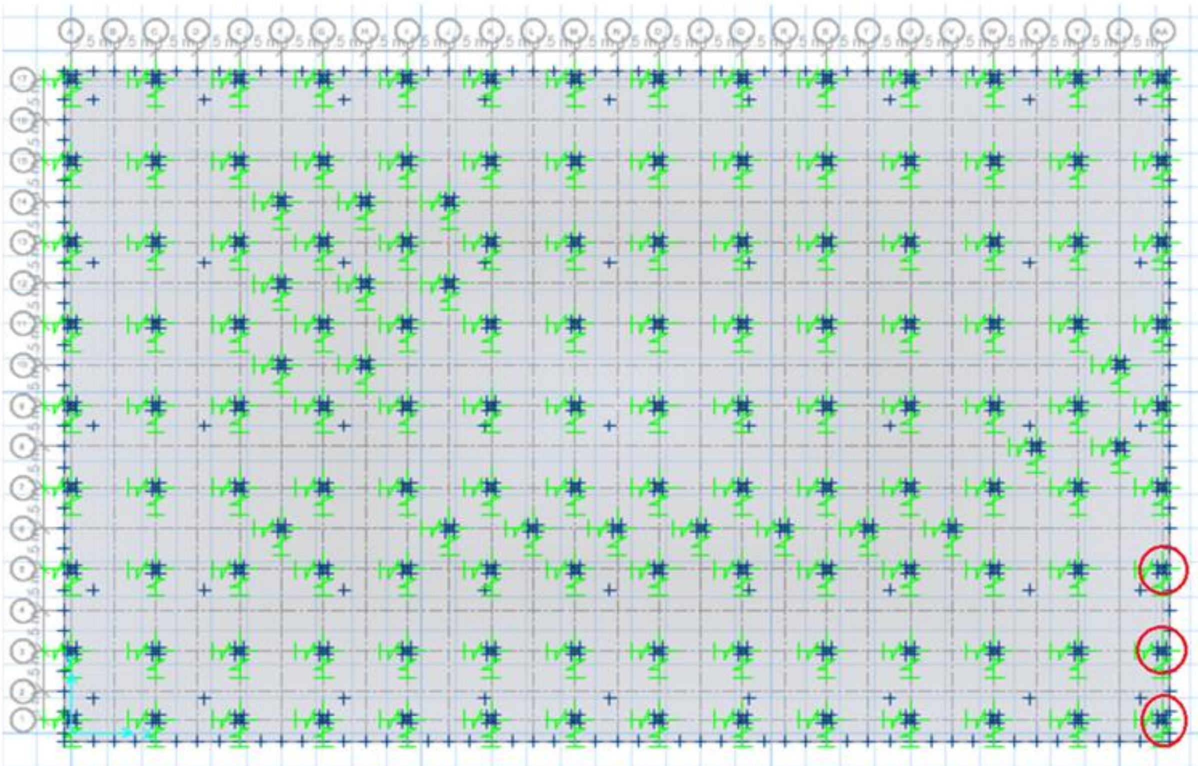

Figure 4: Nodes (1171, 2104, 1600)exceed max capacity

The maximum pile reactions for load combination 115 is 736.093 KN and 168 is 808.442 KN based on the detailed analysis. The pile capacity as per the geotechnical report provided was 720 KN for 20.3 m length. Almost 80 to 90 % utilization is achieved by all the piles and the piles those are marked (in bold) have exceeded the maximum capacity. However as per IS codal provisions, while considering critical load case especially with seismic loads, one or two piles can have capacity up to 10% more than maximum capacity. Therefore, Optimization could not be achieved for the critical load cases.

Pile Load capacity(KN)	No of Piles	% of Piles
<600	33	22.758607
600-650	54	37.241379
650-700	41	28.275862
700-720	8	5.5172414
720-750	4	2.7586207
750-800	4	2.7586207
>800	1	0.6896552
Total	145	100

VI.CONCLUSION

- Piled raft foundation is adopted to reduce the total and different settlement of foundations, and thus estimation of settlement profile of piled raft foundation forms an important design exercise. So accordingly a method is proposed to obtain the settlement profile of piled raft foundation.
- In this proposed method, raft is represented is represented by an elastic plate, while the soil and piles are modelled as bed of equivalent spring at nodal points, and intersecting spring respectively. Software is developed for the analysis of raft using finite difference method, estimation of stiffness for soil and pile and the structural design of raft and pile in SAFE software.
- The load combination 115&168 had been considered. The maximum pile reactions for load combination 115 is 736.093 KN and 168 is 808.442 KN based on the detailed analysis. In load case 115, only node number 2690 exceeds maximum capacity, and in load case 168, three node numbers 1171,2104, 1600 exceeds maximum capacity.
- The analysis adopted in the present study is strictly applicable to vertical loading. In highly seismic area, estimation of the behaviour of piled raft during earthquake becomes an important factor in the foundation design process.

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