A Comparative Study Of Uplift Capacity Of Cylindrical And Belled Piles.

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Abstract : Experimental investigation of single piles and pile groups of triangular pattern (2x1 piles), diamond pattern (2x2 piles) and square pattern (2x2 piles) pile groups have been carried out using the model piles of cylindrical and belled shaped. The piles were made up of concrete (M20) , having diameter of 20mm and of varying length 360mm , 400mm and 440mm. The length to diameter (l/d) ratio have been kept 18, 20 and 22. A total of 24 sets of experiments were carried out. All the piles and corresponding pile groups were tested under vertical uplift loading. Spacing between the two piles in various pile groups was kept three times the piles diameter (3d) in all experiments. The model piles were tested in dry sand bed. Based on the experimental results, behavior of uplift capacity for different piles and pile groups of cylindrical and belled shaped, effect of base enlargement, effect of grouping of piles are discussed in this paper.

***Key Words* –** Belled piles, uplift load carrying capacity, group of piles, cylindrical piles.

I. Introduction

Pile foundations are frequently used to transmit the loads of the super structure to deeper strata if the soil in the subsurface is of inadequate strength. In cohesionless soils, the shaft resistance is an important source of pile capacity under axial loading, especially when the pile is subjected to uplift loading. If structures such as dry docks, basements and pumping station are constructed below the water table then the uplift forces act on the supporting piles.

Foundations of some structures like tall chimneys, transmission towers, mooring systems for ocean surface or submerged platforms, jetty structures etc. are subjected to overturning moments due to wind effects, seismic events, wave actions or ship impacts.

Ramasamy et.al. (2004) have shown that the pull out shaft friction is significantly less than the push in shaft friction. There are few theories which have been developed to find the net uplift load carrying capacity of bored piles Meyerhof et.al. (1986), Chattopadhyay and Pise (1986) and Verma A.K., Joshi Ronak K. (2010) validated through the experimental measurements.

A number of model tests have been conducted by Das (1975), Sharma and Pise (1986), Rao and Kumar (1994) for the piles and that too in homogenous media. Information on belled piles and group of belled piles by varying its l/d ratio is very scare.

Therefore, experimental investigations have been carried out to study the behaviour of uplift load carrying capacity Vs the upward displacement of single pile and pile groups of cylindrical and belled shaped piles in dry sand bed.

These experiments have resulted in ultimate uplift load carrying capacity of both cylindrical and belled piles.

II. EXPERIMENTAL INVESTIGATION

Tests on model piles were carried out in a steel tank of size 750mm x 750mm x 750mm. The tank was sufficiently large enough to take care of the effects of edges of the tank on the test results as the zone of influence for pile and piles groups due to loading is approximated as to be in the range of 3-8 times the pile diameter.

Model piles were prepared from 20mm diameter solid concrete pile with its length varying from 360mm, 400mm, 440mm. Tests were carried out for single pile, 2x1triangular pattern and 2x2 diamond and square pattern of pile groups of cylindrical and belled shaped. The diameter at base of belled piles (D_u) was kept 2 times diameter (d) of pile and the length (l_1) of belled portion was kept 40mm constant in all cases of l/d ratio's 18, 20 and 22. In case of pile groups the spacing between two piles was kept 3d. The model piles were embedded in dry sand bed. The properties of the sandy soil is given in table 1.

Table 1 : Details of soil properties.

Relative Density (%)	0
Angle of internal friction , ϕ	36°
Angle of soil pile friction , δ	24°
Unit weight , (kN/m^3)	15.40
y_{min} (g/cc)	1.54
y_{max} (g/cc)	1.71
y_d (g/cc)	1.54

Piles were subjected to a pulley arrangement with a flexible wire whose one end is attached to pile cap and other end to the tension proving ring through which the load was increased gradually. The experimental setup is been shown in fig.1

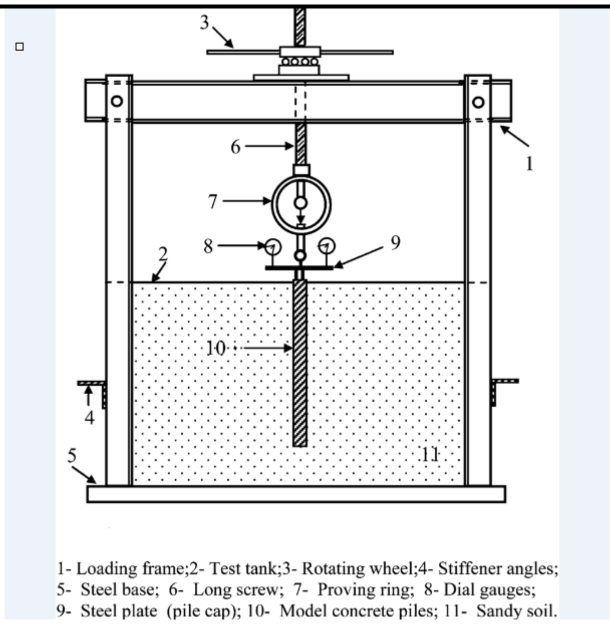

Fig 1. Experimental setup

The load was increased gradually and was kept constant till the corresponding upward displacement became constant which were then measured. The failure was of the pile was marked when the proving ring showed the readings in reversed order. Two dial gauges were attached at diagonal ends of the pile cap to measure the upward displacement of piles. The variation of load (N) and corresponding upward displacement (mm) are shown in chart 1 to 6 for cylindrical and belled piles for various l/d ratios. The percentage increase in uplift load carrying capacity for various configurations of piles are shown in table 2 to 4.

Table 2 : Comparision of ultimate load carrying capacity of cylindrical and belled piles with l/d = 18

Type Of Pile Configurations	Ultimate Uplift Capacity Q_u (N)		Percentage Increase (%)
	Cylindrical Piles	Belled Piles	
Single pile	25.89	30.91	16.24
Triangular pattern (2x1 piles)	62.24	74.77	16.75
Diamond pattern (2x2 piles)	107.36	137.02	21.65
Square pattern (2x2 piles)	113.62	151.64	25.07

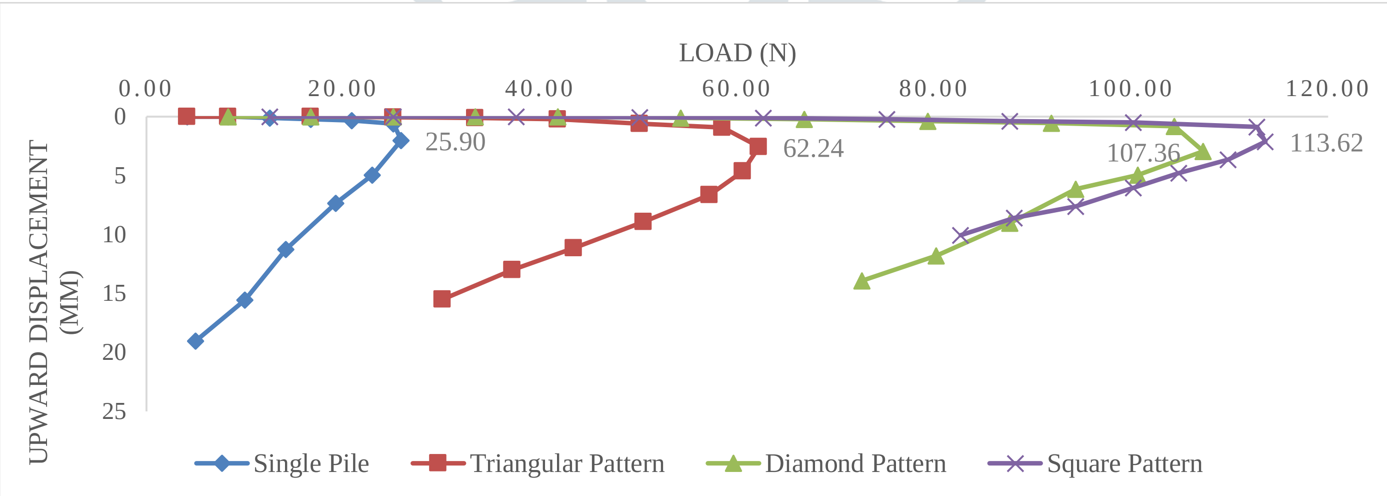

Chart - 1 : Load Vs Upward displacement of cylindrical piles with l/d =18

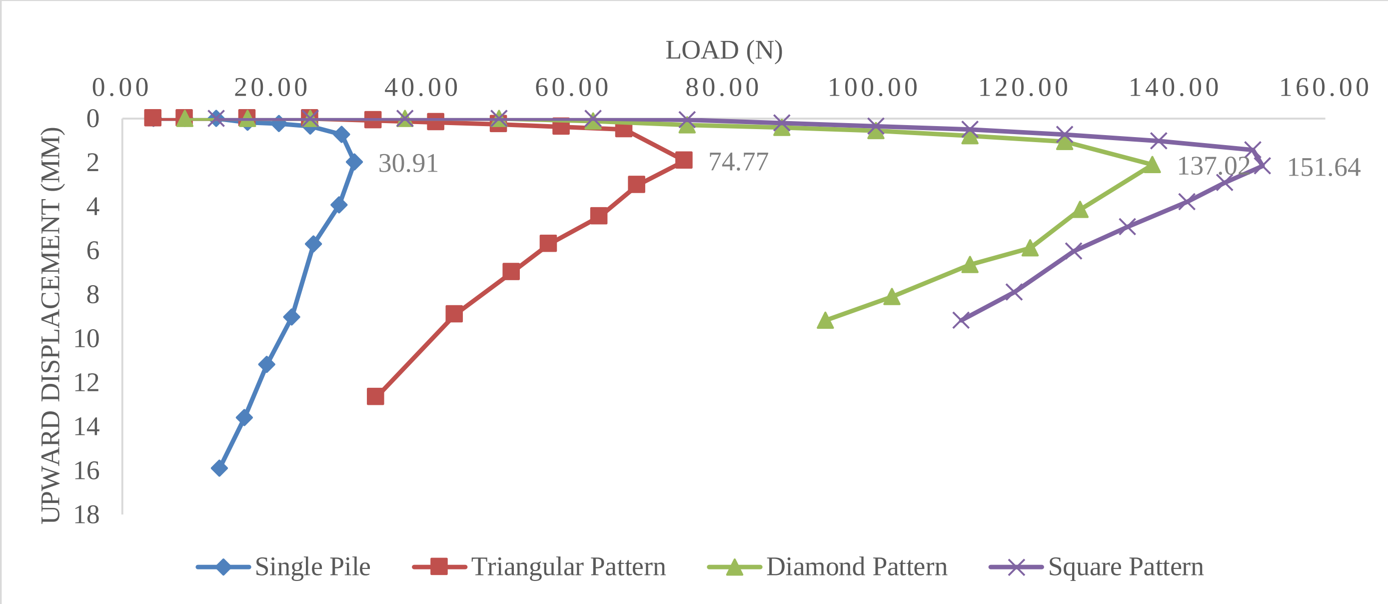

Chart - 2 : Load Vs Upward displacement of belled piles with l/d =18

Table 3 : Comparision of ultimate load carrying capacity of cylindrical and belled piles with l/d = 20

Type Of Pile Configurations	Ultimate Uplift Capacity Q_u (N)		Percentage Increase (%)
	Cylindrical Piles	Belled Piles	
Single pile	30.08	36.76	18.17
Triangular pattern (2x1 piles)	73.10	91.48	20.09
Diamond pattern (2x2 piles)	125.74	162.50	22.62
Square pattern (2x2 piles)	134.09	183.38	26.87

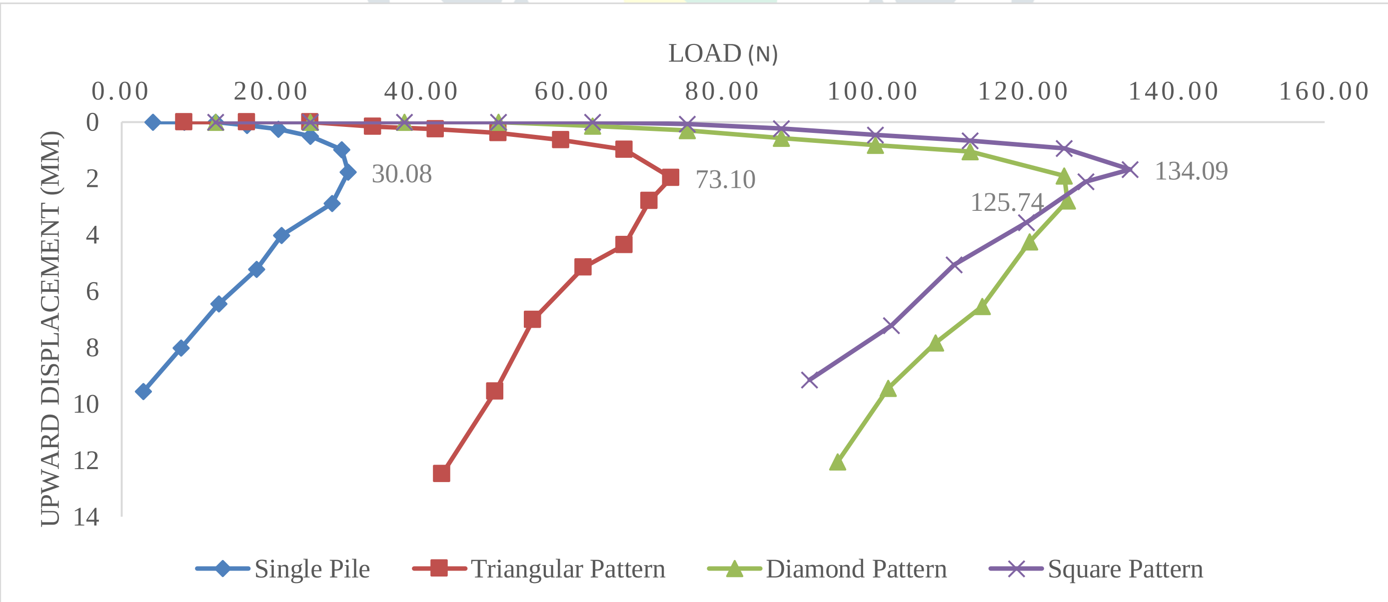

Chart - 3 : Load Vs Upward displacement of cylindrical piles with l/d = 20

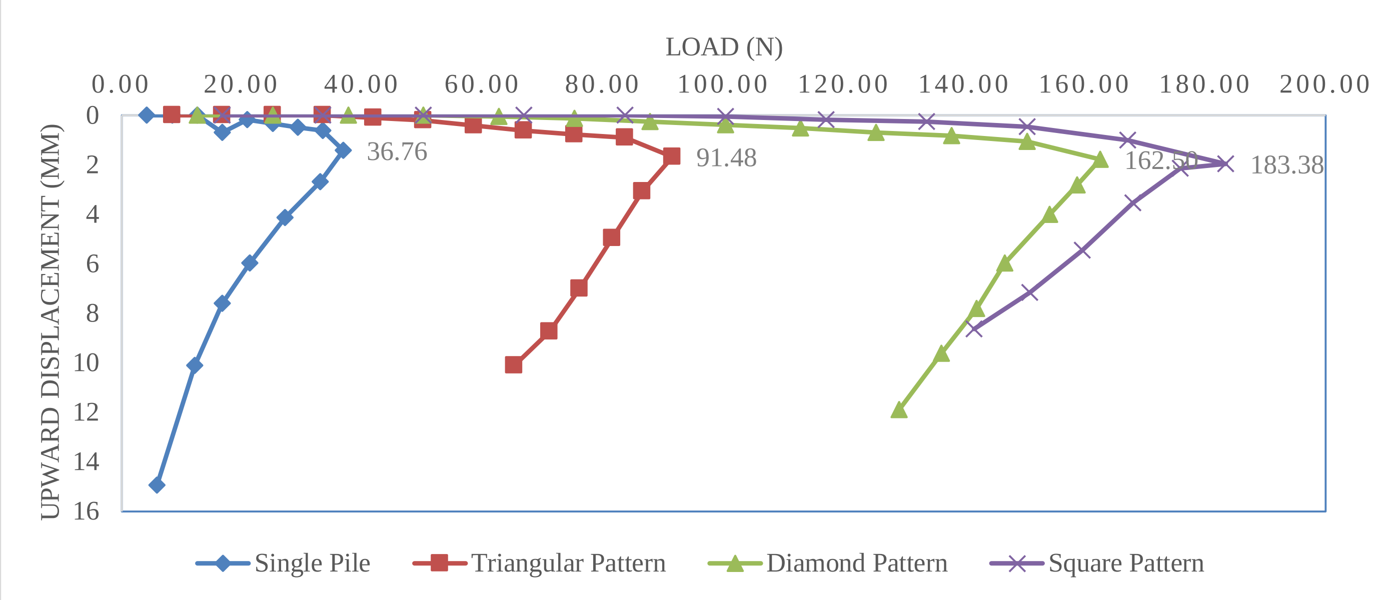

Chart - 4 : Load Vs Upward displacement of belled piles with l/d = 20

Table 4 : Comparision of ultimate load carrying capacity of cylindrical and belled piles with l/d = 20

Type Of Pile Configurations	Ultimate Uplift Capacity Q_u (N)		Percentage Increase (%)
	Cylindrical Piles	Belled Piles	
Single pile	40.10	50.13	20
Triangular pattern (2x1 piles)	98.17	124.48	21.14
Diamond pattern (2x2 piles)	171.69	230.59	25.54
Square pattern (2x2 piles)	166.67	243.12	31.44

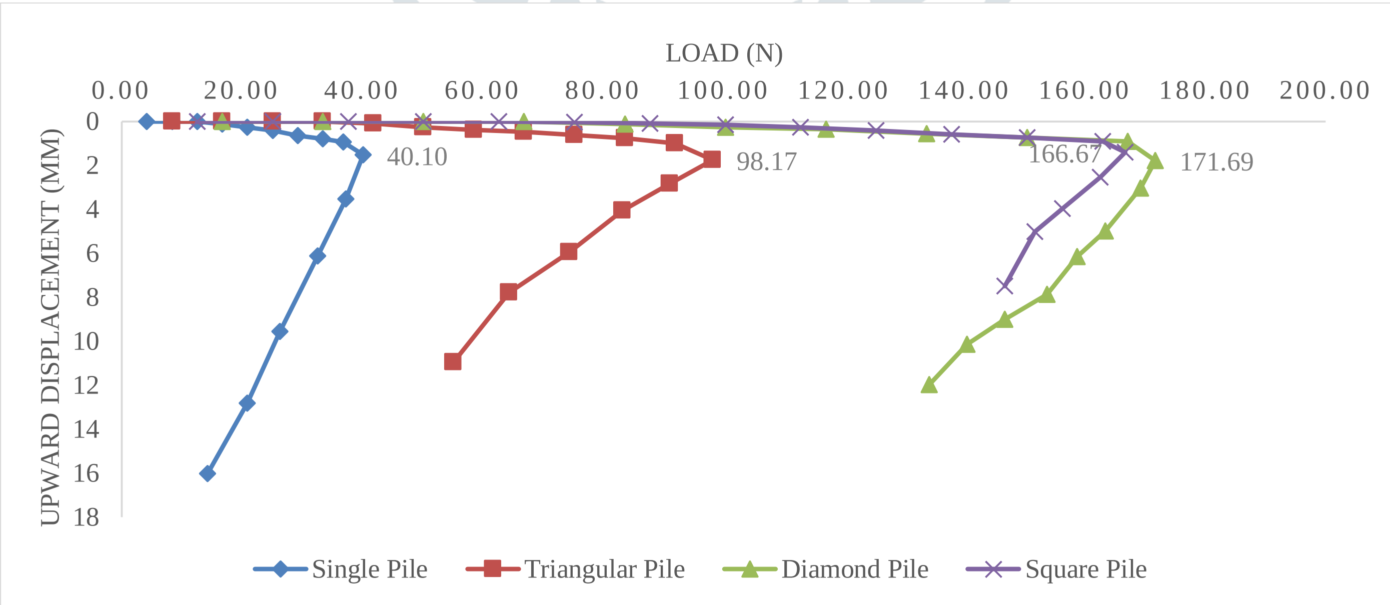

Chart - 5 : Load Vs Upward displacement of cylindrical piles with l/d = 22

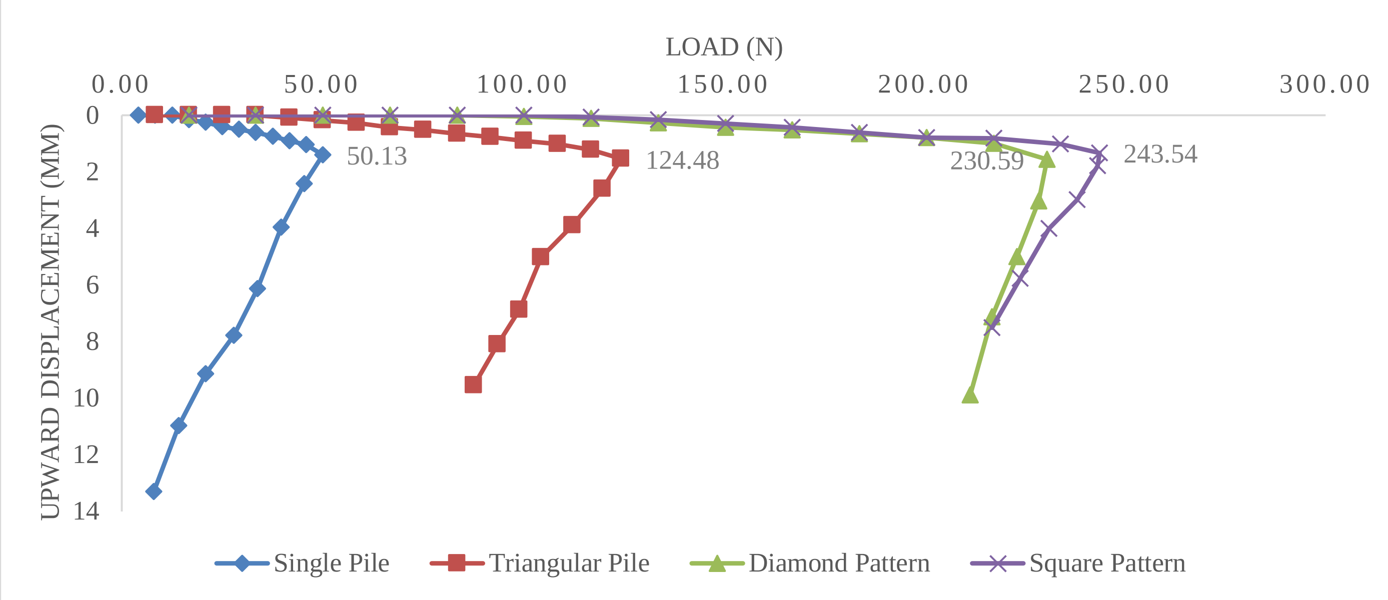

Chart - 6 : Load Vs Upward displacement of belled piles with l/d = 22

III. CONCLUSIONS

- The uplift load carrying capacity of belled piles was more than cylindrical piles for all l/d ratio's.
- The uplift capacity of belled piles of square pattern (2 x 2 piles) is more compared to other single pile and group of piles.
- The uplift capacity of both single and group piles have shown a gradual increase in the uplift load carrying capacity as the l/d ratio increases from 18 to 22.
- The maximum percentage increase in uplift load carrying capacity is obtained when l/d = 22 for both cylindrical and belled piles.
- It is being observed during experiment that the rate of upward displacement increases after ultimate uplift load capacity of a pile and pile groups is reached.
- After the failure of pile or pile groups the decrease in load in less in belled pile compared to cylindrical piles which shows in the stiff behaviour of belled piles.
- Belled piles with square pattern and l/d ratio = 22 has the maximum uplift capacity among all the other pile configurations for all l/d ratios and therefore belled square pattern is most advantageous one.

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REFERENCES

[1] Chattopadhyay, B.C., and Pise, P.J. (1986). "Uplift capacity of piles in sand", Journal of Geotechnics Engineering, Vol.112, No.9, pp. 888-904.
[2] Das, B.M. (1983). "A procedure of estimation of uplift capacity of rough piles, Soil and Foundation", Vol.23, No.3, pp.122-126.
[3] Downs I, Chieurazzi R (1966) "Transmission tower foundations". J Power Div, ASCE, 92(PO2), Proc Paper4750:91–114.
[4] Kulhawy, F.H., Kozera, D.W., and Withaim, J.L. (1979). "Uplift Testing of Model Drilled Shafts in Sand", Journal of Geotechnics and Environmental Engineering, American Society of Civil Engineers, Vol.105, pp.31-47.
[5] Mayerhof GG, Adams JI (1968) "the ultimate uplift capacity of foundations". Can Geotech J Ottaw 5(4):225– 244.
[6] Patra NR, Pise PJ (2003) "Uplift capacity of pile groups in sand", Electronic Journal of Geotechnical Engineering, EJGE.
[7] Sharma BVR, Pise PJ (1994) "Uplift capacity of anchor piles in sand under axial pulling loads". Indian Geotech J 24(3):181–203.
[8] Turner EA (1962) "Uplift resistance of transmission tower foundation". J Power Div, ASCE 88:17–3
[9] Verma A.K., Joshi Ronak K. (2010) "uplift load carrying capacity of piles in sands ". Indian Geotechnical Journal.