MODEL TEST ON UPLIFT CAPACITY OF PILE ANCHORS IN COHESSIONLESS SOIL

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Abstract

Experimental investigations on model single pile anchor and pile group anchors of solid wooden pile having diameter of 40mm diameter and 600mm length have been carried out in a model tank of size (850mm x700mm x750mm) and subjected to uplift loads were conducted on uniformly graded 'kharkai' river sand(G=2.63) obtained from Jamshedpur,india. Anchor plate was provided as different widths (B = 80mm and 120 mm) and thickness 12 mm. The pile caps used for single and pile groups. The pile anchors were kept at 3/4th of total length of pile in different medium of sand. The embedment length to shaft width ratios, L/d=11, L/d=08 and L/d=06, and enlarged base width to shaft width ratios, B/d=2, 3 and center to center spacing of pile anchors in the groups were kept as 3d. All types of piles and pile groups were tested under vertical uplift loading. The load displacement response, ultimate resistance and variation of group efficiency with L/d, B/d and spacing have been studied quantitatively. Theanalytical model of limit equilibrium method has been proposed to predict the net uplift capacity of pile group anchors. The predicted analytical results were compared with experimental results and other previous researchers work. It was found reasonably good agreement with the experimental and other results.

Keywords: *Pile Foundations, Wooden Pile, Pilegroup anchors, Axial uplift loads, uplift capacity, Earth pressure co-efficient, Relative density, Sandysoil.*

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1. INTRODUCTION

When structures are constructed below the ground water table or if they are constructed under water then uplift forces are applied on the basement of the structures. Also in case of structures like transmission towers, mooring systems for ocean surface or submerged platforms, tall chimneys, jetty structures and under ground tanks transmit not only heavy compressive loads but are also subjected to considerable amount of uplift forces. These structures need footings, which can anchor these with the competent strata. Under-reamed piles and anchor piles/groups are being extensively used in such cases depending on the in situ conditions. To study the effect of pile length, pile diameter, shape, surface characteristics and pile tip properties on uplift capacity of piles, laboratory experimental investigation is carried out.

The ultimate resistance capacity of pile anchor is usually taken by considering the shearing resistance mobilized along the rupture surface in addition to the weight of the sand bounded by rupture surface. Meyerhof and Adams (1968) have developed a generalized theory of the uplift resistance of foundations which is embedded in soil. It has been proposed for a strip or continuous footing and modified for circular and rectangular footings. Prakash (1980) modified the expression given by Sharma et al. (1978) for two types of piles i.e.straight shafted Piles and piles with base enlargement, byvarying parameter like base enlargement to shaft diameter and surface roughness.

In the present investigation the uplift capacity of pile anchor and pile group anchors in homogeneous soil has been studied. The various parameters such as length of the pile, shaft width, and spacing of piles have been varied to bring out the effect of these parameters.

2. DETAILS OF EXPERIMENTAL SET UP AND MODEL TESTS

Tests under axial pullout have been carried out on circular wooden piles having diameter 40mm and length 600 mm. The model anchor piles have been tested for different L/d ratios 11, 08, 06 and different B/d ratios 02, 03 for single anchor piles and pile group anchors with different surface roughness of piles and center to center spacing of pile anchors in the groups were kept as 3d.Where L=Embedment depth, d=Width or diameter of pile, B=Width of anchor.

The model tank (size 850mm x 700mm x750 mm deep) was used for the study. Uniformly graded 'kharkai' river Sand obtained from Jamshedpur (India), was used as a foundation medium.

2.1 Properties of Soil Used In the Test

A poorly graded river sand having specific gravity G = 2.63, the coefficient of curvature (Cc) and uniformity coefficient (Cu) of the soil are 1.25 and 2.56. According to Indian standard classification system (IS: 1498-1970) the soil can be classified aspoorly graded sand with a letter symbol SP.

To determine the density and void ratio of sand a number of trials have been carried out for varying heights of fall.It was understood that the height of fall of sand goes on increasing the density of sand increases.

The tests were performed in loose sand condition of dry unit weight 1.48KN/$m^3$and angle of shearing resistance 29° The sand grains are sub angular and limiting void ratios are, e_{min} = 0.502 for maximum dry density of soil 1.86gm/cc ande_{max} = 0.776 for minimum dry density of soil 1.54gm/cc. The placement density was 1.62gm/cc, loose dense packing. In this case relative density of soil (R.D) is 29%.

2.2 Test Arrangement and Procedure

Solid wooden pile of 40 mm diameter was used as model piles. Enlargement of the base (at the 3/4th height) bottom of the pile shaft was provided by circular Base plate of two different widths (B = 80 mm and 120 mm) and thickness 20 mm. The pile caps used for single and 2 x1 pile group anchors were square shapes of variable sizes. The pile anchors were kept in vertical position with spacing varying at 3 times the diameter of piles i.e. 3d distance. The modelanchor piles of different embedment depth 440 mm, 320mm, and 240mm were used.

The technique of sand placement plays an important role in the process of achieving proper density. After proper placement of the piles anchors in empty tank, sand was poured in the tank continuously through the slot of the hopper (having 5 mm slot at one edge) keeping height of fall about 150 mm for loose packing sand, moving horizontally by hand. This technique of sand pouring is termed as 'rainfall technique' and this technique was reported to achieve good reproducible densities (Patra and Pise 2001). Afterhalf or more of the pile anchor length was embedded in sand, caps were carefully removed. Further sand poring was continued till the required embedment depth was reached. The sand surface was leveled carefully. This method of sand pouring gave a predetermined dry density of1.58 gm/cc for loose dense sand. Uplift load was applied to the pile cap through a vertical screw jack arrangement with screw bolt attached to the pile cap and proving ring. Through this system dialgauge readings corresponding to axial displacements were recorded.

Fig 1: Experimental set up

3. EXPERIMENTAL RESULTS

The results obtained from laboratory model tests are summarized and discussed below:

3.1. Pull out Load versus Axial Displacement Response

The axial displacement of the pile anchor and pile group anchors has been plotted against the uplift loads. Typical diagrams for pile anchor and pile group anchors (L/d = 11, 08, 06) are shown in Figs. 2 and 3. The load displacement response of pile anchors and pile group anchors are non-linear in nature. Axial failure is considered when the pile anchor moves out of the soil. It has been observed that for L/d=11, L/d=08 and L/d=06, the maximum displacement measured and it was vary from 2-3 mm for B/d = 2. However, For B/d = 3, the maximum displacement was vary from 3-6 mm. Similarly in case of pile anchors displacement was almost 5.5-7.5 mm for B/d = 2 and 5-9.5mm for B/d = 3, respectively. So at a particular value of the axial displacement, the uplift load increases and corresponding displacement value changes with the increase in base widths i.e.(B/d) ratio and spacing of pile anchors in the groups.

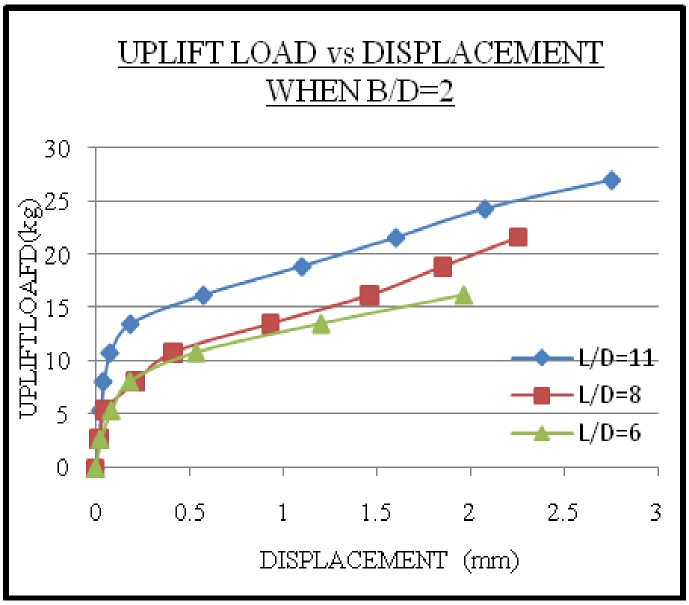

Fig 2: load versus displacement for single anchor pile

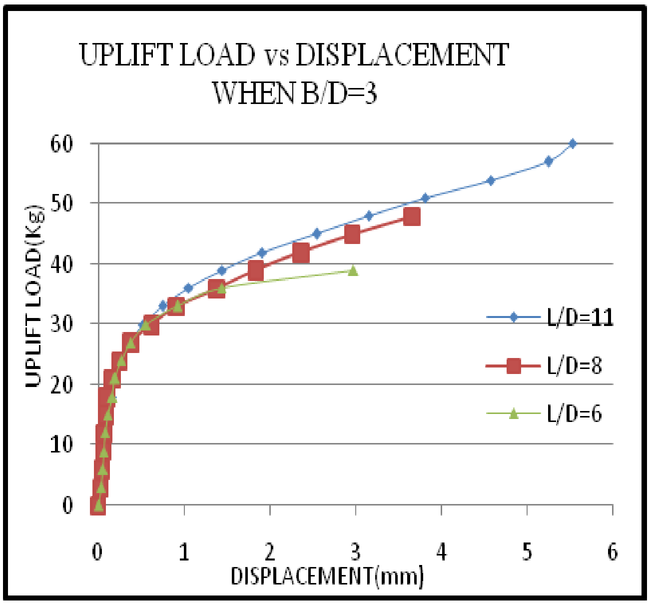

Fig 3: load versus displacement for single anchor pile

3.2. Ultimate Uplift Capacity

Ultimate uplift resistance for each case has been estimated from the load – displacement diagram by using double tangent method. The net ultimate capacity of pile anchors and pile group anchors was found out by subtracting weight of pile anchor sand pile caps. In Table (1) which represented the ultimate resistance for different cases.

Table 1: ultimate uplift loads (Kg)

Type of arrangement	B/d	L/d	spacing	Uplift load capacity	
				Experimental	Theoretical
single	2	11	-	27.0	25.5
single	2	08	-	21.6	16.0
single	2	06	-	16.2	10.0
2x1	2	11	3d	47.0	46.0
2x1	2	08	3d	41.0	30.5
2x1	2	06	3d	34.4	22.0
single	3	11	-	60.0	33.0
single	3	08	-	48.0	24.0
single	3	06	-	38.8	20.0
2x1	3	11	3d	117.8	72.0
2x1	3	08	3d	99.2	44.0
2x1	3	06	3d	80.6	35.0

3.3. Variation of Net Ultimate Uplift Capacity with L/d Ratio

The ultimate uplift load (Q_u), for a single pile anchor, increases with increase in (L/d) ratio i.e. the embedment depth for all (B/d) ratios.It isobserved that for (L/d) increasing from 06 to 11,the increase in ultimate uplift load is about 30% and 41% for B/ d =2 & 3 respectively (refer table: 1).

The ultimate uplift load for the pile group anchors (2x1) increases with (L/d) ratio for 3d spacing and (B/d) ratio. The increase in ultimate capacity (Q_u), is about 26% and 32% for L/d increasing from 06 to 11 for B/d = 2 & 3 respectively (refer table: 1).

So it is concluded that with the increase of embedment depth to shaft width ratio of pile the soil mass resisting capacity is also increasing. The increase in capacity is maximum forB/d = 3.

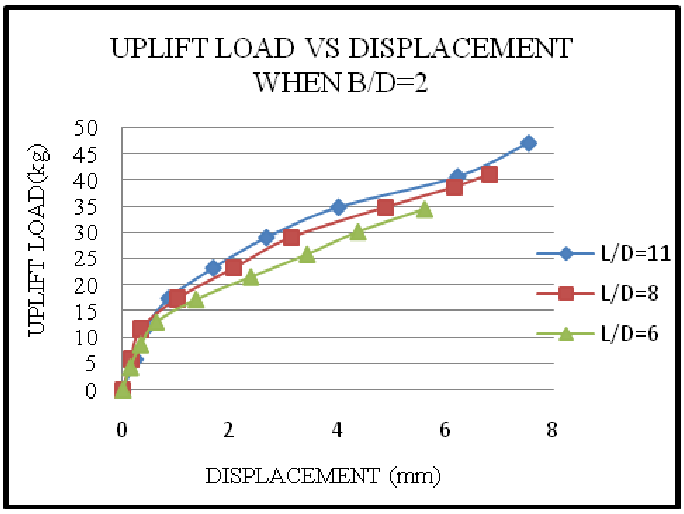

Fig 4: load versus displacement for pile group anchors

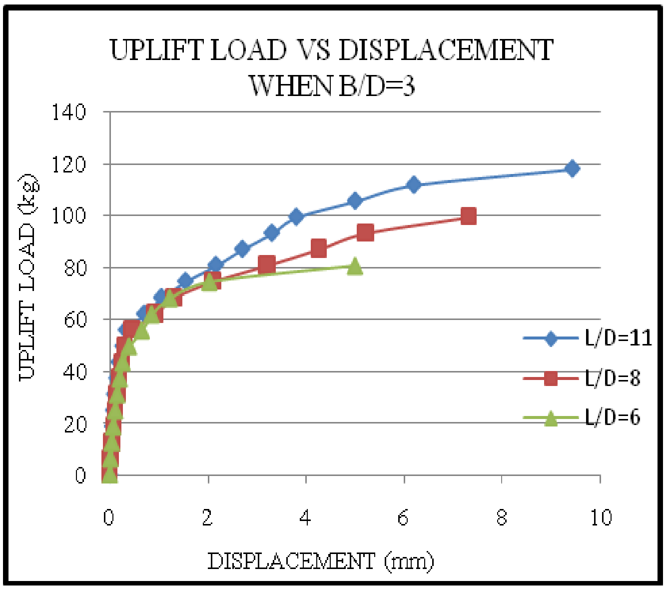

Fig 5: load versus displacement for pile group anchors

3.4 Variation of Net Ultimate Uplift capacity with B/d Ratio

The ultimate uplift load (Q_u) for a single pile anchor and pile group anchor (2x1), for L/D=11, L/D=08, L/D=06 increases with increase in B/d ratio for all cases. It is (Q_u) about 55%, 54%, 51% for single pile and 61%, 58%, 57% respectively for pile group anchor with increase of B/d ratio from 2 to 3.

4 .THEORETICAL ANALYSES

4.1. Single Pile Anchor Capacity

The analytical model of limit equilibrium method is used to predict the uplift capacity of piles anchors and pile group anchors.

The truncated cone model is considered to predict the net uplift capacity of single pile anchor. In the truncated cone model the uplift force is resisted by,

- The weight of the soil in the truncated cone
- Shearing resistance of the soil along the failure surface
- Weight of the pile and pile anchor.

Generally here we are using θ as a $\varphi/2$ value where φ= angle of shearing resistance of soil, this model was originated by Downs and Chieurazzi (1966), Turner (1962.) At the ultimate uplift load the total soil mass of truncated cone shape is lifted up and failure surface reaches the ground surface.

So from the analytical analysis for cohessionless soil (c=0). We get the final expression as $Q_u = 2\gamma(L^2/2)\tan\delta K_p + W$

Where Q_u= ultimate uplift load, K_p=coefficient of passive earth pressure, γ= unit weight of soil, L= embedment depth of pile, δ= angle of wall friction between pile and soil and W= weight of lifted soil mass and weight of anchor and pile

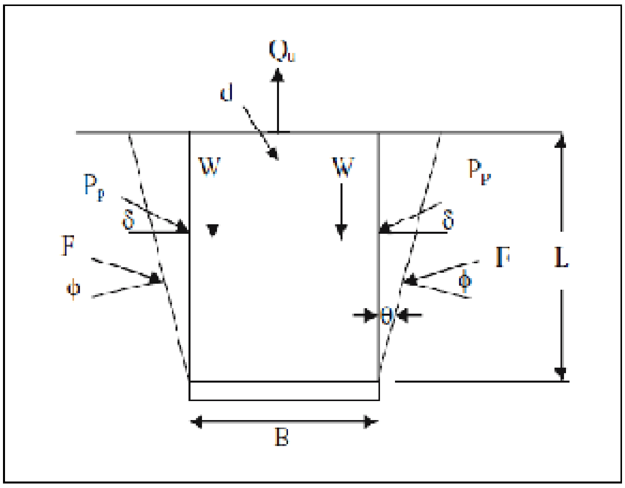

Fig 6: schemetic diagrame of single pile anchor showing different forces

4.2. Pile Group Anchor Capacity

Figure 7 shows the failure criteria for pile group anchors. The net uplift capacity of the pile group anchor is the uplift force resisted by the weight of the soil in the truncated cone, Shearing resistance of the soil along the failure surface, Weight of the pile and pile anchor.

So from the analytical analysis for pile group (2x1) anchors $Q_u = 2\gamma(L_1^2/2)K_p + 2\gamma(L_2^2/2)K_p + W$

Where Q_u= ultimate uplift load, K_p=coefficient of passive earth pressure, γ= unit weight of soil, L_1= embedment depth of pile, L_2 =embedment depth below overlapping zone and W= weight of lifted soil mass and weight of anchor and pile.

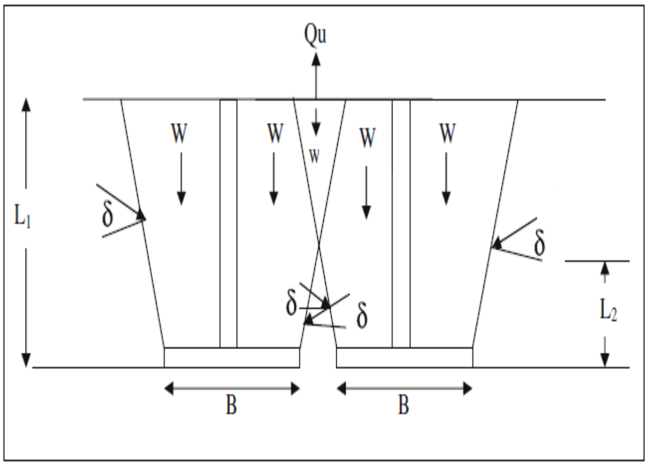

Fig 7: schemetic diagrame for pile group anchor

5. CONCLUSION

From the laboratory investigations that have been carried out the following conclusions may be drawn.

- Pile anchors having more embedment depth offer more resistance capacity than pile anchors having less embedment depth. This is attributed to the involvement of more soil mass in resisting the uplift.The increase in uplift capacity is observed to be maximum for B/d = 3.
- The resistance offered by the pile at any axial displacement increases significantly with increase in L/d ratio.
- The load-displacement curves are found to be non-linear in nature for single pile anchor and pile group anchors. Fora specific width of anchor,the net ultimate resistance increases with embedment depth and spacing.
- It is also observed that ultimate capacity increases with B/d ratio i.e. the ratio of anchor to shaft width increase is more for long pile anchors (i.e. the having more embedment depth).The rate of increase in ultimate capacity is higher when B/d increases from 2 to 3.
- Analytical model based on limit equilibrium method of predicting the net ultimate resistance of pile anchors is proposed in this study and the theoretical results compare reasonably with the experimental results. In general almost all the cases, the theoretical result is close to the observed results.

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