Estimation of Uplift Capacity of Horizontal Plate Anchor in Sand

Prof. V. B. Deshmukh

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Abstract

Abstract- In this paper, a detailed analysis of breakout horizontally laid anchor plate in sandy soil is presented. To compute the distribution of soil reactive pressure on the failure surface, Kötter?s equation is employed. The failure surface is assumed to be in the form of a cone. An analytical expression for the breakout resistance is derived. Results are reported in terms of the breakout factors and net breakout resistance. A comparison is made with the available experimental data and theoretical solutions. Keywords: kötter?s equation, horizontal

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Index terms— kötter?s equation, horizontal circular anchor plate, sand, net breakout resistance, breakout factor.

1 I. Introduction

rectangular and generally they are employed as foundation elements for structures requiring resistance against breakout i.e., transmission towers, sheet pile walls and offshore floating structures. This requires an analysis of behaviour of the anchors.

Several researchers (Mors, 1959;Balla, 1961;Baker and Konder, 1966;Meyerhof and Adams, 1968;Vesic, 1971; Clemence and Veesaert, 1977;Sutherland et al., 1982;Saeedy, 1987;Murray and Geddes, 1987;Ghaly et al.,1991; **??**om, 2012)analysed the breakout resistance of earth anchors using limit equilibrium method. Tagaya et al. (1988) introduced the theoretical formulae for the computation of the anchor pullout resistance based on elostoplastic finite element method, whereas analyses presented by Merifield and Sloan (2006) and Kumar and Kouzer (2008), Tang et al. (2014), Hao et al. (2014) and Bhattacharya and Kumar (2016) were based on the limit analysis coupled with finite element method.

In respect to a dense soil, Balla (1961) studied model and field results and found that, for circular closely approximated to an arc of a circle. From theoretical considerations, the angle of failure surface breakout resistance, P un which is the summation of soil weight contained in the failure zone and resistance to shearing developed on the failure surface was calculated as? ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? ? = D H F D H F H P un , , 3 1 3 ? ? ? (1)

the height of circular anchor,? is the soil unit weight and F 1 (?, H/D), F 3 (?, H/D) are the functions developed by Balla (1961). Balla's (1961) analysis showed a good agreement for the dense sand up-to the embedment medium sand, the analysis overestimated the net breakout resistance. For embedment ratio greater than 5 even in dense sand, the analysis overestimated the breakout resistance due to deep anchor effects wherein the failure zone did not reach the ground level. Baker and Konder (1966) conducted several laboratory model tests and used dimensional analysis to predict the ultimate uplift capacity, P u as given by the following expressions. For shallow circular anchors where, r and t are radius and the thickness of anchor plate respectively and H is the depth of embedment. C 1 , angle of soil internal friction and relative density of compaction. For shallow anchors, the model test results of Baker and Konder (1966) agreed well with the predictions based on Balla's (1961) theory.

Meyerhof and Adams (1968) reported a semitheoretical expression for breakout resistance on the basis of laboratory tests data. For the actual failure surface, simplified geometry was assumed. The failure surface makes an angle, ? with the horizontal in the where, W is the weight of cylindrical soil mass above the circular anchor and S F is the shape factor. The breakout coefficient, K u depends on soil friction angle, ? and was taken equal to 0.95 for ? varying from 30 o to 48 o . The net breakout resistance, P un was expressed asAH F P q un ? = (5)

The breakout factor, F q is given as? tan 1 2 1 ? + + = D H K D H m F u q (6)

Graphs or tables are used to obtain the coefficient, m. Vesic (1971) analysed the case of an explosive point charge for the expansion of a spherical cavity located close to the surface of a semi-infinite, homogeneous and isotropic ground. At the ground case of a circular anchor embedded in sand, the breakout pressure, q u was computed asq u F A H q ? = (7)

where, A is the area of circular anchor and F q is the breakout factor. The values of F q are computed for ? ratios in the range, 0.5 to 8. Clemence and Veesaert (1977) studied the results of laboratory experiments and made an approximation of the observed failure surface to an inverted truncated cone with an apex angle of ?/2, going upwards from the anchor base. The breakout resistance includes the weight of soil within this cone and the shearing resistance developed along the failure surface. For shallow laid circular anchors, the net breakout resistance, P un was estimated in terms of the breakout factor, F q as given by the following expressions.H A P F un q ? = (8) Or ( ) ? + ? ? ? ? ? ? ? ? ? ? ? ? ? + + ? ? ? ? ? ? ? ? ? ? ? ? + ? = 2 tan 33 . 5 2 tan 8 4 3 2 tan 5 . 0 2 cos tan 4 2 2 2 2 0 ? ? ? ? ? D H D H D H D H K F q (9)

where, K 0 is the coefficient of lateral earth pressure at rest. Murray and Geddes (1987) have reported the solutions with both limit equilibrium and limit analyses and made a comparison of the solutions with experimental results for a circular anchor. With the limit equilibrium analysis, the ultimate breakout resistance, P u was expressed by the following equation.

2 (

) (10) In the above equation, A is the area of circular anchor.? ? ? ? ? ? ? + ? ? ? ? ? ? ? + + = ? ? ? ? ? sin 2 2 tan 3 2 1 2 sin sin 2 1 D H D H AH P u? ? tan 2 1 D H AH P u + = (11)

Saeedy (1987) estimated the uplift capacity of circular plate anchors embedded in sand with the assumption of a failure surface as an arc of a logarithmic spiral. The effect of deep condition and compaction during the uplift were considered in this( )µ ? H A F P q u = (12)

where, ? is the compaction factor which is the function of relative density of compaction.

(1963), Mariupol'skii (1965), Kananyan (1966), Adams and Hayes (1967) and Sakai et al. (2007). A number of these studies were primarily concerned with testing foundations for transmission towers (Mors, 1959;Balla, 1961;Turner, 1962 andIreland, 1963).

In the present study, a total of seven experimental results (Balla, 1961;Baker and Konder, 1966;Bemben and Kupferman, 1975;Ovesen, 1981 With upper bound limit solution, the breakout resistance was expressed by the following equation.

Semi-empirical relationships are also available to estimate the breakout resistance of anchors in sand. This refers to the field and/or model testing on horizontal circular anchors or belled piles by Balla (1961), **??**utherland (1965) and Baker and Konder (1966), Mors (1959), Giffels et al. (1960), Turner (1962), Ireland analysis. To account for these conditions, the uplift capacity was expressed as level, the failure surfaces made an angle of (45 o ??/2). The analysis is confined to embedment ratios, ? to the frustum of a cone, making an angle ? with the horizontal and meeting the ground level.

To compute the vertical soil reaction, R v acting on the failure surface, Kötter's (1903) equation is integrated.

The breakout resistance is finally obtained with the summation of R v and total weight, W of soil mass contained in the failure zone.

a) Failure Surface Geometry some initial trials, the following expression for ? is chosen for the analysis. where, dp is the elemental soil reaction pressure along the failure surface, ds is the elemental failure surface length, ? is the soil friction angle, d? is the elemental angle and ? is the angle of failure plane made by the tangent at the point under consideration with the horizontal.

Estimation of Uplift Capacity of Horizontal Plate Anchor in Sand and Geddes, 1987) and two field test results (Sutherland et al., 1982;Tucker, 1987) are referred for comparison. ( )

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sin dp ds ? ? ? = +**(15)**

Integration of Eq. (15) gives, ( )1 sin C s p + + = ? ? ? (16)

Eq. (**??**6) gives the soil reactive pressure that, pressure p has zero value at point B, corresponding to s = 0. Using this condition, C 1 becomes zero and Eq.(**??**6) finally becomes ( ) In the force diagram as shown in Fig. 2, AB is a distribution on failure plane, AB, and s is the distance measured from point B (Fig. 2). The integration constant, C 1 in Eq. (**??**6) is obtained from the condition sin p s = ? ? + ?**(**

Substituting Eqs. (**??**8) and (19) into Eq. (**??**7), the elemental soil reaction, dR is obtained as( ) sin cos dr dR rd s = ? ? ? + ? ? (20) ? ? cos 2 2 tan ? ? ? ? ? ? + ? ? ? ? ? ? ? + = dr r D H s (21)

Substituting Eq. (**??**1) into Eq. (**??**0), the elemental soil reaction, dR is rewritten as In the failure wedge shown in Figs. 3b and 3c, ds). The height of this element is dH, with a slanted height ds and it is located at a distance, s as measured from the ground surface.( ) ? ? ? ? ? ? d rdr dr r D H dR ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? + ? + + =**2**

From Fig. **??**a, the distance, s is obtained as( ) ? ? ? ? ? ? d rdr dr r dr r D H dR ? + ? + + = 2 2 2 2 2 tan 2 cos sin (23)

With dr 2 ? 0, Eq. (**??**3) becomes ( ) ? ? ? ? ? ? d dr r rdr D H dR ? ? ? ? ? ? ? ? ? ? ? ? ? ? + + = 2 2 2 tan cos sin (24) ( ) ( ) ? ? ? ? ? ? ? ? ? d dr r rdr D H dR v + ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? + + = cos 2e) Net Breakout Resistance v un R W P 2 ? = (28) ( ) ? + + ? = C D D C D C un P 3 4 2 3 8 3 3 3 2 cos 2 3 2 sin 6 ? ? ? ? (29)

where,? ? ? ? ? ? ? ? ? ? ? ? ? + = ? 3 2 tan 2 H D C

and D = diameter of the circular anchor plate.

The above simple expression gives the net breakout resistance of a horizontal circular plate anchor calculations with no need of any tables or graphs. The breakout factor, F q is given asH A P F un q ? = (30)

where, A is the area of horizontal circular anchor plate.

4 III. Comparison with the Experimental Data

The results of theoretical predictions (Balla, 1961 ( ) ( ) ? + ? + ? ? ? ? ? ? + + + = 2 tan 3 4 2 tan cos 6 cos sin 2 2 D H D D D H R v ? + = 8 3 3 2 tan 3 tan D D H W ? ? ? ? (27)

Murray and Geddes, 1987) are presented in Table 1a and comparisons with two field results reported by Sutherland et al. (1982) and Tucker (1987) are deviations of the theoretical solutions with respect to the experimental results are reported in Tables 2a and 2b. For a better understanding of the relative predictive capability of the proposed solution, a cumulative frequency distribution of the data corresponding to the percentage deviations is further reported in Tables 3a and 3b. shows deviations in the range, 2% to 45% in 51 cases and in the remaining cases, the range is 55% to 100%. Predictions based on the solution proposed by Vesic (1971) show deviations in the range of 2% to 45% for 22 cases and in the remaining 27 cases, the deviations are as high as 50% to 100%.

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The method of Clemence and Veesaert (1977) shows deviations in the range, 2% to 45% for 34 cases and in the remaining 19 cases, the deviations are as high as 50% to 100%. The solution proposed by Murray and Geddes (1987) shows absolute deviations in the range of 2% to 45% for 51 cases and in the remaining 2 cases, the deviations are as high as 50% to 100%. Saeedy's (1987) method shows deviations in the range, 2% to 45% in 46 cases and in the remaining case, the range is 55% to 100%.

The proposed solution shows deviations in the range, 2% to 45% in 52 cases and in the remaining case, the range is 55% to 100%. Proposed solution and Saeedy's (1987) method show errors in the range, 0% to 5% in 9 and 12 cases respectively, whereas, in respect to the other methods, only 0 to 8 cases show deviations in this range.

From the above discussion it is seen that, Balla's (1961) method makes better predictions in 96% of the cases when compared to the experimental data.

6 Estimation of Uplift Capacity of Horizontal Plate Anchor in Sand

In general, Balla's (1961) method shows a good agreement for dense sand up-to the embedment ratio of 5. It requires a chart for using the required functions. Vesic's (1971) method shows a good performance in 45% of the cases. However, it also requires a chart or The method of Meyerhof and Adams (1968) makes good predictions in 96% of the cases; but two charts are needed to select the proper values of the net breakout factor and the shape coefficient. The method of Clemence and Veesaert (1977) makes good predictions in only 64% cases. It involves an assumption in respect to the coefficient of earth pressure at rest.

The proposed analysis method considers failure surface in the form of frustum of a cone. It makes predictions that are very close to the experimental values in 98% cases. Thus, the performance appears to be superior to the other methods. Although the proposed analysis makes an approximation while using Kötter's (1903) equation, it is improved with a proper selection of the angle, ? as per Eq. (**??**2). The integration is fairly simple, yielding a closed form expression for the net uplift resistance (Eq. 29), which is easy for calculations, with no need for graphs or tables. Kötter's (1903) equation plays a significant role in the analysis.

7 IV. Conclusions

The proposed analysis method is simple giving a closed form solution. It is also easy for hand calculations. Kötter's (1903) equation is successfully employed for axi-symmetric conditions with a proper choice of angle at which the failure surface intersects the ground level. No assumptions are necessary for the coefficient of earth pressure and the results show a very close agreement with the experimental data.

8 References Références Referencias

From Tables 3a and 3b it is seen that, in 28 out of 29 cases, Balla's (1961) theoretical method shows table for using a proper value of the breakout coefficient. [1]

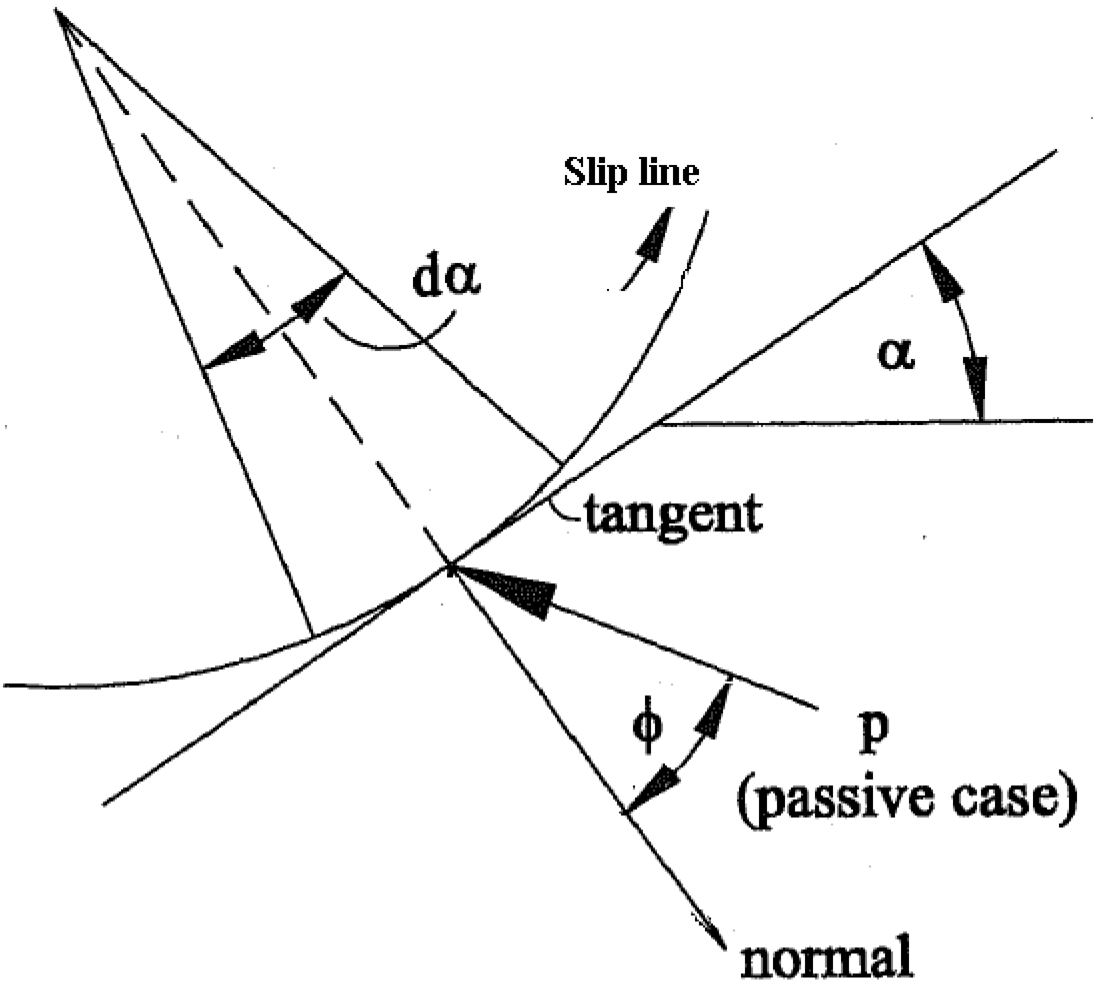

Figure 1:

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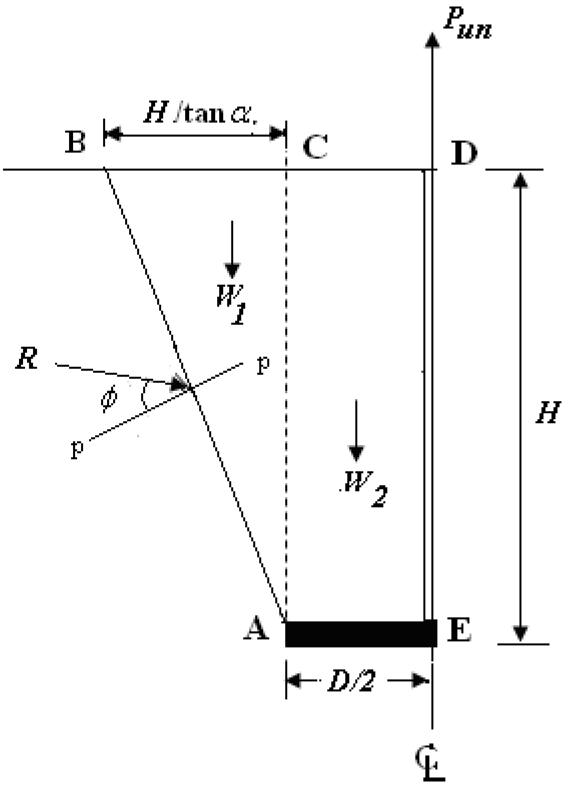

Figure 2:

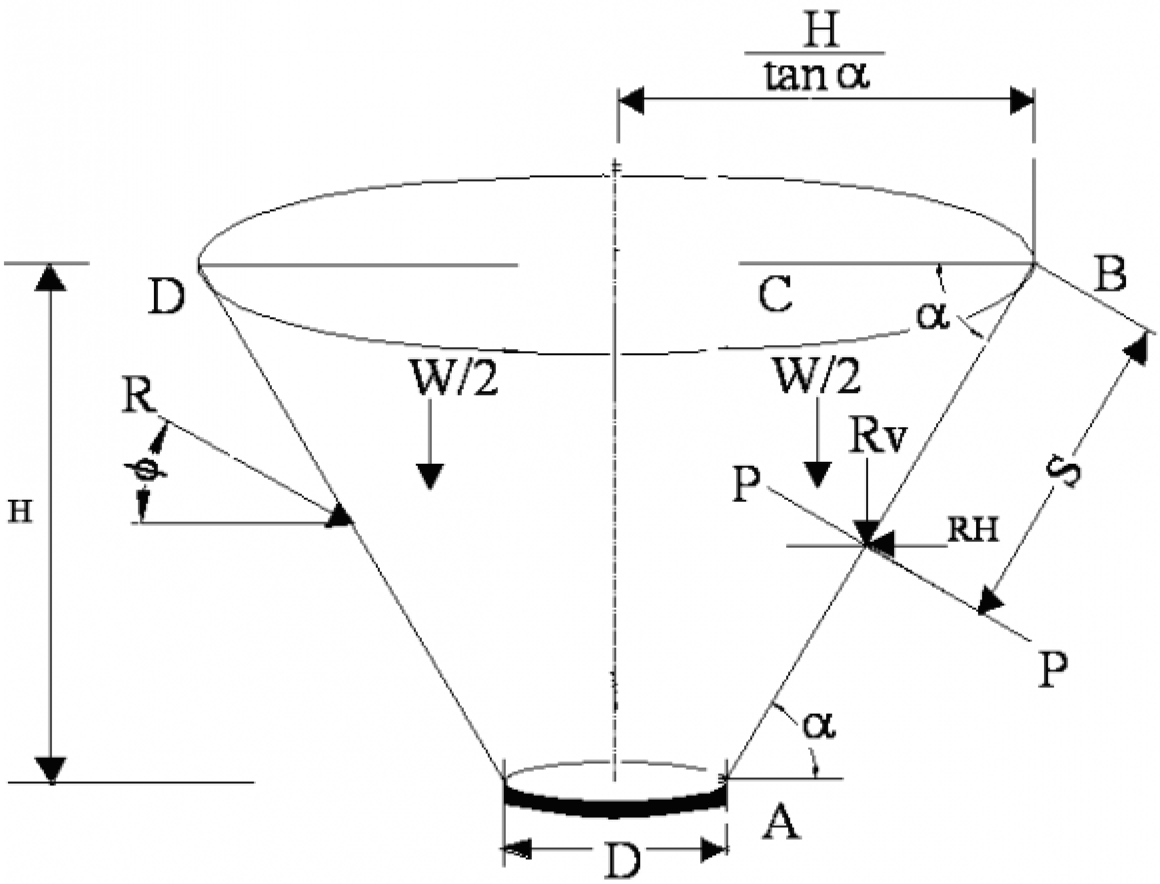

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Figure 3: Figure 1 :

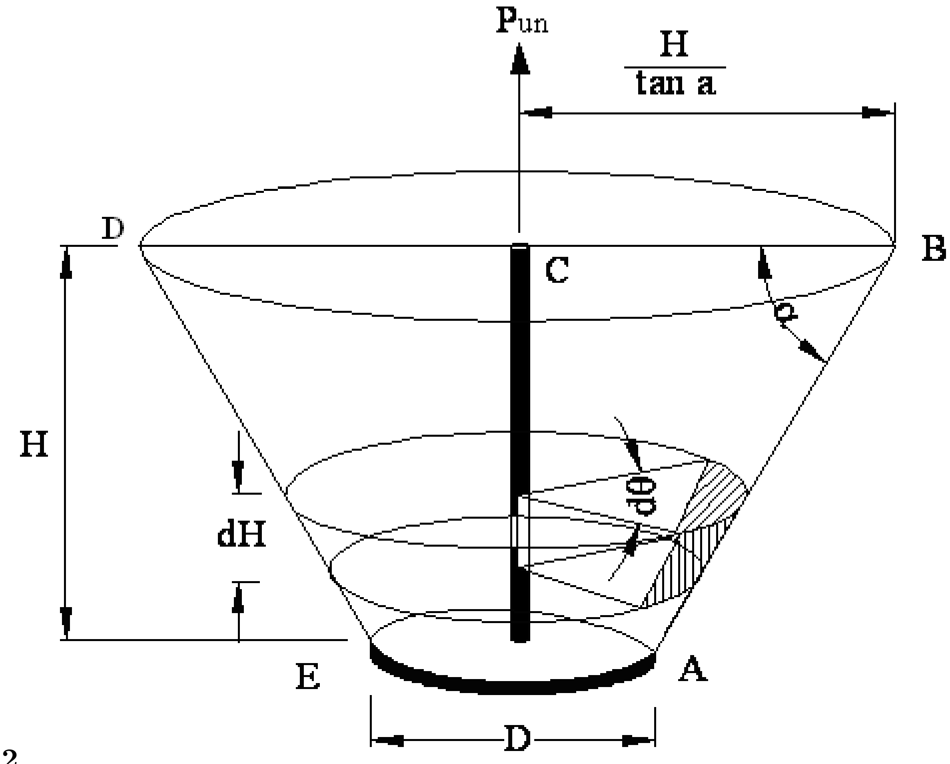

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Figure 4: Figure 2 :

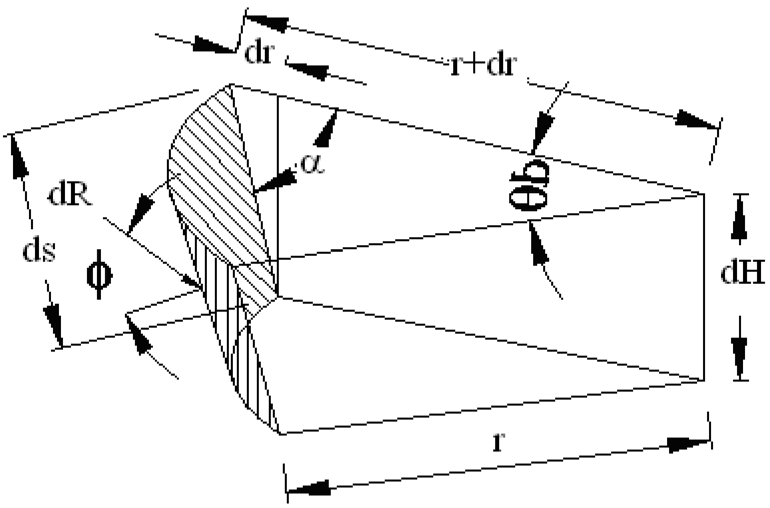

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Figure 5: 17)

Figure 6:

1a

Table 1a: Contd

Exp. H ? ? (o) Exp. Proposed Method Method Method Me

?

Exp. Results m H ? kN/m 3 Exp. Proposed Method Method Method Method M

Ovesen 0.02 ?(o) 45 1 ? values 4.77 3.52 3.83 4.142

Results m kN/m 3 0.04 45 2 10 Method 7.44 1 8.688 2 7.14

(1987)

0.05 0.06 38 0.55 2.96 45 3 19 1.96 12.44 1.95 15.415 12.413 11.081 3

D = 0.02

0.10 0.08 - 38 1.11 4.45 45 4 30 3.207 19.50 3.200 24.064 19.64 3.0

m Balla

0.10 45 5 37 27.63 34.635 25.862 N.A.

0.15 38 1.68 6.11 4.74 4.768 4.78

(1961) Murray 0.05 18 44 1 3.52 3.43 3.72 4.13

and 0.20 0.08 38 2.22 8.51 44 1.63 5.4 6.56 5.64 6.258 6.337 6.42 6.02

D = 0.09 m Geddes 0.15 44 3 14.54 12.26 14.405 12.32

0.24 38 2.77 11.0 8.66 8.594 7.51

(1987) 0.23 44 4.6 27.66 23.15 27.968 23.20

0.30 D = 0.0508 0.25 38 3.33 11.78 11.059 44 5 35.19 26.40 10.982 32.056 25.86 11.20

m Bemben 0.30 - 46 44 6 1 5.26 47.25 35.46 3.61 4.054 43.496 34.81 N.A.

and

46 2 11.13 7.71 9.232 N.A.

Kupferman - N.A.

46 3 27.66 20.36 16.534

(1975) N.A.

46 5 40.24 28.91 37.51

[Note: Estimation of Uplift Capacity of Horizontal Plate Anchor in Sand]

Figure 7: Table 1a :

1a

Estimation of Uplift Capacity of Horizontal I

Table 1a: Cont

Exp. H H ? ? ? (o) Exp. Proposed Method

Results Exp. Results m kN/m 3 m kN/m 3 ? ? ? values Method 1 1

(val- Method

o ues

)

Baker and 0.52 17.9 42 7 40.607 41.642 47.571

0.08 43 0.84 3.47 2.89 3.06

Konder 0.45 17.93 42 6 32.760 32.048 36.622

(1966) 0.19 43 1.9 7.13 6.52 7.22

Ilamparuthi 0.37 17.89 42 5 24.543 24.048 27.211

et al. D=0.0756m 0.28 0.45 17.92 42 43 2.87 12.15 9 55.140 63.846 11.0 12.59 7

17 D =0.0504m 0.37 17.92 42 0.39 43 3.91 18.98 7.5 45.731 46.693 17.29 19.98 5

(2002)

D = 0.1 m Sutherland (1982) Field Test H 0.47 0.59 0.69 Results m Sutherland 4.57 et al. 5.18 (1982) 6.4 et

D = 2.39 m 7.0 42 2.94 2562 2659 4237

Note:

Method 1. Meyerhof and Adams (1968)

Method 2. Saeedy (1987)

Method 3.Balla (1961)

Method 4.Clemence and Veesaert (1977)

Method 5. Murray and Geddes (1987)

Method 6.Vesic (1971)

Figure 8: Table 1a :

1b

Figure 9: Table 1b :

1c

Field Test H		?		Field Proposed	Method	Method	Method	Method	Method	Met
		? (o) ?								
Results	m	kN/m 3		Test Method	1	2	3	4	5	6
	1.68	38	1.38 4.73 3.91		4.412	3.95	4.12	11.54	4.737	3.0
	1.93	42	1.59 7.95 5.14		5.80	5.18	4.957	14.38	6.036	3.41
	1.915	41.5 1.57 6.29 4.98			5.63	5.10	4.95	14.03	5.88	3.36
Tucker										
	1.732	41.5 1.42 6.69 4.48			5.021	4.78	4.39	12.83	5.273	3.32
(1987)		10.37								
	2.147	41.5 1.76 4.67 5.66			6.46	6.23	5.56	15.79	6.707	4.15
D = 1.22 m										
	1.952	41.5 1.6		7.09 5.09	5.761	5.18	4.94	14.28	6.0128 4.10	
	2.196	41.5 1.8		7.27 5.95	6.82	7.02	5.86	16.33	7.068	4.29
						Method				
Method 2.Saeedy (1987)						Method 6. Vesic				
Method 3. Balla (1961)										

Figure 10: Table 1c :

2a

Estimation of Uplift Capacity of Horizontal Plate Anchor in Sand

		1	-31.369	-22.928	N.A.				
	46	2	-30.728	-17.053	N.A.				
Kupferman	46	3	-26.392	-40.224	N.A.				
(1975)	46	5	-28.156	-6.784					

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H m kN/m 3 ? 0.10 0.15 18 Method 1. Meyerhof and Adams (1968) Proposed Method Exp. Resul

D = 0.09 m	0.20	38	2.22	-22.914	-26.463				
	0.24	38	2.77	-21.273	-21.873	-31.727	-13.855	10.737	-1.782
	0.30	38	3.33	-6.121	-6.774				

Figure 11: Table 2a :

2a

Estimation of Uplift Capacity of Horizontal Plate Anchor in Sand

Exp. Results	H	?	? (o)	?	Proposed Method	Method	Method	Method	Method	Method	Method
	m	kN/m 3			Method	1	2	3	4	5	6
Baker and	0.52	17.9	42	7	-2.174	11.789	-2.174	N.A.	127.258	20.987	-43
Konder	0.45	17.93	42	6	-2.013	10.872	-3.087	N.A.	131.812	20.671	-3
(1966)											
	0.37	17.89	42	5	15.789	33.483	14.334	N.A.	157.671	42.777	N.
D=0.0756m											
	0.45	17.92	42	9	2.104	16.99	2.104	N.A.	24.272	25.728	26
D =0.0504m	0.37	17.92	42	7.5	-1.7	12.181	-1.7	N.A.	128.329	21.53	27
	0.30	17.92	42	6	54.545	79.585	54.226	N.A.	236.523	-42.105	N.
	0.45	17.97	42	12	23.191	43.617	23.191	N.A.	89.787	38.723	N.
D= 0.0378m	0.37	17.97	42	10	1.942	-4.854	1.942	N.A.	179.935	18.77	12
	0.30	17.97	42	8	-31.369	-22.928	N.A.	N.A.	10.167	-23.498	-52

Figure 12: Table 2a :

2a

Murray	0.05							
			44	1	-2.557	5.682	17.330	- 8.239
and	0.08							
			44	1.63	4.444	17.352	11.481	- 1.111
Geddes	0.15							
		-	44	3	-15.681	- 0.928	-15.268	-24.120
(1987)	0.23							
			44	4.6	-16.305	1.114	-16.124	N.A.
D = 0.0508	0.25 m 0.30		44	5	-24.979	- 8.906	-26.51	N.A.
			44	6	-24.952	- 7.945	-26.328	N.A.

Exp. Results Ovesen	H m 0.04 0.02	? kN/ 3	? (m o) 45	? 1	Proposed Method Method Method Method 1 2 3 -26.205 -19.706 -13			
			45	2	-25.600	- 13.120	-28.600	-34.310
(1987)	0.06	-	45	3	-34.526	- 18.868	-34.668	-41.679
D = 0.02 m	0.08		45	4	-35.000	- 19.787	-34.533	-46.017
	0.10		45	5	-19.919	- 6.392	-30.103	N.A.

Figure 13: Table 2a :

2a

Estimation of Uplift Capacity of Horizontal Plate Anchor in Sand

Exp. Results	H m	? kN/m 3	? (o)	?	Proposed Method	Method 1	Method 2	Method 3	Method 4	Method 5	Method 6
	0.08	17	43	0.84	-16.715	-11.816	N.A.	N.A.	15.706	-5.187	-29.
Ilamparuthi	0.19		43	1.9	-8.555	1.262	-2.244	-17.363	14.645	6.648	-37.
et al.	0.28		43	2.87	-9.465	3.621	-2.305	-14.551	13.034	6.963	-45.
(2002)	0.39		43	3.91	-8.904	5.269	-5.269	-19.916	12.006	6.928	-47.
D = 0.1 m	0.47	17	43	4.75	-5.942	9.903	-0.970	N.A.	12.180	10.493	-44.
	0.59		43	5.97	-5.892	11.223	-6.902	N.A.	11.620	10.513	-48.
	0.69		43	6.91	-11.642	5.108	-10.711	N.A.	9.993	5.962	-51.
Sutherland			41	1	-28.188	-26.532	-30.649	-29.083	11.570	-17.539	-46.085
et al.		-	41	3	-30.203	-26.212	-28.299	-32.602	7.563	-16.846	-58.629
			41	4	-16.350	-11.560	-15.750	-20.755	10.035	-0.820	-51.
(1982)			41	7	-37.728	-33.358	-38.603	N.A.	3.932	-26.137	-65.495
			41	8	-40.324	-35.991	-41.287	N.A.	3.266	-29.254	-67.332

Figure 14: Table 2a :

2b

Estimation of Uplift Capacity of Horizontal Plate Anchor in Sand

Field Test Results	H m	? ? (o) ? kN/m 3		Proposed Method	Method 1	Method 2	Method 3	Method 4	Method 5	Method 6
Sutherland	4.57	42	1.91	-15.61	-3.56	-9.744	-22.30	128.29	-0.74	-41.37
et al.	5.18	42	2.17	-21.05	-8.174	-26.25	-21.05	110.48	-6.30	-52.06
		10.37								
(1982)	6.4	42	2.67	25.09	23.692	-0.63	6.347	183.62	23.69	-35.37
D = 2.39m	7.0	42	2.94	3.786	65.379	44.49	35.675	254.72	66.39	-14.07
	1.68	38	1.38	-17.33	-6.72	-16.49	-12.89	143.97	0.148	-32.004
	1.93	42	1.59	-35.34	-27.04	-34.84	-37.65	80.88	-24.07	-41.207
Tucker	1.91	41.5	1.57	-20.82	-10.49	-18.92	-21.30	123.05	-6.518	-40.320
(1987)	1.73	41.5	1.42	-33.03	-24.95	-28.55	-34.38	91.77	-21.13	-33.878
D = 1.22 m		10.37								
	2.14	41.5	1.76	21.2	38.33	33.405	19.06	238.11	43.618	-35.759
	1.95	41.5	1.6	-28.21	-18.74	-26.94	-30.32	101.41	-15.19	-28.832
	2.19	41.5	1.8	-18.15	-6.19	-3.44	-19.39	124.62	-2.7785	-37.097

Method 1: Meyerhof and Adams (1968)
Method 2: Saeedy (1987)
Method 3: Balla (1961)
Method 4: Clemence and Veesaert (1977)
Method 5: Murray and Geddes (1987)

Figure 15: Table 2b :

3a

0-5	9	6	12	2	4	8	0
5-10	6	12	3	2	10	8	1
10-15	1	8	4	3	16	5	0
15-20	9	8	6	6	3	10	0
20-25	9	5	3	5	1	11	0
25-30	8	5	7	2	0	5	6
30-35	7	3	8	5	0	0	3
35-40	2	2	1	2	0	1	4
40-45	1	2	2	1	0	3	8
45-50	0	0	0	1	0	1	8
> 50	1	2	1	0	19	1	19

Method 1: Meyerhof and Adams (1968)
Method 2: Saeedy (1987)
Method 3: Balla (1961)
Method 4: Clemence and Veesaert (1977)
Method 5: Murray and Geddes (1987)
Method 6: Vesic (1971)

Figure 16: Table 3a :

3b

Estimation of Uplift Capacity of Horizontal Plat

25-30	42	44	35
30-35	49	47	43
35-40	51	49	44
40-45	52	51	46
45-50	52 53	51	46
> 50		53	47

Method 1: Meyerhof and Adams (1968)

Method 3: Balla (1961) Method 2: Saeedy (1987) Method 4: Clemence and Veesaert (1977) sab

Absolute deviation (%) Proposed Method Method 1 Method 2 Method 3 Method 4 Method 5 M

10-15	16	26	19
15-20	25	34	25
20-25	34	39	28

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Figure 17: Table 3b :

.1 List of symbols

The following symbols are used in this paper.

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