Numerical analysis of soil bearing capacity by changing soil characteristics

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ABSTRACT. In this research work by changing different parameters of soil foundation like density, cohesion and foundation depth and width of square foundation at angle of friction of 0° to 50° with increment of 5°, numerically safe bearing capacity of soil foundation is calculated and it is attempted to assess economical dimension of foundation as well as understanding variation range of bearing capacity at different degree. It could help of civil engineering in design of foundations at any situation.

KEYWORDS. Safe bearing capacity, Density, Cohesion of soil (c), Angle of friction (φ) and Dimension of foundation

INTRODUCTION

Improvement of soil foundation is a method to disabling earthquake forces and stabilization of soil foundation. For achieving this aim designing a series of foundations by changing gradually the main parameters of soil is the shortest way to better understanding soil characteristics.

It has been reported the effect of soil confinement on the behavior of a model footing resting on sand under eccentric – inclined load [1]. Rea and Mitchell conducted a series of model plate loading tests on circular footings supported over sand-filled square-shaped paper grid cells to identify different modes of failure and arrive at optimum dimensions of the cell [2]. Mahmoud and Abdrabbo presented an experimental study concerning with a method of improving the bearing capacity of strip footing resting on sand sub-grades utilizing vertical non-extensible reinforcement. They found out this type of reinforcement increases the bearing capacity of sub-grades and modify the load–displacement behavior of the footing [3]. The investigations also made on the laboratory-model tests for the bearing capacity of a strip foundation supported by a sand layer reinforced with layers of geo-grid [4]. Research on the ultimate bearing capacity of strip and square foundations supported by sand reinforced with geo-grid has also been performed [5]. Das and Omar presented the ultimate bearing capacity of surface strip foundations on geo-grid-reinforced sand and un-reinforced sand [6]. Dash et al. investigated the use of vertical reinforcement along with horizontal reinforcement. The reinforcement consisted of a series of interlocking cells, constructed from polymer geo-grids, which contain and confine the soil within its pockets [7]. Schimizu and Inui carried out load tests on a single six-sided cell of geo-textile wall buried in the subsurface of the soft ground [8]. Mandal and Manjunath used geo-grid and bamboo sticks as vertical reinforcement elements and studied their effect on the bearing capacity of a strip footing [9]. Rajagopal et al have studied the strength of confined sand and the influence of geo-cell confinement on the strength and stiffness behavior of granular soils [10]. Dash et al. performed an experimental study on the bearing capacity of a strip footing supported by a sand bed reinforced with a geo-cell mattress [11]. Study of bearing capacity of footing without reinforcement under eccentric inclined loads by many researchers has been carried out [12-15].

Nearly 340 foundations by adopting Terzaghi method have been calculated and the results presented in form of tables and graphs, the result helps better understanding of improving of soil foundation bearing capacity.

METHODOLOGY AND EXPERIMENTS

By adopting of Terzaghi method and altering characteristics of soil such density, cohesion, angle of friction of soils and dimension of foundation safe bearing capacity of soil foundation has been evaluated. Here three hundred forty one problems by assuming various soil properties have been solved and results of them in form of table and graph have been considered.

For all models, safe bearing capacity considered to assess soil foundation improvement thorough the interpreting of the suggested results. Formulas for calculation of safe bearing capacity are the following:

$$qf = 1.3C\,Nc + \gamma DNq + 0.4\,\gamma BN\gamma \quad (1)$$

$$qnf = qf - qnf = qf - \gamma D \quad (2)$$

$$qs = (qnf / F) + \gamma D \quad (3)$$

Also Nq, Nc and Nγ are the general bearing capacity factors and depend upon 1) Depth of footing 2) Shape of footing 3) Φ, have been used from suggestion by the Terzaghi calculation method [16].

RESULTS AND DISCUSSION

Improvement of any site could be possible, if soil characteristics of site were clearly identified [17]. Increasing Cohesion of the soil has more effect on bearing capacity when degree of friction is low (Tab. 1 and Fig. 1). Changing of soil density at any level of friction has constant effect on bearing capacity (Tab. 2 and Fig. 2). Increasing depth of the foundation has more effect on bearing capacity when degree of friction is low (Tab. 3 and Fig. 3). Increasing width of the foundation has less effect on bearing capacity when friction is low (Tab. 4 and Fig. 4).

It could be suggested when a soil has low friction, increasing depth of foundation is the best way of increasing bearing capacity or increasing cohesion of soil by adding clay mineral to the soil foundation, this technique could be done by employment of mixing soil technique. In a soil with high friction, increasing width of foundation could be best way to increase its bearing capacity.

In general decreasing depth of foundation leads to a weak bearing capacity, and appeared maximum declination in soil foundation stability. Soil density is acting like gravity force to holding foundation in stable conditions, decreasing that is deduction of holding gravity force of foundation.

Sl. No	Φ	q_s if C=0 (kN/m²)	q_s if C=1 (kN/m²)	q_s if C=2 (kN/m²)	q_s if C=3 (kN/m²)	q_s if C=4 (kN/m²)	q_s if C=5 (KN/m²)
1	0	21.00	23.47	25.94	28.41	30.88	33.35
2	5	27.53	30.70	33.86	37.02	40.19	43.35
3	10	38.50	42.66	46.82	50.98	55.14	59.30
4	15	56.47	62.06	67.65	73.24	78.83	84.42
5	20	89.13	96.80	104.47	112.14	119.81	127.48
6	25	148.17	159.04	169.92	180.80	191.67	202.55
7	30	263.43	279.55	295.67	311.79	327.91	344.03
8	35	501.67	526.71	551.76	576.81	601.85	626.90
9	40	1051.63	1093.10	1134.57	1176.04	1217.51	1258.98
10	45	2615.43	2690.10	2764.76	2839.42	2914.09	2988.75
11	50	8301.30	8451.88	8602.47	8753.05	8903.63	9054.22

Table 1: Safe bearing capacity of soil when cohesion of soil (C) is varied, soil density is 14 kN/m³ and width and depth of foundation are equal to 1.5 and 2.5 m, respectively.

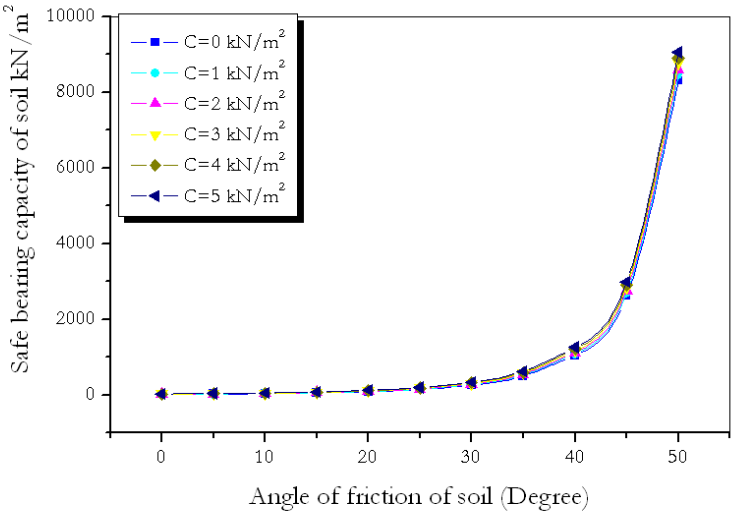

Figure 1: Safe bearing capacity Vs angle of friction of soil

Sl. No	Φ	q_s if γ=14 (kN/m³)	q_s if γ=15 (kN/m³)	q_s if γ=16 (kN/m³)	q_s if γ=17 (kN/m³)	q_s if γ=18 (kN/m³)	q_s if γ=19 (kN/m³)	q_s if γ=20 (kN/m³)
1	0	21.00	22.50	24.00	25.50	27.00	28.50	30.00
2	5	27.53	29.50	31.47	33.43	35.40	37.37	39.33
3	10	38.50	41.25	44.00	46.75	49.50	52.25	55.00
4	15	56.47	60.50	64.53	68.57	72.60	76.63	80.67
5	20	89.13	95.50	101.87	108.23	114.60	120.97	127.33
6	25	148.17	158.75	169.33	179.92	190.50	201.08	211.67
7	30	263.43	282.25	301.07	319.88	338.70	357.52	376.33
8	35	501.67	537.50	573.33	609.17	645.00	680.83	716.67
9	40	1051.63	1126.75	1201.87	1276.98	1352.10	1427.22	1502.33
10	45	2615.43	2802.25	2989.07	3175.88	3362.70	3549.52	3736.33
11	50	8301.30	8894.25	9487.20	10080.15	10673.10	11266.05	11859.00

Table 2: Safe bearing capacity of soil when soil density (γ) is varied, cohesion is zero and width and depth of foundation are equal to 1.5 and 2.5 m, respectively.

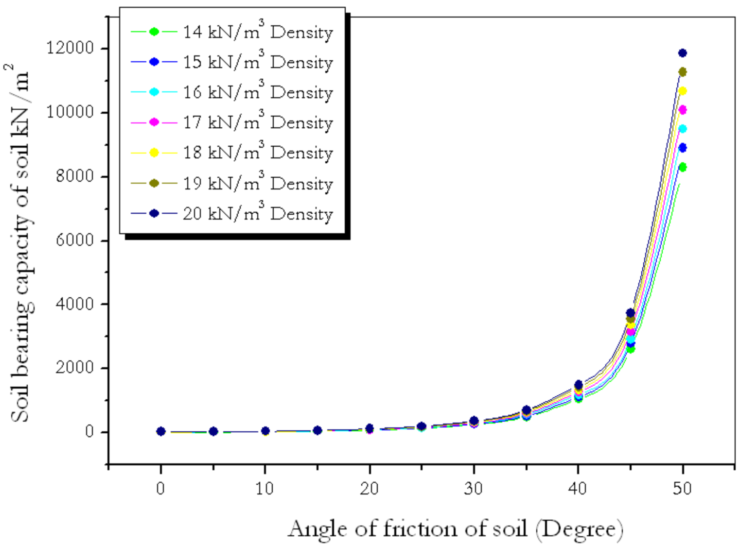

Figure 2: Safe bearing capacity Vs angle of friction of soil.

Sl. No	Φ	q_s if d=0.7 (m)	q_s if d=0.8 (m)	q_s if d=0.9 (m)	q_s if d=1 (m)	q_s if d=1.1 (m)	q_s if d=1.2 (m)	q_s if d=1.3 (m)	q_s if d=1.4 (m)	q_s if d=1.5 (m)
1	0	9.80	11.20	12.60	14.00	15.40	16.80	18.20	19.60	21.00
2	5	14.09	15.77	17.45	19.13	20.81	22.49	24.17	25.85	27.53
3	10	20.95	23.15	25.34	27.53	29.73	31.92	34.11	36.31	38.50
4	15	32.57	35.56	38.55	41.53	44.52	47.51	50.49	53.48	56.47
5	20	54.04	58.43	62.81	67.20	71.59	75.97	80.36	84.75	89.13
6	25	93.29	100.15	107.01	113.87	120.73	127.59	134.45	141.31	148.17
7	30	171.97	183.40	194.83	206.27	217.70	229.13	240.57	252.00	263.43
8	35	339.64	359.89	380.15	400.40	420.65	440.91	461.16	481.41	501.67
9	40	740.65	779.52	818.39	857.27	896.14	935.01	973.89	1012.76	1051.63
10	45	1960.98	2042.79	2124.59	2206.40	2288.21	2370.01	2451.82	2533.63	2615.43
11	50	6744.13	6938.77	7133.42	7328.07	7522.71	7717.36	7912.01	8106.65	8301.30

Table 3: Safe bearing capacity of soil when depth of foundation (d) is varied, cohesion is zero, width of foundation is 2.5 m and soil density (γ) is 14 kN/m³.

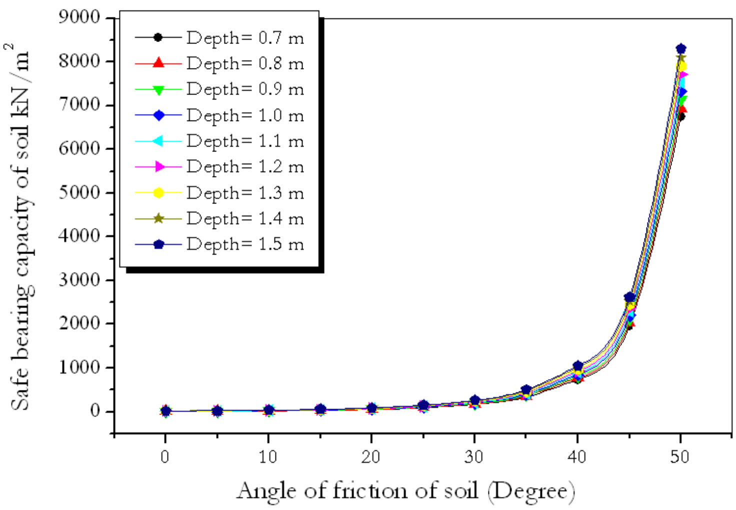

Figure 3: Safe bearing capacity Vs angle of friction of soil

Sl. No	Φ	q_s if w=1.7 (m)	q_s if w=1.8 (m)	q_s if w=1.9 (m)	q_s if w=2.0 (m)	q_s if w=2.1 (m)	q_s if w=2.2 (m)	q_s if w=2.3 (m)	q_s if w=2.4 (m)	q_s if w=2.5 (m)
1	0	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00
2	5	26.79	26.88	26.97	27.07	27.16	27.25	27.35	27.44	27.53
3	10	36.71	36.93	37.16	37.38	37.60	37.83	38.05	38.28	38.50
4	15	52.73	53.20	53.67	54.13	54.60	55.07	55.53	56.00	56.47
5	20	81.67	82.60	83.53	84.47	85.40	86.33	87.27	88.20	89.13
6	25	133.68	135.49	137.30	139.11	140.92	142.73	144.55	146.36	148.17
7	30	234.01	237.69	241.37	245.05	248.72	252.40	256.08	259.76	263.43
8	35	438.35	446.26	454.18	462.09	470.01	477.92	485.84	493.75	501.67
9	40	901.70	920.44	939.19	957.93	976.67	995.41	1014.15	1032.89	1051.63
10	45	2171.17	2226.70	2282.23	2337.77	2393.30	2448.83	2504.37	2559.90	2615.43
11	50	6579.19	6794.45	7009.72	7224.98	7440.24	7655.51	7870.77	8086.04	8301.30

Table 4: Safe bearing capacity of soil when width of foundation (w) is varied, cohesion is zero, depth of foundation is 1.5 m and soil density (γ) is 14 kN/m³.

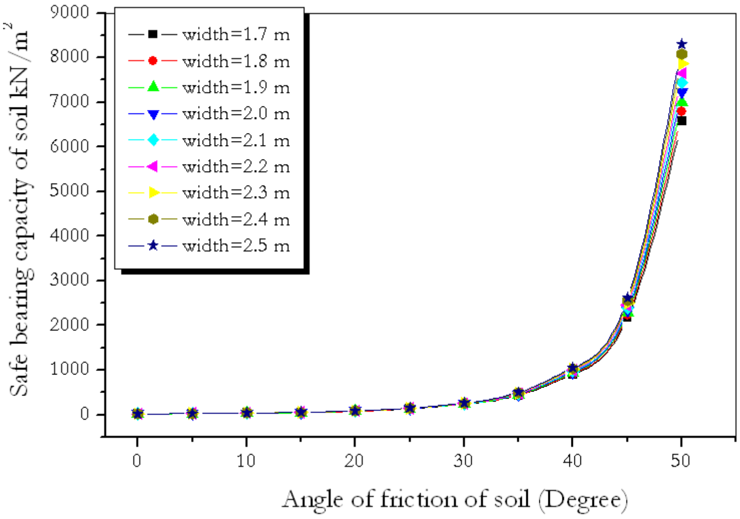

Figure 4: Safe bearing capacity Vs angle of friction of soil.

CONCLUSION

By understanding all factors, which effected to the soil, could be starting way of the improvement of any soil. Some element have linear and some of them nonlinear effect on soil bearing capacity. Unit weight has linear correlation with bearing capacity at any degree of angle of friction, cohesive of soil and width and depth of foundation have nonlinear correlation with bearing capacity at any angle of friction. Data has been produces in this paper could make clear economical design of any foundation. Increasing of bearing capacity in a soil with low angle of friction is not same, as a soil with high level of angle of friction, at any of them should apply proper technique.

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