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Assessment of Different Methods for Determinng Bearing Capacity for Shallow Foundation on Hill Slope

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Abstract:** The bearing capacity of soil is a crucial factor in foundation design, and it can be determined using various methods such as IS 6403:1981, Meyerhof (1957), Hansen (1970), and Terzaghi (1943), among others. This paper aims to study the most suitable method for assessing the bearing capacity of soil in hilly regions like Aizawl, Mizoram. In this regard, the Durtlang locality which is the most developing area under the Aizawl Municipal Corporation (AMC) has been selected for the study area. The study involved collecting undisturbed soil samples from ten different locations of the study area which were then tested in the laboratory to determine their engineering properties. Based on the obtained soil properties, the safe bearing capacity (SBC) was calculated using different methods, including IS 6403:1981, Meyerhof (1957), Hansen (1970), and Terzaghi (1943). A comparative analysis was conducted to evaluate the SBC values derived from these methods. Moreover, a parametric analysis was also conducted to study the impact of cohesion 'c' and the angle of internal friction 'Φ' of soil on the bearing capacity of soil. The study concluded that as the cohesion of the soil increased, the angle of internal friction tended to decrease. On the other hand, the safe bearing capacity (SBC) was found to increase with a higher angle of internal friction. The results of the comparative analysis revealed that, for the selected soil samples, the bearing capacities calculated using IS 6403:1981, Meyerhof (1957), and Terzaghi (1943) were higher than those derived from Hansen's (1970) equation. Notably, both Meyerhof (1957) and Hansen (1970) incorporate the slope angle in their bearing capacity calculations, whereas IS 6403:1981 and Terzaghi (1943) provide general formulas that do not account for slope effects. These findings highlight that the method chosen for calculating bearing capacity has a significant impact on the results.

***Keywords:** Bearing Capacity, Hill Slope, Shallow Foundation, is Code, Terzaghi's Method, Meyerhof's Method, Hansen Method*

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I. INTRODUCTION

The foundation is the most fundamental part of any structure. It carries the overall weight of the structure. Hence it is essential to design the building's foundation properly. A shallow foundation is a foundation unit supporting a building by transmitting loads to nearby soil or rock. In each site, the foundation's depth is no more than 3 meters below the surface, and its depth-to-bread ratio is less than 1 [1].

Due to the fact that hill slopes are further vulnerable to failure than other forms of earth formation, it is essential to investigate the bearing capacity in this scenario. Engineers need to be aware of the soil's maximum bearing capacity beneath a structure to construct shallow footing of a suitable size and form. The amount of soil loading at the foundation's base that causes shear failure of the soil layer is referred to as the ultimate bearing capacity of the soil. Shallow foundations are typically used for modest to medium-rise buildings. Determining the bearing capacity's minimal value is the objective in this case: (1) due to a foundation instability; and (2) based on the slope's general stability [2]. The bearing capacity of a foundation in cohesive soil may be determined by its stability. However, foundation failure always determines the bearing capacity in noncohesive soil [3].

The ultimate bearing capacity of soil at the foundation level can be calculated using several bearing capacity equations by various researchers as shown in Table 1. However, using an alternative approach to assess bearing capacity produces a distinct outcome. The researchers' numerous approaches, which are based on the Limit equilibrium method, Slip line method, and Finite element method, are available to assess the stability of shallow foundations on or near slopes. A quick summary of critical bearing capacity studies and their equations are discussed in Table 1.

The present study is conducted in a hilly area of Aizawl, Mizoram, i.e [23]. Durtlang. Using IS 6403:1981, Meyerhof (1957), Hansen (1970), and Terzaghi’s (1943), the bearing capacity of soil for the selected slope is determined, and a comparison of the outcomes from these approaches is carried out [24]. The equations proposed by various researchers for calculating bearing capacity on a hill slope are considered [25].

Table 1: Formulae for Bearing Capacity Calculation

SL/No.	Authors &Codes	Formula	Remarks
1	Prandtl's(1920) [4]	$q_{ult} = \frac{c}{\tan\emptyset}\left[\left\{tan^2\left(45+\frac{\emptyset}{2}\right)e^{\pi\tan\emptyset}\right\}-1\right]$	To develop the equations for the bearing capacity of cohesionless soils, an assumption was made that the soil is weightless and took into consideration the equilibrium of the plastic sectors.
2	Terzaghi (1943) [5] *(i) Strip(continous)*	$q_{ult} = cN_c + qN_q + 0.5\gamma BN_\gamma$	Based on plastic theory and by using the superposition principle and considering the weight of the soil.
	(ii)Square	$q_{ult} = 1.3cN_c + qN_q + 0.4\gamma BN_\gamma$	
	(iii) Circular	$q_{ult} = 1.3cN_c + qN_q + 0.3\gamma BN_\gamma$	
	(iv) Rectangular	$q_{ult} = (1+0.3\frac{B}{L})cN_c + qN_q + (1-0.2\frac{B}{L})\gamma BN_\gamma$	
3	Skempton (1948) [6]	$q_{uilt(unsat)} = \left[\frac{q_{u(unsat)}}{2}\right]\left[1+0.2\left(\frac{B}{L}\right)\right]N_{unsat}$	Interpreting the bearing capacity of saturated fine-grained soils assuming undrained conditions based on Terzaghi's bearing capacity factor
4	Skempton (1951) [7]	$q_{ult} = cN_c + \gamma D_f$	Design for clayey soil.
5	Meyerhof(1963) (i) *Vertical Load*	$q_{ult} = cN_c.s_c.d_c + \gamma.D.N_qd_q + 0.5\gamma B'N_\gamma s_\gamma d_\gamma$	Using the shearing strength of the soil above the foundation level, the expression for bearing capacity was derived for both shallow and deep foundations.
	(ii) Inclined load	$q_{ult} = cN_c.s_c.i_c + \gamma.D.N_qi_q + 0.5\gamma B'N_\gamma s_\gamma i_\gamma$	
6	Meyerhof (1957) [8] For Shallow foundation	$q_{ult} = cN_c\lambda_{c\beta} + qN_q\lambda_{q\beta} + 0.5\gamma BN_\gamma\lambda_{\gamma\beta}$	This equation was developed for a shallow foundation near the slope edge.
7	Hansen(1970) [9] (i) *For cohesionless soil*	$q_{ult} = cN_c.s_c.i_c.d_c.g_c.b_c + \gamma.D.N_q.i_q.d_q.g_q.b_q + 0.5\gamma B'N_\gamma.s_\gamma.i_\gamma.d_\gamma.b_\gamma$	The Hansen equation is further the extension of Meyerhof's equation. This equation can be used for any type of foundation for calculating bearing capacity.
	(ii) For $\emptyset = 0$	$q_{ult} = 5.14.c_u(1+s'_c+d'_c-i'_c-g'_c-b'_c)+\gamma.D$	
8	Meyerhof(1974) [10]	$q_{ult} = C_{uo}N_c + q_o + 2(H^2\gamma' + 2H_{qo})$	Based on the punching shear method for sand overlaying clay
9	Vesic(1975) [11]	$q_{ult} = (5.14-2\beta)c + \gamma D_f(1-\tan\beta)^2 - \gamma B\sin\beta(1-\tan\beta)^2 - 2\beta$	Vesic concluded that the bearing capacity factor N_γ has a below zero value for frictionless soil when the weight of the soil is not considered. Considering, $N_c = 5.14$ and $N_q = 1$
10	IS 6403:1981 [12] *General shear failure*	$q_{ult} = cN_c.s_c.d_c.i_c + q.(N_q-1)s_qd_qi_q + B\gamma'N_\gamma s_\gamma d_\gamma i_\gamma W'$	Based on shear and allowable settlement criteria by taking into consideration the footing's shape, the loading's inclination, the embedment's depth, and the water table's impact.
	Local shear failure	$q_{ult} = cN'_c.s_c.d_c.i_c + q.(N'_q-1)s_qd_qi_q + B\gamma'N'_\gamma s_\gamma d_\gamma i_\gamma W'$	
11	Rankine's (1885) [13]	$q_{ult} = \gamma D_f\left[\frac{1+\sin\emptyset}{1-\sin\emptyset}\right]^2$	Design based on loose earth, dry granular sandy soil
12	Huang & Meng (1997) [14]	$q_{ult} = \eta\gamma + (B+\Delta B)N_\gamma + \gamma dN_q$	They developed an analysis employing the deep-footing and wide-slab failure technique to determine the maximum bearing capacity of a ground improvement foundation.
13	Oloo et .al (1997) [15]	$q_{ult} = [c' + (u_a-u_w)\tan\emptyset^b]N_c\varepsilon_c + qN_q\varepsilon_c + 0.5B\gamma\varepsilon_\gamma N_\gamma$	The equations developed according to the supposition that the bilinearity of unsaturated soil ultimate bearing capacity failure envelope.
14	Wayne et al. (1998) [16] *Square footing*	$q_{u(R)} = q_b + \frac{4c_as_ad}{B} + 2\gamma_1d^2\left(1+\frac{2D_f}{d}\right)\frac{k_sS_s\tan\emptyset_t}{B} + \frac{4\sum_{i=1}^{n}T_iS_t\tan\delta}{B} - \gamma_td$	Based on the failure modes of reinforcement an analytical approach for assessing the ultimate bearing capacity of reinforced soil foundations.
15	Yang et al. (2005) [17]	$q_{ult} = 2C_tB_o(f_4+f_5+f_6) - \frac{\gamma B_o^2}{2}(f_1+f_2) - q_oB_of_3$	Using upper bound solution with modified Hoek-Brown failure.
16	Cerato et al. (2006) [18] For square and circular footing on cohesionless soil	$, q_{ult} = 0.5\gamma BN_\gamma^*$	Modified SBC factors of Terzaghi's. The bearing capacity factors depend on relative density, shape factors, and width of footings.
17	Vanapalli & Mohammed (2007) [19]	$q_{ult} = \{c' + (u_a-u_w)b[1-S^{\varphi_{BC}}\tan\emptyset'] + (u_a-u_w)_{AVR}S^{(\varphi_{BC})}\tan\emptyset'\}N_c\varepsilon_c + 0.5B\gamma\varepsilon_\gamma N_\gamma$	The equations were developed by employing the effective shear-strength parameters and the soil-water characteristic curve
18	Sherif et al. (2007) [20]	$q_{ult} = cN_c + D\gamma_xN_q + 0.5B\tan\beta_m\gamma_\gamma N_\gamma$	Based on Terzaghi's equation ($\alpha - method$)
19	Chen(2008) [21]	$q_{ult} = cN_c + qN_q + 0.5\gamma BN_\gamma + \Delta_{qr}$	Bearing factors are the same as Teraghi's(1943), whereas $\Delta_{qr}$is has greater bearing capacity as a result of tensile force
20	Kalindi et al. (2011) [22]	$q_{ult} = x_1\gamma D^{x_2}.N_q.F_{aqs}.F_{qd} + x_3\gamma B^{x_4}N_\gamma F_{\gamma s}F_{\gamma d}$	Modified Meyerhof's (1963) equation.

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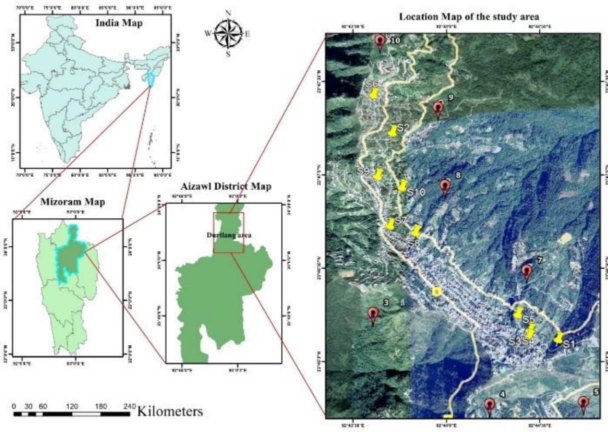
II. STUDY AREA

The municipal areas of the vulnerable slopes in Aizawl have been studied and identified [26]. Durtlang is selected as the study area after investigation due to its history of slope failure in the past. Moreover, Durtlang is undergoing a development area where people have lived and constructed houses for the past 4-5 years. Durtlang is located in the northern part of Aizawl. According to Aizawl Municipal Corporation (AMC), Durtlang comes under AMC Ward I, as shown in Table 2. Ten (10) sites in the Durtlang area were selected, where soil samples were collected, and a geotechnical investigation was carried out. The locations and characteristics of the ten selected sites at Durtlang are shown in Table 2.

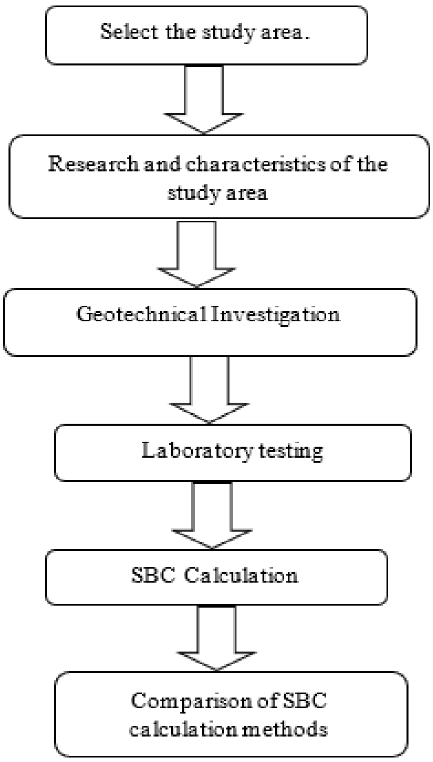


[Fig.1: Location of the Study Area Map]

Table 2: Location and Characteristics of the Selected Slopes

Sl/No.	Location	Amc Ward No.	Coordinates	Slope Height (M)	Slope Angle
1	S1	I	23º46’07"N 92º44’35”E	20	35º
2	S2	I	23º47’13"N 92º43’42” E	10	28º
2	S3	I	23º44'01"N 92º42'55"E	12	30°
2	S4	I	23º 46' 10"N92º 44' 26"E	15	25°
5	S5	I	23º46'20"N 92º44'25"E	6.1	30°
6	S6	I	23º 47' 25"N92º 43'36"E	3	18°
7	S7	I	23º46’43.348"N 92º43’41.278”E	12	20°
8	S8	I	23º46’41.5"N 92º43’49.4”E	15	45°
9	S9	I	23°46'59.16"N 92°43'37.27"E	10	25°
10	S10	I	23°46'55.58"N 92°43'45.11"E	11	30°

III. MATERIALS AND METHODOLOGY



[Fig.2: Methodology Flowchart]

Soil samples are collected from 10 sites in the Durtlang area for this study. The sample collecting locations and slope morphology are observed, shown in Table 2. Undisturbed samples from each site at a depth of 2m were collected. The samples were taken to the laboratory on the same day of sample collection and oven-dried for 24 hours before beginning laboratory testing. Laboratory tests such as Specific Gravity, Atterberg's Limit test, Compaction Factor Test, and Direct Shear Test were performed to assess the soil's various physical, index, and engineering properties. Depending on the results obtained from the laboratory, the soil types are categorized according to the Unified Classification System (1942). Table 2 and Table 3 show the index properties and engineering properties of the soil samples. The safe bearing capacity of soil is calculated based on four methods such as IS 6403:1981, Meyerhof (1957), Hansen (1970), and Terzaghi’s(1943). The parametric analysis is performed to compare the methods used by checking the impact of the soil properties and bearing capacity on the ultimate bearing capacity of the soil.

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Table 3: Index Properties and Engineering Properties of the Selected Soil Samples

Sl/No.	Location	Amc Ward No.	Soil Parameters							USC Classification of Soil
			Specific Gravity	Plasticity Index (PI)(%)	Liquid Limit (%)	Unit Weight (Kn/M3)	OMC (%)	C In Kn/M2	Φ	
1	S1	I	2.91	3.31	24.92	15	14	13.35	42.78	CL
2	S2	I	2.51	4.52	30.52	15.05	12	18.84	26.65	CL-ML
3	S3	I	2.57	0.43	30.42	15.79	18	17.76	39.89	ML or OL
4	S4	I	2.61	18.59	40.2	16	16	28.203	20	CL
5	S5	I	2.49	10.55	36.25	15.69	18	53.07	12.29	ML or OL
6	S6	I	2.49	12.71	47.93	16.18	20	33.35	12	MH or OH
7	S7	I	2.47	20.67	42.13	16.97	18	32.45	10.89	CL
8	S8	I	2.57	13.8	38.53	17.65	16	28.45	20.96	ML or OL
9	S9	I	2.46	8.05	30.6	19.23	20	49.34	13.7	CL
10	S10	I	2.47	7.01	35.3	20	20	15	24.23	ML or OL

The four methods for calculating the bearing capacity of soil used in this paper are IS 6403:1981, Meyerhof (1957), Hansen (1970), and Terzaghi (1943). The calculation of the bearing capacity obtained from these methods is shown in Table 4.

Meyerhof (1957) A theoretical solution was proposed by Meyerhof (1957) using Eqn. 1 to establish the ultimate bearing capacity of a shallow foundation on a slope or near its top edge.

$$q_{ult} = cN_{cq} + 0.5\gamma BN_{\gamma q} \quad \dots \quad (1)$$

Where, N_{cq}, $N_{\gamma q}$ = bearing capacity factors

Hasen (1970) presented the following equation for the ultimate bearing capacity of a shallow foundation placed at the slope edge given by Eqn. 2

$$q_{ult} = cN_c\lambda_{c\beta} + qN_q\lambda_{q\beta} + 0.5\gamma BN_\gamma\lambda_{\gamma\beta} \quad \dots \quad (2)$$

Where $q = \gamma D_f$

N_c, N_q and N_γ, are bearing capacity factors

$$N_c = (N_q - 1)\cot\emptyset$$

$$N_q = e^{\pi\tan\emptyset}\frac{1+\sin\emptyset}{1-\sin\emptyset}$$

$$N_\gamma = 1.5N_c tan^2\emptyset$$

$\lambda_{c\beta}$, $\lambda_{q\beta}$ and $\lambda_{\gamma\beta}$, are slope factors

For Ø>0, $\lambda_{c\beta} = \frac{N_q\lambda_{q\beta}-1}{N_q-1}$

For Ø=0, $\lambda_{c\beta} = 1 - \frac{2\beta}{\pi+2}$

$$\lambda_{q\beta} = \lambda_{\gamma\beta} = (1-\tan\beta)^2$$

Terzaghi's (1943) Terzaghi (1943) developed a rational bearing capacity equation for strip footing by assuming the foundation general shear failure is bearing capacity failure. The theory was an extension of Prandtl's theory (1921)

$$q_u = \frac{Q_{ult}}{B} = cN_c + qN_q + 0.5\gamma BN_\gamma \quad \dots \quad (3)$$

Where Q_{uilt} = ultimate load per unit length of footing,
c=cohesion,
γ = effective unit weight of soil,
B = width of footing,
D_f = depth of footing,
N_c, N_q, and Nγ are the bearing capacity factors.
Ø= angle of internal friction.

The following equations express the bearing capacity factors

$$N_c = (N_q - 1)\cot\emptyset$$

$$N_q = \frac{a_\theta^2}{2cos^2(45° + \emptyset/2)}$$

Where $a_\theta = e^{\eta tan\emptyset}$, $\eta = (0.75\pi - \emptyset/2)$

$$N_\gamma = 1.5\tan\emptyset\frac{K_{p\gamma}}{cos^2\emptyset} - 1$$

Where $K_{p\gamma}$ =passive earth pressure coefficient

IV. ALLOWABLE BEARING CAPACITY CALCULATION AND COMPARISION

The allowable bearing capacity of soil on ten (10) selected sites is calculated using four different methods as shown in Table 4 and the variations of these methods on the allowable bearing capacity are calculated using the chart as shown in Fig 3.

Table 4: The Bearing Capacity Observed at Each Site by IS Code 6403:1981, Meyerhof (1957), Hansen (1970), and Terzaghi (1943)

Sl/No.	Location	IS Code 6403:1981 (KN/m^2)	Meyerhof (1957) (KN/m^2)	Hansen (1970) (KN/m^2)	Terzaghi's (1943) (KN/m^2)
1	S1	1736.53	827.43	316.28	1797.34
2	S2	261.08	340.67	122.33	290.19
3	S3	1193.5	817.11	399.08	1253.4
4	S4	184.83	165.2	98.36	130.93
5	S5	99.84	307.4	10	163.69
6	S6	120.89	226.78	79.29	104.85
7	S7	104.95	210.93	33.91	93.04
8	S8	193.22	142.25	15	142.26
9	S9	187.41	291.11	19.11	164.39
10	S10	226.67	337	152.15	162.67

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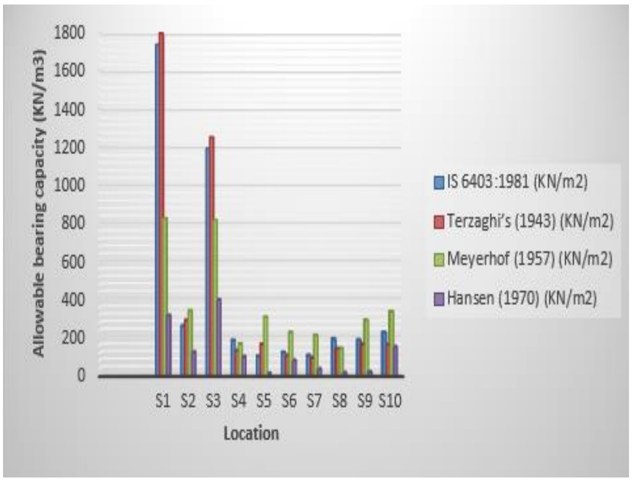


[Fig.3: Chart Showing the Allowable Bearing Capacity of Soil on Selected Sites]

As shown in Table 4 and Fig 3, there are some variations in the allowable bearing capacity calculated by different methods. Among the four methods, IS 6403:1981 and Terzaghi's(1943) provide a general bearing capacity of soil calculation that does not take slope angle into account whereas Meyerhof (1957) and Hansen (1970) provide calculations of soil bearing capacity for slopes that take slope angle into account.

Therefore, Meyerhof's (1957) and Hansen's (1970) methods give less bearing capacity compared to IS 6403:1981 and Terzaghi's (1943). According to Fig. 3, the allowable bearing capacity for the site (S1) is higher for Terzaghi's (1943) and IS code (1981) than it is for the other two approaches. Meyerhof (1957) and Hansen (1970) proposed their theoretical formulae for foundations located at the edge of the slope.

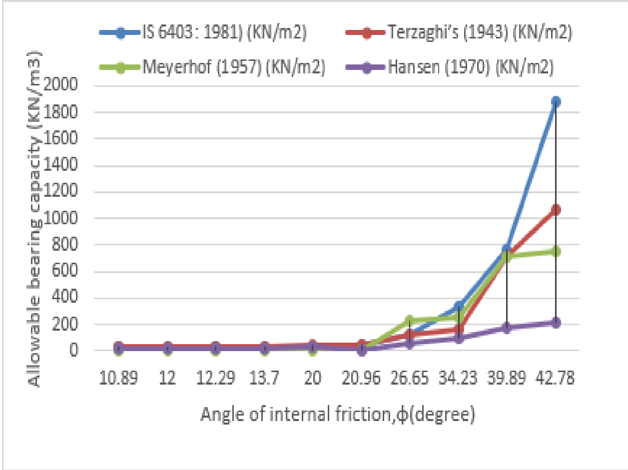
Therefore, the calculation of the bearing capacity of soil is based on the slope angle. As a result, the allowable bearing capacity for the site (S1), which has a steep slope with a slope angle of 35°, is lower compared to the IS code (1981) and Terzaghi's (1943). Similarly, the higher the slope angle of the sites, the higher the allowable bearing capacity for IS 6403:1981 and Terzaghi's(1943) methods whereas it is low for Meyerhof's (1957) and Hansen's (1970) methods. The bearing capacity, however, also depends on cohesion and angle of internal friction of soil, its unit weight, and depth of foundation.

Meyerhof (1957) therefore provides the maximum bearing capacity compared to the other approaches in sites S2, S5, S6, S7, S9, and S10 whereas Hansen (1970) provides the minimum bearing capacity compared to other approaches in all the sites. As a result, parametric analysis is essential for comprehending how each parameter affects the soil's bearing capacity.

V. PARAMETRIC ANALYSIS AND DISCUSSION

In each selected site, the application of different bearing capacity calculation methods, such as IS 6403:1981, Meyerhof's (1957), Terzaghi's (1943), and Hansen's (1970), are illustrated to comprehend the differences obtained depending on the soil properties.

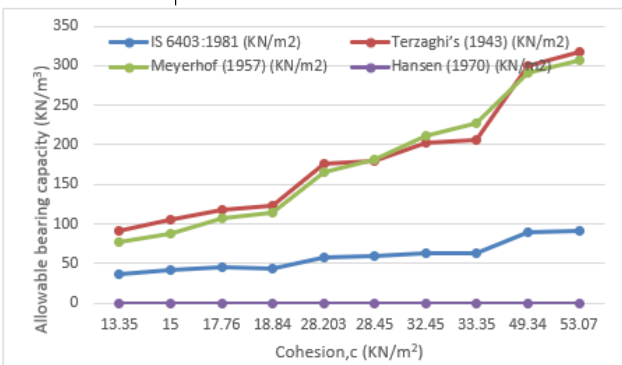
I. The effect of the angle of internal friction on allowable bearing capacity in all sites when c=0.



[Fig.4: Angle of İnternal Friction vs Allowable Bearing Capacity of Soil]

As observed from Fig. 4, for all methods, the allowable bearing capacities rise exponentially as the angle of friction increases. The allowable bearing capacities are approximately similar for all the methods when the angle of internal friction is low i.e.; 0° to 20° whereas the difference of all the methods increases when the angle of internal friction increases. Moreover, Fig. 3 shows that, compared to other approaches, the IS 6403:1981 equation forecasts a maximum bearing capacity at a higher friction angle. Hansen (1970) and Meyerhof (1957) devised their respective equations for shallow foundations at hill slopes. Comparing all the methods, Meyerhof's (1957) and Terzaghi's (1943) provide results that are largely comparable when the angle of internal friction is low whereas when the angle of internal friction increases Meyerhof (1957) provides inconsistent results as compared to Terzaghi's (1943). This is due to the fact that according to Meyerhof (1957), both the slope angle and the angle of internal friction of soil determine the allowable bearing capacity. Hansen (1970) forecasts the lowest bearing capacity among the approaches.

II. The effect of cohesion on the allowable bearing capacity of soil when ϕ=0.



[Fig.5: Cohesion vs Allowable Bearing Capacity of Soil]

As the cohesiveness increases, the allowable bearing capacity for all methods decreases significantly, as observed in Fig. 5. Higher cohesiveness values have a relatively low internal friction angle, which decreases the allowable bearing capacity. Terzaghi's (1943) and Meyerhof's (1957) equation forecasts a higher bearing capacity for pure cohesive soil. In contrast to Hansen (1970), who only provides the calculation of bearing capacity for granular soil when the foundation is located at the edge of a slope, the graph demonstrated that cohesion had an impact on the allowable bearing capacity at each site for all approaches. With these findings, Terzaghi (1943) and Meyerhof (1957) provide results that are comparable to those of the other methods.

VI. CONCLUSION

This study represents a comparative analysis of bearing capacity calculation by different methods such as IS6403:1981, Meyerhof (1957), Terzaghi's (1943), and Hansen (1970) in Aizawl City, Mizoram. The main conclusions derived from the present study are as follows:

1. The magnitude of bearing capacity varies with the method adopted for the calculation.
2. From this study, it is observed that the bearing capacity is governed by foundation failure in non-cohesive soil whereas it is governed by the stability of slope in cohesive soil.
3. For hilly areas like Mizoram, it is safe to apply Hansen (1970) and Meyerhof (1957) methods for calculating the bearing capacity for the foundation located at the edge of the slope as the allowable bearing capacity is based on the soil properties and the slope geometry.
4. For conservative design, the method that provides the lowest bearing capacity for shallow foundations on slopes is taken into consideration.
5. A drawback of this study is that samples were only collected from each site at a depth of 1 m; if samples had been taken at varying depths, the effect of D/B of footing on the bearing capacity might have been assessed, giving accurate findings for designing the foundation.
6. As the load inclination factor not being included in Terzaghi's (1943) equations, it is not suitable for bases on sloped terrain or footings with moments and horizontal loads. However, bearing capacity can be quickly computed using Terzaghi's (1943) equation where $D/B \leq 1$. Nonetheless, Terzaghi's (1943) equations have been widely employed due to their simplicity.

However, the outcome will vary depending on the equations used by engineers in applying different equations for the same soil at the same depth. Therefore, to get accurate results, comparing the commuted values of bearing capacities is suggested using at least two methods. The third approach employing an arithmetic average value for the allowable bearing capacity of soil for foundation design, can get more accurate results if the first two methods do not give accurate results. The present paper will help future developers in determining the bearing capacity calculation for development in hill slopes.

DECLARATION STATEMENT

I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it has been conducted without any external sway.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is contributed solely.

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