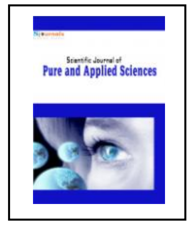
Sjournals
Scientific Journals
Scientific Journal of Pure and Applied Sciences (2013) 2(2) 72-78
ISSN 2322-2956

Contents lists available at Sjournals
Scientific Journal of
Pure and Applied Sciences
Journal homepage: www.Sjournals.com



Original article

Comparison of standard penetration test methods on bearing capacity of shallow foundations on sand

S.B. Akpila

Department of Civil Engineering, Rivers State University of Science and Technology, P.M.B 5080, Port Harcourt, Nigeria.

*Corresponding author; Department of Civil Engineering, Rivers State University of Science and Technology, P.M.B 5080, Port Harcourt, Nigeria.

A R T I C L E I N F O

Article history:
Received 12 February 2013
Accepted 20 February 2013
Available online 28 February 2013

Keywords:
Net allowable
Bound limits
Models
Stratification

A B S T R A C T

A comparison of standard penetration test methods on bearing capacity analysis of shallow foundations on sand using analytical methods proposed by Parry, Meyerhof and modified Meyerhof has been carried out. The results showed three bound limits; upper, middle and lower bonds of net allowable bearing capacity, $q_{n(a)}$, values for isolated pad foundations placed on sand. Perry's method gave higher values followed by the modified Meyerhof's method and lastly by the Meyerhof's method. Generally, $q_{n(a)}$ showed a decreasing trend as foundation breadth and depth increased. The $q_{n(a)}$ of modified Meyerhof's model can be approximated by applying a factor of safety, FS, of 3.25 on Perry's model. Similarly, $q_{n(a)}$ of Meyerhof's model can be approximated by applying a factor of safety, FS, of 2.0 on the modified Meyerhof's model.

1. Introduction

In foundation analysis and design, bearing capacity requirements is one of the two basic criteria to be satisfied. Bearing capacity requirement ensures that foundations do not undergo shear failure under loading, and three types of shear failures have been identified to occur under foundation induced loading; general shear failure, punching shear failure and local shear failure. Details of these failure mechanisms have been reported in literatures (Singh, 1992; Caquot, 1934; Terzaghi, 1943; De Beer and Vesic, 1958; Vesic, 1967). The use of correlations based on Standard Penetration Test, SPT, in evaluation of bearing capacity on sand is necessitated by the extreme difficulty of obtaining undisturbed samples for laboratory test in addition to the inherent heterogeneity of sand deposits. The use of SPT test in the analysis of bearing capacity has been reported in literatures (Craig, 1987; Bowles, 1977; Som and Das, 2006; Braja, 1999; Tomlinson, 2001). Details of the field application of Standard Penetration Test are specified in BS 1377.

This paper therefore attempts to present a comparative study on bearing capacity of shallow foundations on sand using methods of standard penetration tests.

2. Materials and methods

2.1. Bearing capacity analysis

A bearing capacity analysis for isolated pad foundation placed on sand was carried out on soil stratigraphy generally consisting of loose, silty to slightly silty SAND, overlying medium-dense, slightly silty SAND formation. In computing bearing capacity, an average SPT value of 4 which was obtained up to depth B below the footing; where B is breadth of foundation was used. Subsurface information was achieved through borings to 24 metres depth below ground level. The proposed isolated pad foundations were to be placed one metre below the sand formation which had been reclaimed with hydraulically dredge sand to meet desired grade level of existing flexible pavement located off the project site (Figure 1.0). Bearing capacity is analysed for foundation breadth B, varying from 1-1.6m and placed at foundation depths varying from 1.0-1.6m.

2.2. Analytical methods

The following in-situ SPT methods were adopted in evaluating bearing capacity of shallow foundations placed on sand;

2.2.1. Parry (1977) approximate method

The ultimate bearing capacity of shallow foundation placed on sand is given by the following expression;

$$q_u(MN/m^2) = 0.24N_f\left(\frac{D_f+0.13B}{D_f+0.75B}\right) \quad (1)$$

where N_f = SPT value from field at a depth of 0.75B below the proposed base of the foundation, D_f and B = depth and width of foundation in metres respectively.

It is emphasized that for $D_f/B < 1$, Equation (1) may be approximated as follows;

$$q_u(MN/m^2) = 0.24N_f \quad (2)$$

2.2.2. Meyerhof (1956) method

According to Meyerhof's theory, an estimated maximum foundation settlement of 25.4mm is allowed and the net allowable bearing capacity is given by the expression;

$$q_{n(a)(kN/m^2)} = 11.98N, \quad \text{for } B \leq 1.22\text{m} \quad (3)$$

$$q_{n(a)(kN/m^2)} = 7.99N\left(\frac{3.28B+1}{3.28B}\right)^2, \quad \text{for } B>1.22\text{m} \quad (4)$$

where N is corrected SPT value and $q_{n(a)}$ is the net allowable bearing capacity.

2.2.3. Modified meyerhof (1956) method

The modified Meyerhof (1956) correlation for bearing capacity using Standard Penetration Resistance is presented by Bowles (1997) for an allowable settlement of 25.4mm as follows;

$$q_{n(a)} = 19.16NF_d\left(\frac{s}{25.4}\right) \qquad for\ \ B \leq 1.2m \quad (5)$$

$$q_{n(a)} = 11.98N\left(\frac{3.28B+1}{3.28B}\right)^2 F_d\left(\frac{s}{25.4}\right) \quad for\ B > 1.2m \tag{6}$$

where

F_d = depth factor = 1+ 0.33 (D_f / B) ≤ 1.33 (7)

S = tolerable settlement

N = average penetration number

B = foundation breadth

D_f = foundation depth

3. Results and discussion

3.1. Soil stratification

This is obtained from boring records and laboratory tests. The soil profile generally consists of about 1m brown silty SAND with organic clay, underlain by loose, grey, silty to slightly silty SAND from 1- 12m depth. This formation is immediately underlain by medium - dense, grey to brown, slightly silty SAND up to 24m depth of exploration.

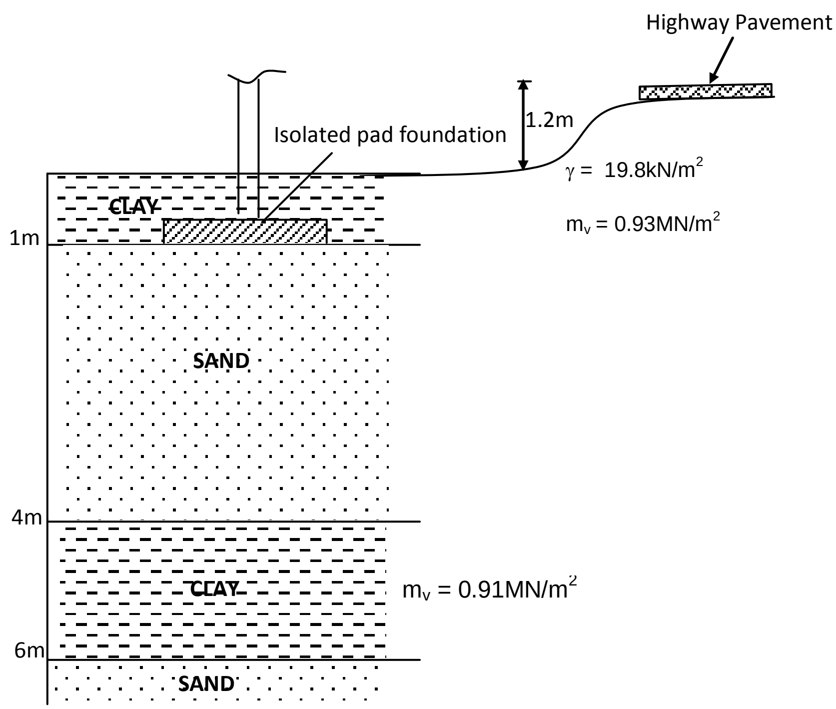


Fig. 1. Pad foundation placed on sand formation.

3.2. Bearing capacity based on SPT models

The results of net allowable bearing capacity, $q_{n(a)}$, of shallow foundations on sand based on Parry, Meyerhof and modified Meyerhof Standard penetration test models for foundation breadth, B, and D_f varying from 1.0 - 1.6m are depicted in Figures 2- 5. Generally, $q_{n(a)}$ showed a decreasing trend as foundation breadth and depth increased.

At D_f = 1.0m and foundation breadth, B, varying from 1.0 - 1.6m, the net allowable capacity $q_{n(a)}$ ranged from 47- 45kN/m^2 respectively for Meyerhof's model. The modified Meyerhof model had $q_{n(a)}$ values ranging from 102 - 81kN/m^2 for B ranging from 1.0 - 1.6m respectively. Similarly, Parry's model had $q_{n(a)}$ values ranging from 309 - 263kN/m^2 for same range of foundation breadth respectively. At D_f = 1.2, the $q_{n(a)}$ for Meyerhof model had same values ranging from 47- 45kN/m^2 but results of the modified Meyerhof model had $q_{n(a)}$ varying from 102 - 85kN/m^2 while Parry's model had $q_{n(a)}$ ranging from 327 - 281kN/m^2 for B varying from 1.0 - 1.6m respectively. As D_f increases, the same values of $q_{n(a)}$ for Meyerhof's model were obtained but modified Meyerhof model maintained $q_{n(a)}$ of 102kN/m^2 at B = 1.0m and a marginal increased in $q_{n(a)}$ value at B = 1.6m.

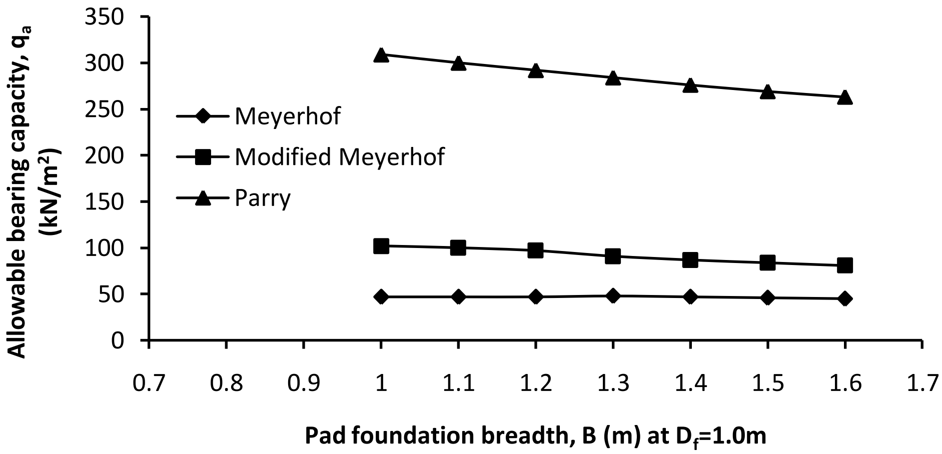


Fig. 2. Variation of Pad foundation breadth and allowable bearing capacity at D_f=1.0m.

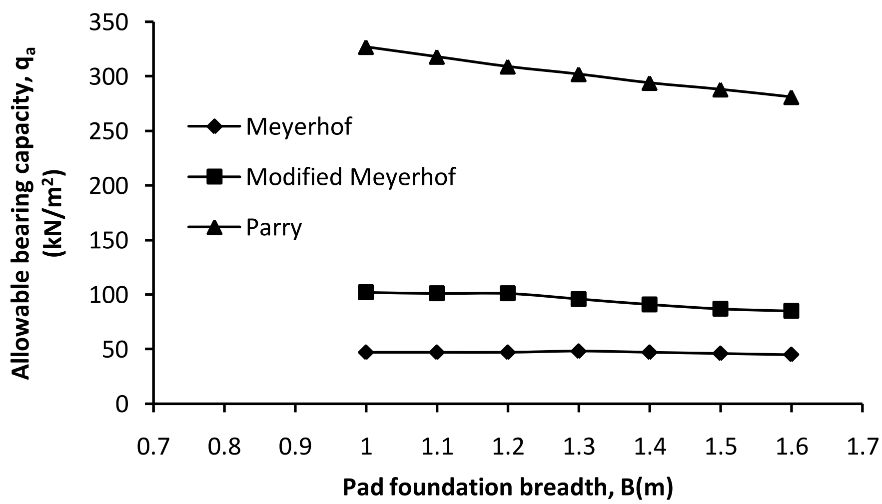


Fig. 3. Variation of Pad foundation breadth and allowable bearing capacity at D_f =1.2m.

In all cases of D_f and B, Perry's model had higher $q_{n(a)}$ compared to the Meyerhof's models and the $q_{n(a)}$ of modified Meyerhof's model can be approximated by applying a factor of safety, FS, of 3.25 on Parry's model. Similarly, $q_{n(a)}$ of Meyerhof's model can be approximated by applying a factor of safety, FS, of 2.0 on the modified Meyerhof's model. The generated $q_{n(a)}$ models for Parry, modified Meyerhof and Meyerhof SPT approaches of shallow foundations on sand for varying foundation depths and breadth are presented in Table 1.0.

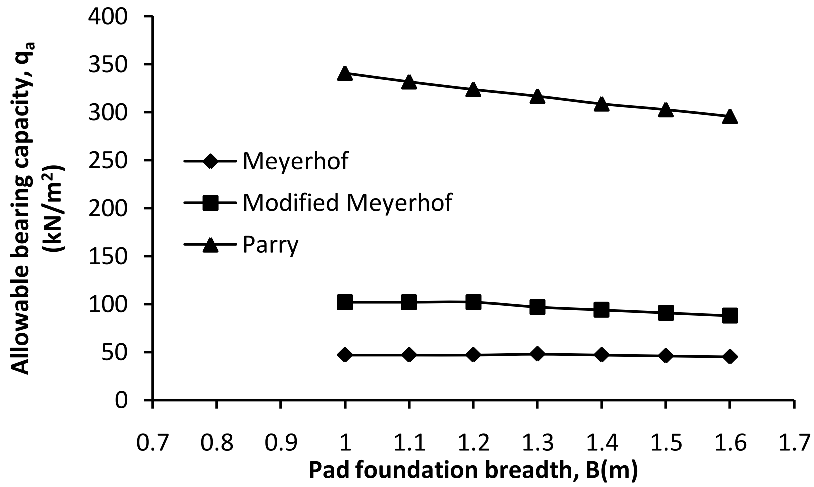


Fig. 4. Variation of Pad foundation breadth and allowable bearing capacity at D_f=1.4m.

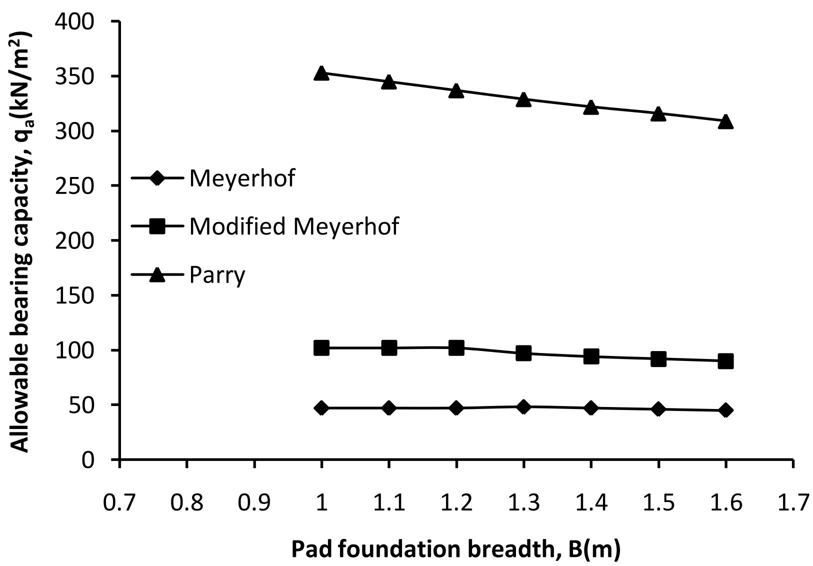


Fig. 5. Variation of Pad foundation breadth and allowable bearing capacity at D_f=1.6m.

3.3. Proposed model verification

The proposed modified net allowable bearing capacity models obtained from Parry, Meyerhof and Modified Meyerhof SPT models are presented in Table 1. Details of predicted and calculated net allowable bearing capacity are also presented. It is observed that both calculated and observed net allowable bearing capacities are reasonably reproducible.

4. Conclusion

Based on the results of $q_{n(a)}$, of shallow foundations on sand using Parry, Meyerhof and modified Meyerhof Standard penetration test models for foundation breadth, B, and D_f varying from 1.0 - 1.6m, the following conclusion can be drawn.

- Generally, $q_{n(a)}$ showed a decreasing trend as foundation breadth and D_f increased.
- In all cases of D_f and B, Parry's model had higher $q_{n(a)}$ compared to the Meyerhof's models
- The $q_{n(a)}$ of modified Meyerhof's model can be approximated by applying a factor of safety, FS, of 3.25 on Parry's model.
- Similarly, $q_{n(a)}$ of Meyerhof's model can be approximated by applying a factor of safety, FS, of 2.0 on the modified Meyerhof's model.
- The predictive SPT models for Parry, Meyerhof and modified Meyerhof can serve as preliminary tools in the choice of $q_{n(a)}$ of shallow foundations placed on sand.

Table 1
Proposed models.

(D_f/B) ratio	**Proposed Models**	**B =1.0m**		**B =1.2m**		**B =1.4m**	
		$q_{n(a)}$ Cal.	**$q_{n(a)}$ Pred.**	**$q_{n(a)}$ Cal.**	**$q_{n(a)}$ Pred.**	**$q_{n(a)}$ Cal.**	**$q_{n(a)}$ Pred.**
1.0	$q_{n(a)Parry}$ = -77.14B + 385	309	307	292	292	276	277
	$q_{n(a)Meyerhof}$ = -2.857B +50.42	48	47	48	47	47	46
	$q_{n(a)Modified\ Meyerhof}$ = -37.5B + 140.4	102	103	97	95	91	88
1.2	$q_{n(a)Parry}$ = -76.07B + 401.6	327	325	310	310	295	295
	$q_{n(a)Meyerhof}$ = -2.857B +50.42	48	47	48	47	47	49
	$q_{n(a)Modified\ Meyerhof}$ = -31.78B + 136.0	102	104	101	98	91	92
1.4	$q_{n(a)Parry}$ = -74.28B + 414	341	340	324	325	309	310
	$q_{n(a)Meyerhof}$ = -2.857B +50.42	48	48	48	47	47	46
	$q_{n(a)Modified\ Meyerhof}$ = -25.71B + 130	102	104	102	99	94	99
1.6	$q_{n(a)Parry}$ = -73.21B + 425.3	353	352	337	337	322	323
	$q_{n(a)Meyerhof}$ = -2.857B +50.42	48	48	48	47	47	46
	$q_{n(a)Modified\ Meyerhof}$ = -22.85B + 126.7	102	104	102	99	94	95

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