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EFFECT OF REINFORCEMENT ON BEARING CAPACITY OF FOUNDATIONS

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ABSTRACT

This work presents results of analytical method used in finding out the bearing capacity of reinforced and unreinforced sand at 20 different trial pits with a varying thickness. Microsoft office excel was used to do the calculations. The undisturbed soil shear strength parameters used makes it possible to find all the other required parameters of the soil. Prototype of the foundation considered is resting on the soil, and is of specified geometry. Geogrid is the material that was used to reinforce the soil, which an increase in the strength of the soil, where by the bearing capacity ratio (BCR) calculated is increasing with increase in the thickness of the geogrid material. 6 cases were considered at each of the 20 samples obtained from different trial pits, in which the cases are functions of the depth (thickness) of the geogrid at that point. Each point shows an increase in the bearing capacity when reinforced than unreinforced, and it continues to increase as the thickness is increasing. The graphs of BCR against thickness of reinforcement plotted for each trial pit, shows the nature of increment in the bearing capacity as the thickness of geogrid is increased. Almost all the graphs show a similar increment nature, which verify that at any point the reinforcement presence add strength to a soil and it increases as the thickness is increase.

Keywords: Foundation, Bearing Capacity, Shear Strength, Geosybthetics.

I. INTRODUCTION

The scarcity of proper construction sites in many places in the world lead to the use of available ones, where the bearing capacities of the underlying soil is low. In the absence of good material different techniques are involved, depending on technical and economic factors, this involve the use of soil stabilization or replacement, soil reinforcing and so on. Use of geosynthetics as reinforcement for improving the performance of shallow foundations has been proposed by engineers over time. In the cases of poor to marginal ground conditions, geosynthetic reinforcement was proved to be a cost-effective solution and in some cases open up the possibility of constructing shallow foundations in lieu of deep foundations. Among the range of geosynthetics available (geocell, geotextile, geonet, and geogrid), geogrids are the most preferred type of geosynthetic materials for reinforcing the foundation beds, Latha and Somwanshi, (2008).

The load supporting power of ground is termed its bearing capacity. This power of a soil gives safety against shear failure or rapture of soil. The term 'ultimate bearing capacity' is the load intensity (gross bearing capacity) at which the soil fails in shear, q_f or q_u, (Abdulfatah, 2011).

Lack of proper soil investigation is one of the major problems that lead to failures of many buildings, and bearing capacity of a soil is one of the basic information required for almost all civil engineering constructions. Stresses transmitted by a foundation to underlying soils must not cause bearing-capacity failure or excessive foundation settlement, (AFM 88-3, 1983).

The primary objective of this study is to compare the relative performance in improving the bearing capacity of foundation with and without geogrid at different depth. This is achieved through the use of results from laboratory tests of shear strength parameters of 20 trial pits, given property of a geogrid material, given geometry of foundation prototype and using the data to;

- **i.** Obtain the bearing capacity of the soil base on reinforce and unreinforced method analytically base on strip foundation, and
- **ii.** Vary the values of *d* (depth of reinforcement), and analyse the effect.
- **iii.** Compare the bearing capacity of reinforced and unreinforced sand at different depths.

II. MATERIALS AND METHODS

2.1 Materials Used for the Analysis

In this research, two basic materials that were considered are soil and geosynthetic material. In which the bearing capacity of the soil alone is obtain, and then it's reinforced at different thicknesses and the effect is obtain and compared. The materials used are described below base on technical requirements.

2.1.1 Soils

The materials were obtained from an undisturbed sample gotten at one meter at strategic places within Kano University of Science and Technology, Wudil. Kano state experiences a semi-arid or tropical continental type of climate with distinct seasonal regimes, oscillating between cool to hot dry and humid to wet.

A.Aysen (2002) states that; 'the shear strength along any plane is mobilized by cohesion and angle of internal friction, collectively referred to as shear strength parameters'. The direct shear test conducted give all the required results needed to obtain the required soil parameters, which are C and ϕ, and they were used to calculate the needed parameters for soil bearing capacitiy, as shown in table 2.1.1.1, obtain by Ibrahim (2011). Bearing capacity factors were obtained from Terzhaghi bearing capacity coefficients.

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Table 2.1.1.1: Required Soil Properties

Trial pit no.	Cohession, C(KN/m^2)	Angle of internal friction, ϕ(º)	Bearing capacity factors that depend on ϕ			Unit weight of soil, ɤ (kN/m³)
			N_c	N_q	N_γ	
1	15	27	29.24	15.9	11.6	19.23
2	13	35	57.75	41.44	45.41	18.35
3	10	34	52.64	36.5	38.04	18.56
4	5	33	48.09	32.23	31.94	19.66
5	4	34	52.64	36.5	38.04	17.84
6	0	29	34.24	19.98	16.18	49.61
7	26	27	29.2	15.9	1106	20.67
8	0	31	40.41	25.28	22.65	16.12
9	0	23	21.75	10.23	6	19.93
10	0.5	33	48.09	32.23	31.94	18.47
11	15	34	52.64	36.5	35.04	19.69
12	0.5	30	37.16	22.46	19.13	17.9
13	13	33	48.09	32.23	31.94	18.24
14	0	31	40.41	25.28	22.85	18.41
15	0	24	23.36	11.4	7.08	19.72
16	0	9	9.09	2.44	0.44	20.08
17	16	31	40.41	25.28	22.65	18.15
18	0	30	37.16	22.46	19.13	17.2
19	8	25	14.8	5.6	2.25	15.46
20	10	30	37.16	22.46	19.13	15.78

2.1.2 Geosynthetics

The common geosynthetics materials available in market are geocell, geotextile, geonet, and geogrid. In this paper, geogrids are considered which according G. Madhavi Latha and Amit Somwanshi, 2008 are the most preferred type of geosynthetic materials for reinforcing the foundation beds.

The geogrid was taken to be of 0.02m width of longitudinal ribs, and 0.27m center-to-centre spacing of the longitudinal ribs. The properties of the geogrid are shown in table 2.1.2 as given by C.R. Patra et al, 2004.

Table 2.1.2: physical properties of the geogrid

Peak tensile strength	60kN/m
Tensile strength at 2.0%s strain	14kN/m
Tensile strength at 5.0% strain	30kN/m
Strain at break	8%
Aperture size	94mm x 42mm

2.2 Geometric Parameters

Fig. 2.2 shows a strip foundation (width B) being supported by sand, which is reinforced with N number of geogrid layers. The vertical spacing between consecutive geogrid layers is h. The top layer of geogrid is located at a depth u measured from the bottom of the foundation. The width of the geogrid reinforcements under the foundation is b. The depth of reinforcement, d, below the bottom of the foundation is given as;

$$d = u + (N - 1)h, \quad (1)$$

The beneficial effect of reinforcement for increasing the bearing capacity has been generally expressed in the past in terms of a no dimensional quantity called the bearing capacity ratio (BCR) given by;

$$BCR = \frac{q_{u(R)}}{q_u}, \quad (2)$$

Where; $q_{u(R)}$ and q_u is the ultimate bearing capacities on reinforced and unreinforced sand, respectively.

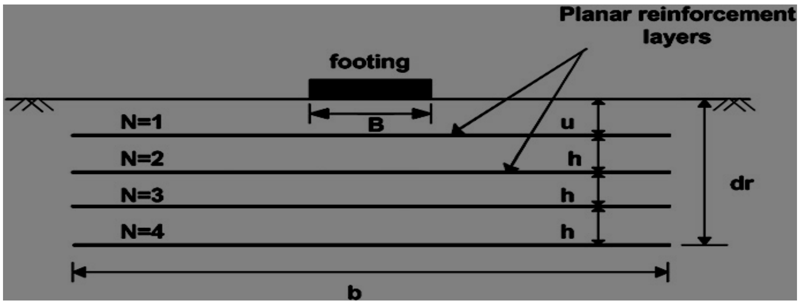

Fig 2.3: Layout and Configuration of Geogrid-Reinforcement in Sand, Under Shallow Strip Foundation on Sand.

2.3 Bearing Capacity Calculations

So many works has been done on bearing capacity of a soil, and many analytical formulae were suggested. Some of the researches include that of Skepton's 1951, Meyerhof 1951 and 1963, Hansen 1957 and 1970, Vesic 1973, and others, as mention by Ranjan and Rao, (2000).

For the course of this paper the formula used are stated below:

Tests for surface foundation on reinforced sand

$$q_u = \frac{1}{2}\gamma BN_\gamma F_{\gamma d} + qN_q F_{qd}, \quad (3)$$

Where; q_u is the bearing capacity of the soil,

$$q = \gamma d_f, \quad (4)$$

N_q and N_γ the bearing capacity factors, $F_{\gamma d}$ and F_{qd} are depth factors.

$$F_{qd} = 1 + 2\tan\emptyset(1 + \sin\theta)^2 \frac{d_f}{B}, \quad (5)$$

$$F_{\gamma d} = 1, \quad (6)$$

Where; d_f is depth of the foundation, and B is width of the foundation.

Tests for foundation on reinforced sand

It was taken to be a surface foundation supported by multi-layered geogrid reinforcement. The ultimate loads, $q_{u(R)}$ were obtained using Huang and Menq (1997) tentative relationship, given as

$$q_{u(R)} = 0.5(B + \Delta B)\gamma N_\gamma + \gamma d N_q, \quad (7)$$

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Where; $\Delta B = 2d\tan\beta$, (8)

$$\tan\beta = 0.68 - 2.071\left(\frac{h}{B}\right) + 0.743(CR) + 0.03\left(\frac{b}{B}\right), \quad (9)$$

Where; CR is the cover ratio = w/W (10)

Where; w is the width of longitudinal ribs, and W the canter-to-canter spacing of the longitudinal ribs.

III. RESULTS AND DISCUSSIONS

For any foundation to be stable, the soil beneath it should have the supporting power to convey and transmit all the loads. Design of foundation consists of two different parts: one is the ultimate bearing capacity of soil below the foundation and second is the acceptable settlement that a footing can undergo without any adverse effect on the superstructure, Alam, (2014). Use of geogrid has been proved in this work to increase the bearing capacity of the soil, which is also economical.

Table 4.0 shows the bearing capacity of unreinforced, reinforced soil, and bearing capacity ratio (*BCR*). Increase in the thickness of the geosynthetic material (*d*) also shows a linear proportionality with the soil bearing capacity at 20 different locations; this was seen as the *BCR* increase with *d*. The 6 cases considered base on the reinforcement thicknesses taken at *d* = 0, 0.6, 0.85, 1.1, and 1.35m respectively.

To get the relationships at all the positions, 20 graphs were plotted for each trial sample (figure 4.01 to figure 4.20). The graphs were plotted of d against BCR which almost all shows linear increment, this is saying that when the thickness increases, the bearing capacity is increasing as the BCR is increasing.

Table 4.0: Bearing capacity of unreinforced and reinforced soil, and bearing capacity ratio (*BCR)* at different thickness of geogrid (*d*).

Trial pit no.	q_u (kN/m)	$q_{u(R)}$(kN/m)						BCR					
		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
		d=0.1 m	d=0.35 m	d=0.6 m	d=0.85 m	d=1.1 m	d=1.35 m	d=0.1 m	d=0.35 m	d=0.6 m	d=0.85m	d=1.1 m	d=1.35 m
1	445	507	614	691	767	844	920	1.14	1.38	1.55	1.72	1.90	2.07
2	1235	1513	1780	1970	2160	2350	2540	1.23	1.44	1.59	1.75	1.90	2.06
3	1084	1315	1553	1722	1891	2061	2230	1.21	1.43	1.59	1.75	1.90	2.06
4	999	1201	1423	1581	1740	1898	2057	1.20	1.42	1.58	1.74	1.90	2.06
5	1042	1264	1492	1655	1818	1981	2144	1.21	1.43	1.59	1.75	1.90	2.06
6	1480	1717	2064	2311	2559	2807	3055	1.16	1.39	1.56	1.73	1.90	2.06
7	473	535	650	732	815	897	979	1.13	1.38	1.55	1.72	1.90	2.07
8	625	737	880	982	1084	1186	1288	1.18	1.41	1.57	1.74	1.90	2.06
9	584	684	819	915	1012	1109	1205	1.17	1.40	1.57	1.73	1.90	2.06
10	938	1128	1337	1486	1634	1783	1932	1.20	1.42	1.58	1.74	1.90	2.06
11	1120	1342	1594	1773	1953	2133	2312	1.20	1.42	1.58	1.74	1.90	2.06
12	608	711	852	953	1053	1154	1254	1.17	1.40	1.57	1.73	1.90	2.06
13	927	1114	1320	1467	1614	1761	1908	1.20	1.42	1.58	1.74	1.90	2.06
14	715	846	1008	1125	1241	1358	1474	1.18	1.41	1.57	1.74	1.90	2.06
15	316	351	430	486	542	598	654	1.11	1.36	1.54	1.72	1.89	2.07
16	57	57	74	86	99	111	123	1.00	1.31	1.52	1.74	1.95	2.17
17	703	830	991	1106	1220	1335	1450	1.18	1.41	1.57	1.74	1.90	2.06
18	584	684	819	915	1012	1109	1205	1.17	1.40	1.57	1.73	1.90	2.06
19	112	118	148	170	192	213	235	1.05	1.32	1.52	1.71	1.90	2.10
20	536	627	751	840	929	1017	1106	1.17	1.40	1.57	1.73	1.90	2.06

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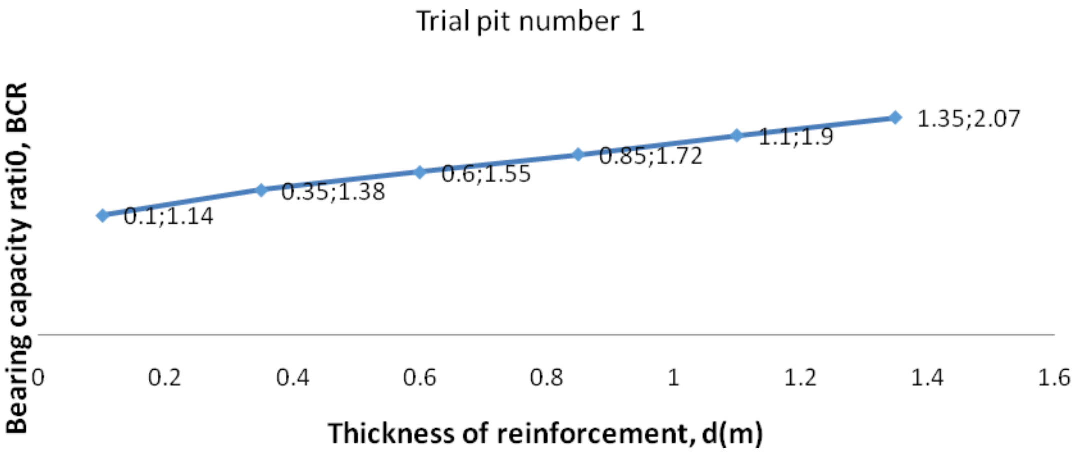

Figure 4.01: Relationship between bearing capacity and thickness of geogrid material on a soil.

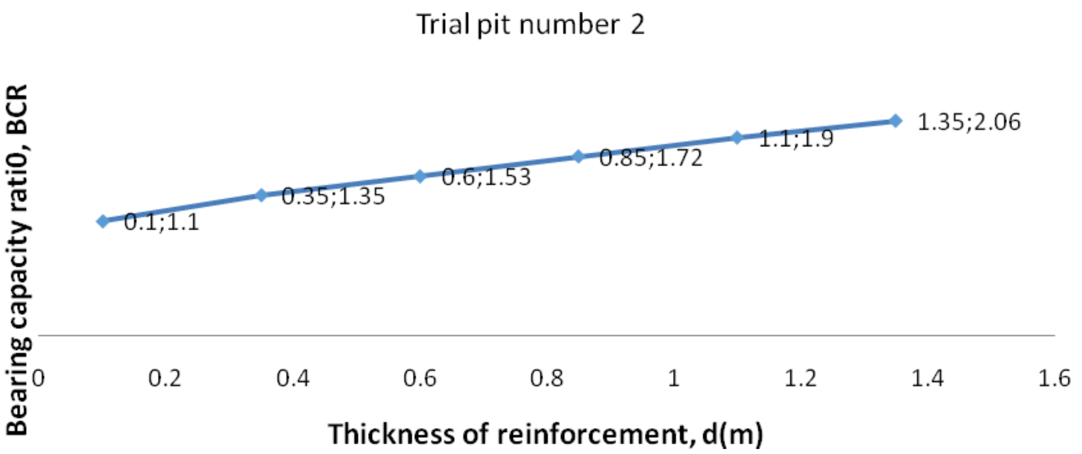

Figure 4.02: Relationship between bearing capacity and thickness of geogrid material on a soil.

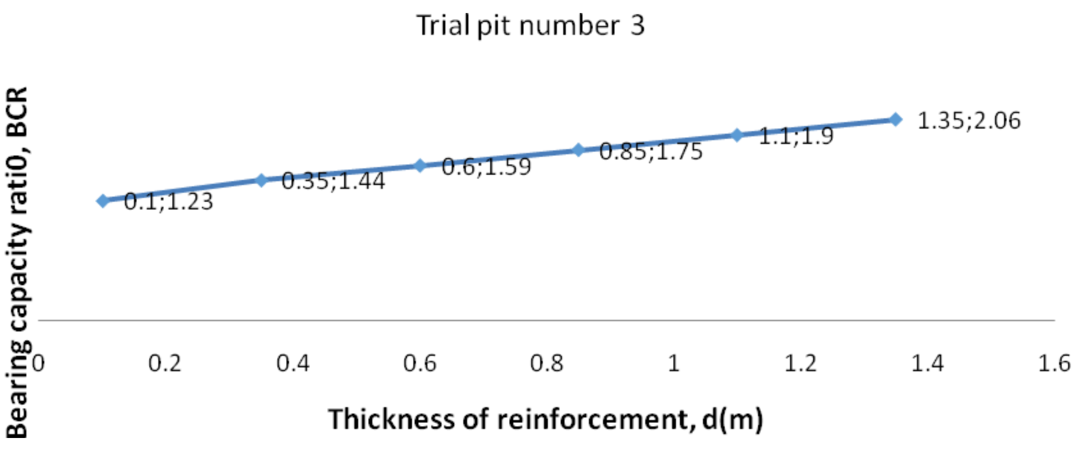

Figure 4.03: Relationship between bearing capacity and thickness of geogrid material on a soil.

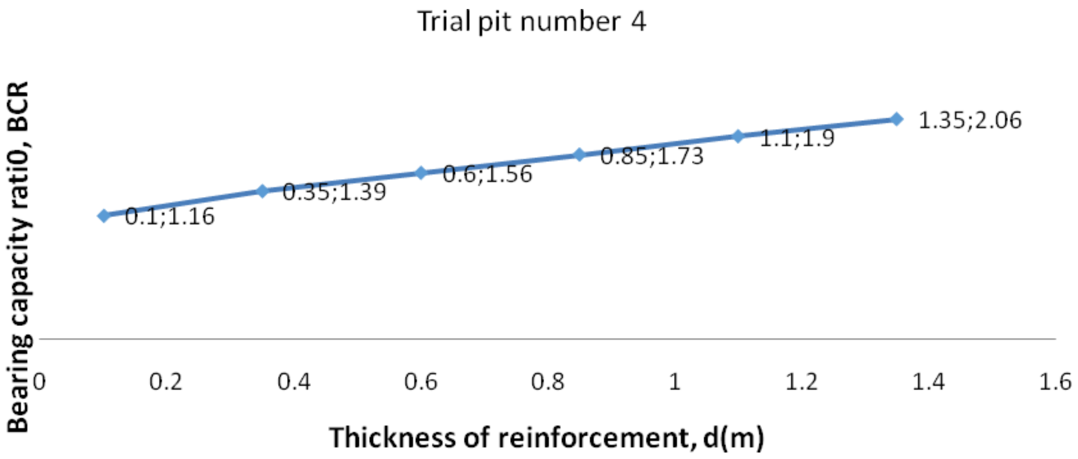

Figure 4.04: Relationship between bearing capacity and thickness of geogrid material on a soil.

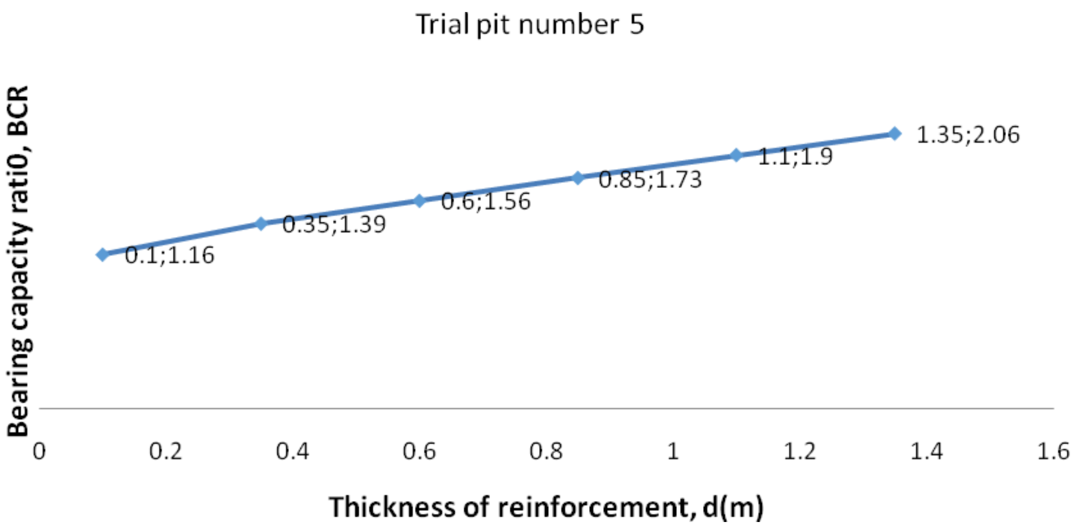

Figure 4.05: Relationship between bearing capacity and thickness of geogrid material on a soil.

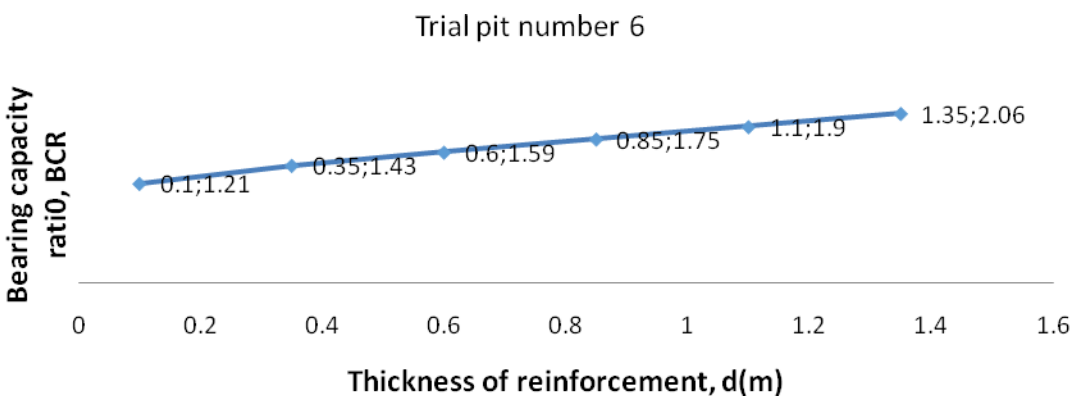

Figure 4.06: Relationship between bearing capacity and thickness of geogrid material on a soil.

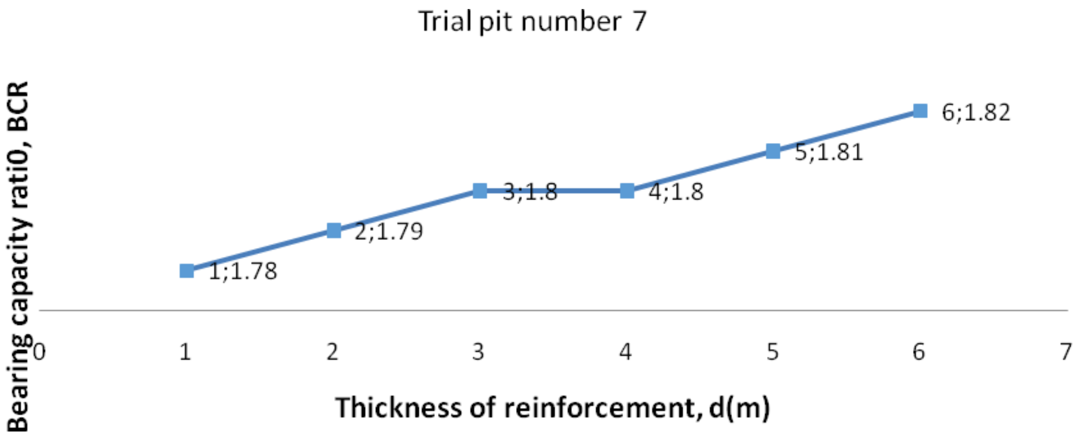

Figure 4.07: Relationship between bearing capacity and thickness of geogrid material on a soil.

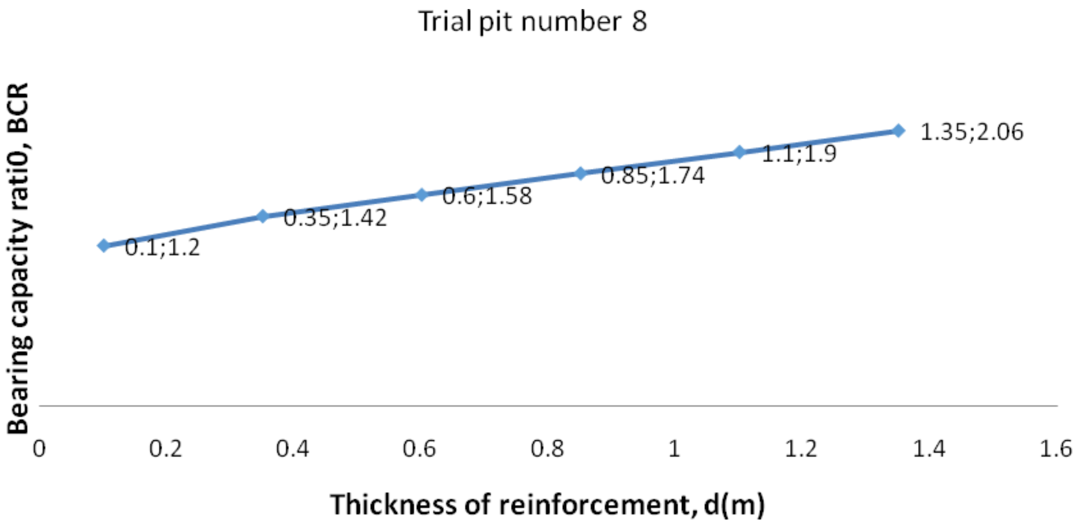

Figure 4.08: Relationship between bearing capacity and thickness of geogrid material on a soil.

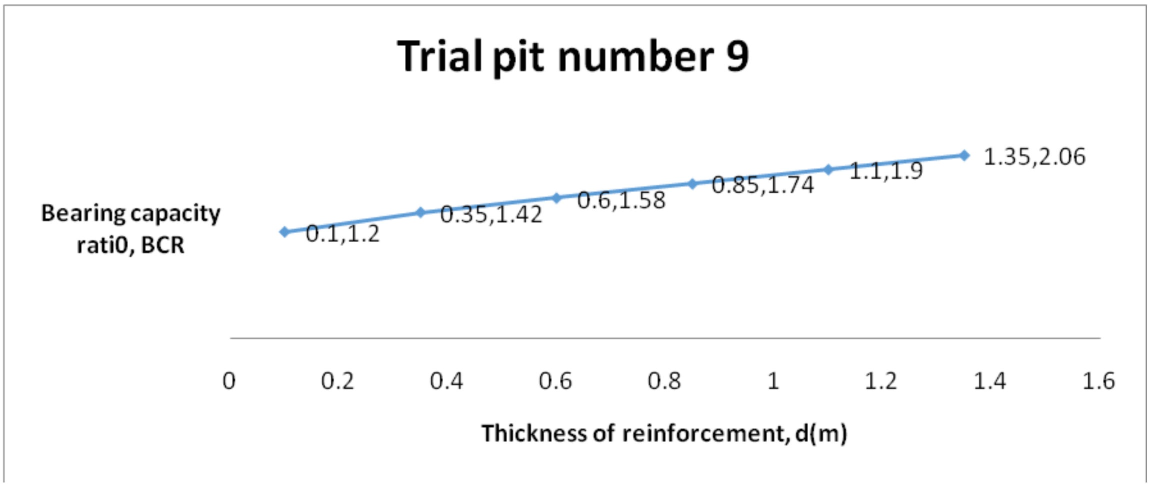

Figure 4.09: Relationship between bearing capacity and thickness of geogrid material on a soil.

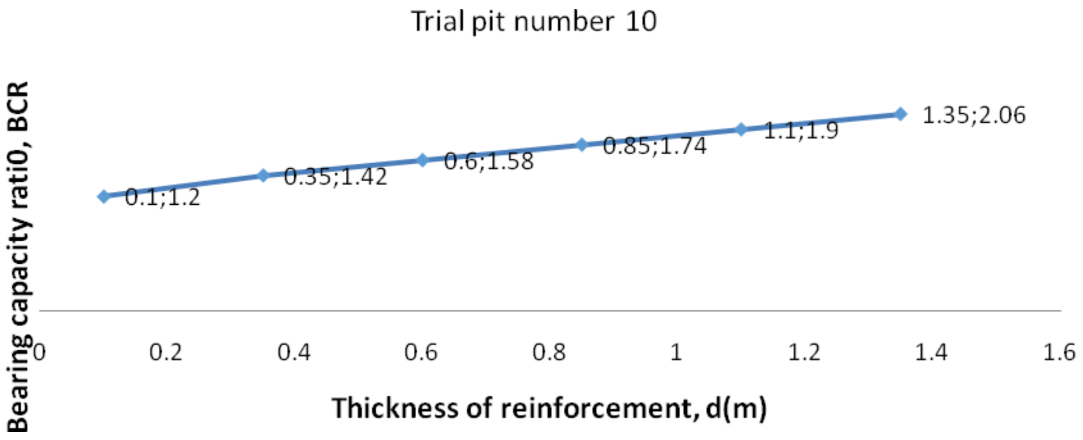

Figure 4.10: Relationship between bearing capacity and thickness of geogrid material on a soil.

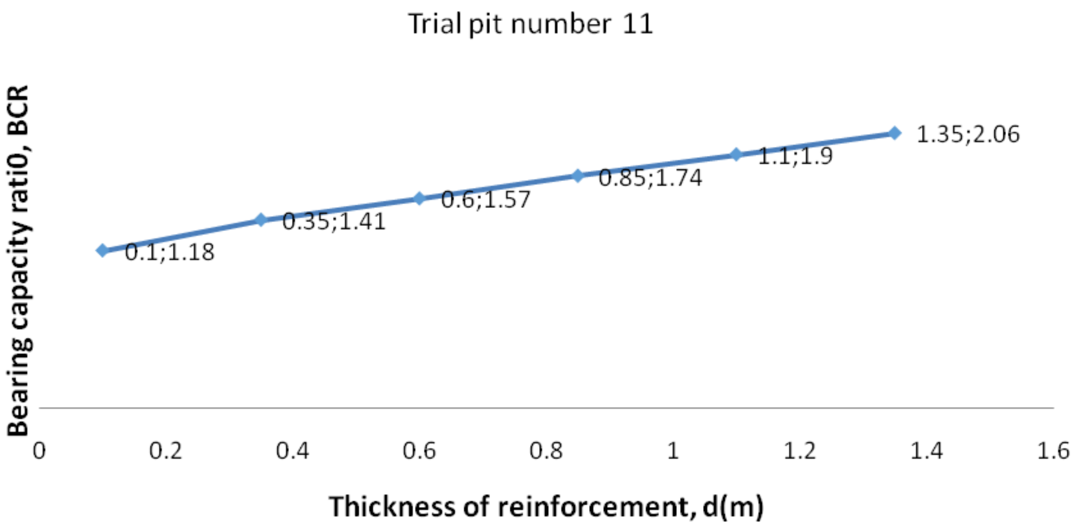

Figure 4.11: Relationship between bearing capacity and thickness of geogrid material on a soil.

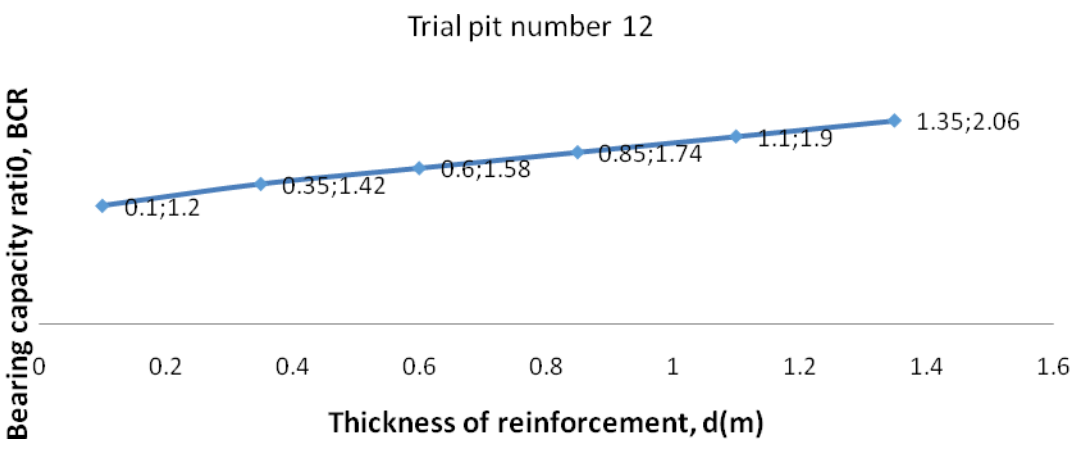

Figure 4.12: Relationship between bearing capacity and thickness of geogrid material on a soil.

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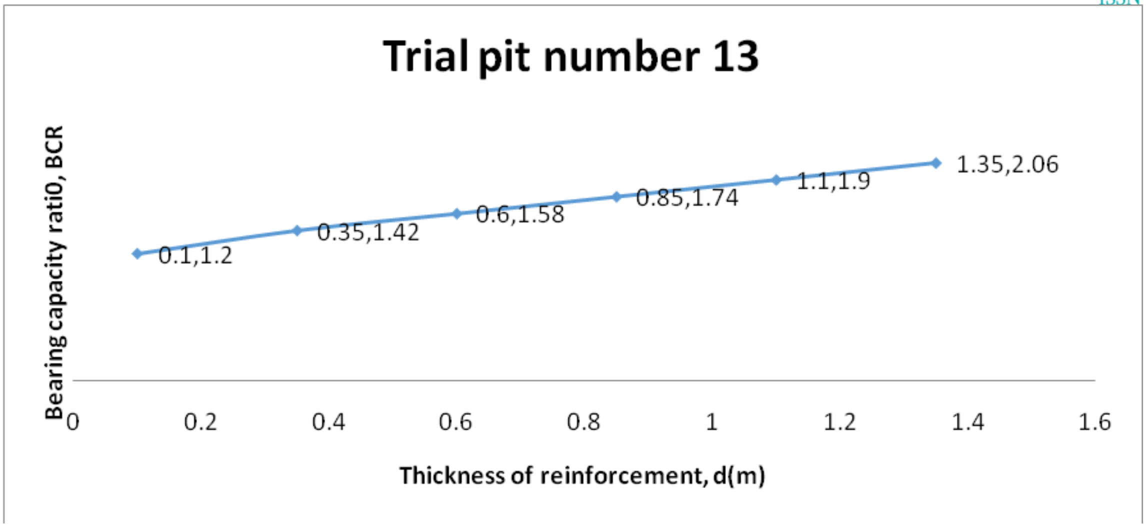

Figure 4.13: Relationship between bearing capacity and thickness of geogrid material on a soil.

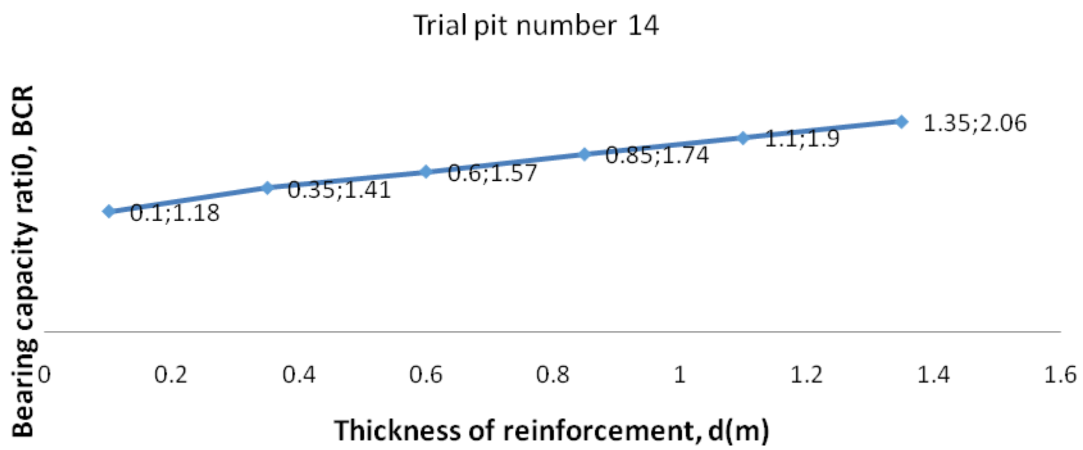

Figure 4.14: Relationship between bearing capacity and thickness of geogrid material on a soil.

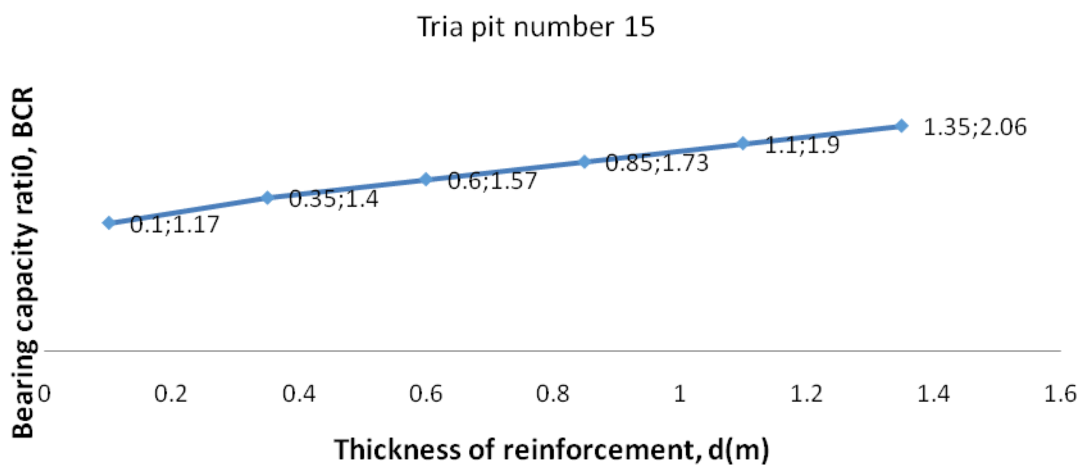

Figure 4.15: Relationship between bearing capacity and thickness of geogrid material on a soil.

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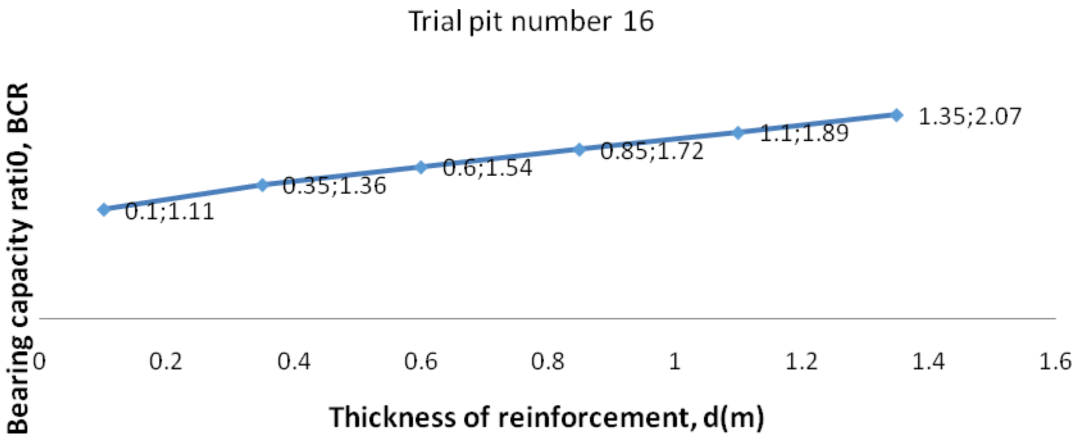

Figure 4.16: Relationship between bearing capacity and thickness of geogrid material on a soil.

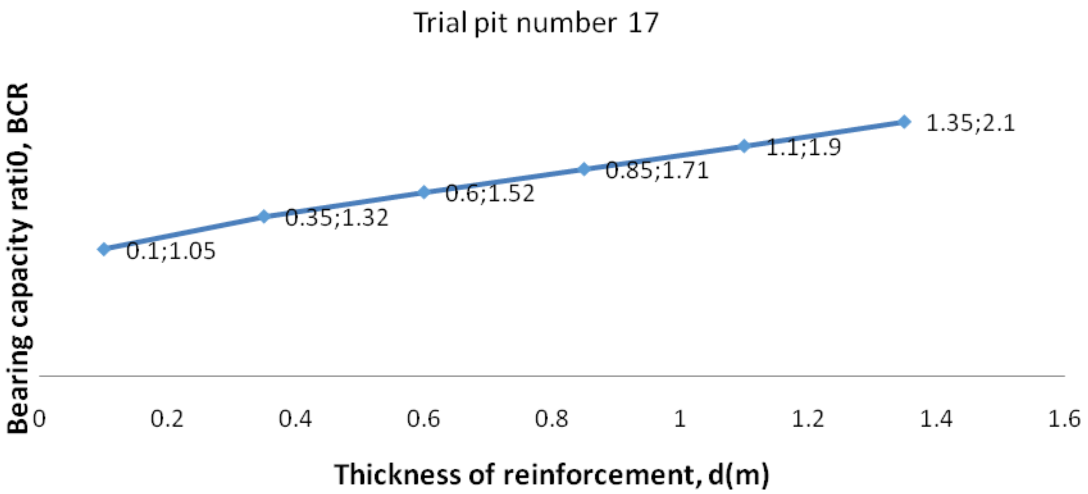

Figure 4.17: Relationship between bearing capacity and thickness of geogrid material on a soil.

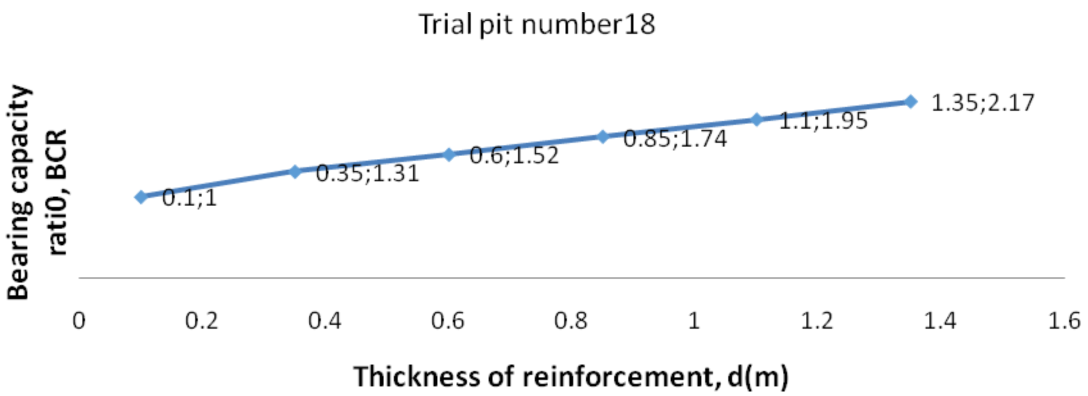

Figure 4.18: Relationship between bearing capacity and thickness of geogrid material on a soil.

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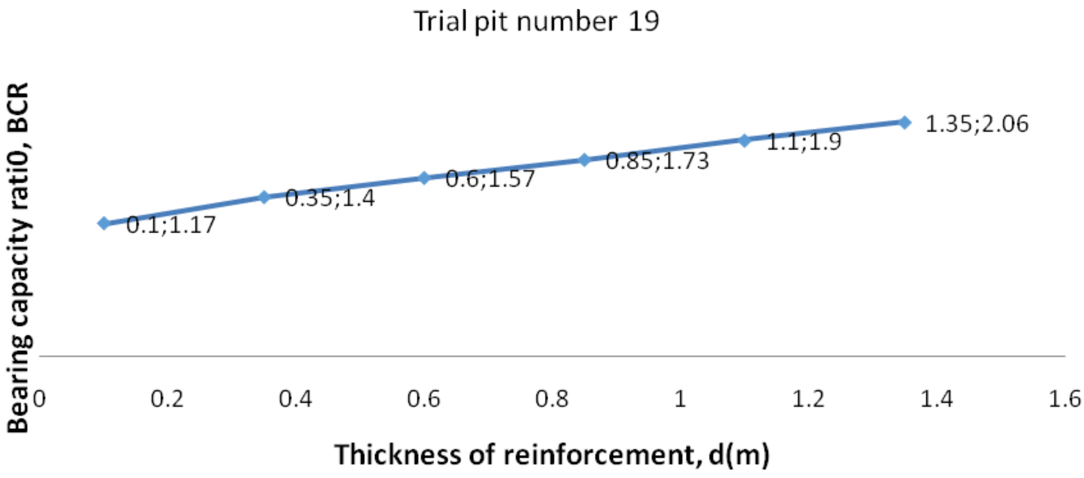

Figure 4.19: Relationship between bearing capacity and thickness of geogrid material on a soil.

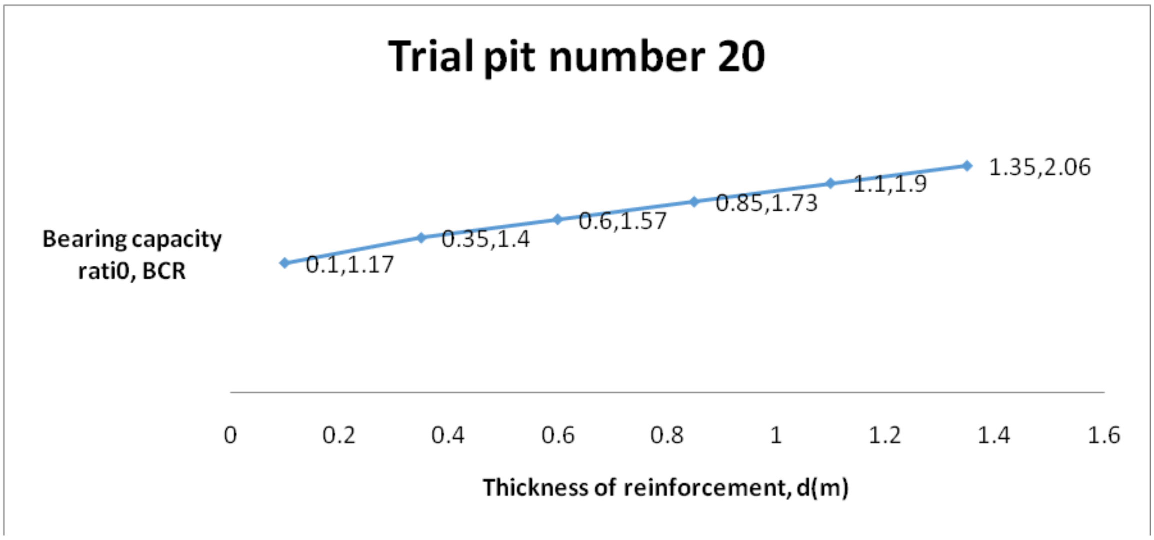

Figure 4.20: Relationship between bearing capacity and thickness of geogrid material on a soil.

IV. CONCLUSION AND RECOMENDATIONS

4.1 Conclusion

In this paper, analytical method was used to determine the bearing capacity ofunreinforced and reinforced sand at different thickness of the reinforcement (geogrid). Bearing capacity ratio (BCR) was obtained for each of the 20 samples of soils obtained from different trial pits each. Graphs were plotted so as to see the nature of the increments in the bearing capacity of all the soil samples as the thickness of the reinforcement increases. Within the limits of this research work, the following conclusions can be made:

- The BCR calculated show how geogrid material add strength to soil.
- Graphs of BCR against *d*, shows the nature of increment of bearing capacity of a soil as the reinforcement thickness is increase.
- Percentage increase of the bearing capacity at *d* = 0, 0.6, 0.85,1.1, and 1.35 m, gives averagely 16, 40, 57, 73, 90, and 107 % respectively.

4.2 Recommendation

Investigations of this type are highly recommended for any places that have a bad soil, before designing and suggesting the type of foundation to use.This can as well make construction economical and faster.

It's also recommended that this research should be expanded and that a generalize ratio should be made for any thickness of geogrid material at a given depth and width.

Further research should also consider Biological and Environmental effect on the reinforcement material.

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