A STUDY ON BEHAVIOUR OF CENTRALLY LOADED SHALLOW FOUNDATION ON SAND BED REINFORCED WITH GEOGRID, FAILURE AND IMPROVEMENT: A LITERATURE REVIEW

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Abstract- The study pertains to the investigation of the effect of embedment on the load carrying capacity and settlement of strip foundations on sand reinforced with geogrids. Geogrid being an inextensible reinforcing material is widely used all over the world mainly for retaining walls, abutments slope protection and below the foundation in poor soil. Some research works have been done the investigators regarding the optimum placement of geogrids below surface footing however, the work on centrally loaded embedded foundations reinforced with multilayer of geogrids have not been reported in literature. Therefore in this paper attention is being paid to the load carrying capacity and settlement behavior of centrally loaded embedded footing reinforced with multilayer of gerogrids. Strip foundations are considered and loads applied have been used at the reinforced material and sand as the medium. The studies show

1. In centrally loaded surface footing the load carrying capacity is increased to about 3.55 times by providing geogrid as reinforcement. The load carrying capacity the reinforced soil increases with increase in the depth of embedment while these decrease in settlement because of placement of geogrid.

2. The number of layers of geogrid has significant effect on load carrying capacity and settlement of foundations. Decrease in the layer of geogrid decreases the load carrying capacity and increases the settlement of foundation.

Keywords-Geogrid, Foundation, Reinforcement, Bearing capacity.

I.INTRODUCTION

The reinforced soil is the soil in which the metallic, synthetic or geogrids are provided to improve it's engineering behavior. The technique of ground improvement by providing reinforcement was also in practice in olden days. Babylonians built ziggurats more than three thousand years ago using the principle of soil reinforcement. A part of the Great Wall of China is also an example of reinforced soil construction. Dutch & Romans had used soil reinforcing technique to reinforce willow animal hides & dikes. Basic principles underlying reinforced soil construction was not completely investigated till Henery Vidal of France who demonstrated it's wide application & developed the rational design procedure. A further modified version of soil reinforcement was conceived by Lee who suggested a set of design parameters for soil reinforced structures in 1973.

Rising land costs & decreasing availability of areas for urban infill has established that previously undeveloped areas are now being considered for the sitting of new facilities. However these undeveloped areas often possess weak underlying foundation material a situation that presents interesting design challenges for Geo technical engineers. To avoid the high cost of deep foundation modification of the foundation soil or the addition of a structure fill is essential.

Binquet & Lee (1975) investigated the mechanism of using reinforced earth slab to improve the bearing capacity of granular soils. They tested model strip

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footings on sand foundations reinforced with wide strips cut from household aluminum foil. An analytical method for estimating the increased bearing capacity based on the tests was also presented. Fragaszy & Lawton also used aluminum reinforcing strips & model strip foundations to study the effects of density of sand & length of reinforcing strips on bearing capacity.

In this paper a brief review of the available literature regarding the mode of the failure of soil mass various theories with equations to find out the ultimate bearing capacity, types of reinforcing materials used in soil and the behavior of reinforced soil is presented.

Many theories are available for the determination of ultimate bearing capacity of footing for various load conditions and for various types of soils. However, few research publications are available indicating the method of determining the load carrying capacity of foundations in reinforced cohesion less soil.

II- MODES OF FUNDATION FAILURE AND IMPROVEMENT

A foundation is that part of the structure, which is in direct contact with, and transmitting loads to the ground provides support to the structure. Safe bearing capacity is defined as the maximum pressure, which the soil can carry safely without the risk of shear failure. Shear failure may result from foundation failure as well as from excessive settlement. The ultimate bearing capacity is the minimum gross pressure intensity at the base of the foundation at which the soil fails in shear. Before the application of load, the soil below the base of the footing is in elastics equilibrium, when load is applied settlement occurs & the soil passes from elastic to plastic equilibrium with failure.
The three principle modes of shear failure in soil are shown in fig.1.
(i) General shear Failure
(ii) Local shear Failure
(iii) Punching shear Failure

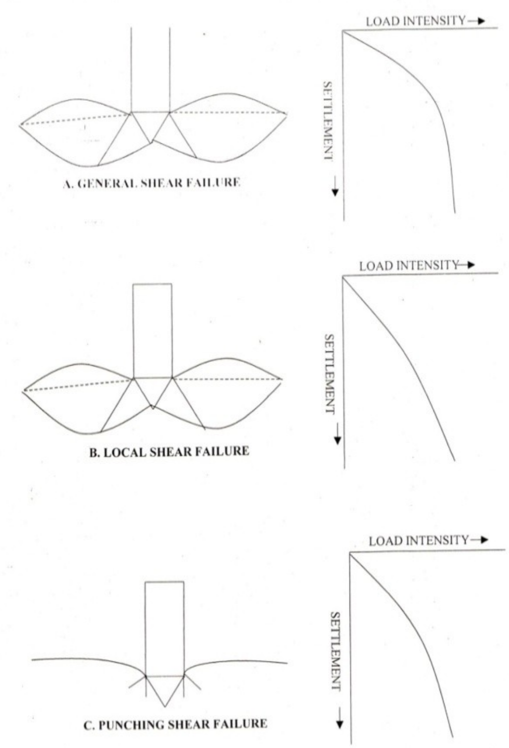

Fig.1 Modes of shear failure

In general shear failure the soil properties are assumed to be such that a slight downward movement of the footing develops fully plastic zones and the soil bulges out. It occurs in relatively incompressible soil. Here it is found that the failure is sudden and castrophic. Dense sand having R.D. greater than 70% fails under general shear failure.

In case of local shear failure large deformations may occur below the footing before the failure zones are fully developed, and is associated with considerable vertical soil movement before soil bulging takes place. This type of failure may take place in fairly soft or loose and compressible soil. Loose sand having R.D. between 50-70% fails under local shear failure.

In case of punching shear failure no lateral movement takes place. When the load is increased, vertical movement of the footing takes place and the soil surrounding the footing remains relatively in original position i.e. it does not take part in failure. Hence there will be no tilting of footing and no bulging of surface soil. This type of failure is expected in loose sand having greater compressibility and R.D. less than 35%.

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2. 1 Bearing capacity equations

A number of equations based on theoretical analysis and experimental investigations are available to determine the ultimate bearing capacity of a soil. The concept of general shear failure was first given by Prandtl and then this theory was further extended by Terzaghi.

Prandtl showed that the Ultimate Bearing Capacity is given by

$$q_u=C/\tan\Phi[1+\sin\Phi)/1-\sin\Phi)\varepsilon^{n\tan\Phi}-1] \quad (1)$$

When C = **0,** q_u = **0** which is not practically possible.

Terzaghi presented the following equation for Ultimate Bearing Capacity for general shear failure condition

$$q_u=CN_c+\gamma DNq+0.5\gamma BN\gamma \quad (2)$$

The above equation is valid for continuous footing.

For square and circular footings

$$(q_u)square=1.3CNc+\gamma DN_q+0.4\gamma BN\gamma \quad (3)$$

$$(q_u)circular=1.3CN_c+\gamma DN_q+0.3\gamma BN\gamma \quad (4)$$

Where N_c, N_q, $N\gamma$, are the bearing capacity factor.

For local shear failure Terzaghi recommended a reduction in the values of C and tanΦ by two - third of the values taken for general shear failure.

2.2 Ground improvement

The bearing capacity of soil depends upon the property and type of soil. In case of heavy and important structure it is essential to increase the bearing capacity of soil by adopting suitable techniques for the enhancement of load carrying capacity of soil which is known as ground improvement. Depending upon the type of soil, nature of improvement required availability of materials and economy various types of ground improvement have been developed. Main purposes of ground improvement are
(i) To reduce the settlement.
(ii) To increase the bearing capacity.

2.2.1Techniues of ground improvement

A traditional method of soil improvement for road and building foundations in soft soil consists of providing a stiffer load bearing base over the soft sub grade. Ground improvement can also be done either with the help of admixture or without admixture. Ground improvement by stabilization is a good example of improvement without admixture.

Compaction of soil also represents an effective ground improvement technique. Compaction increases the shear strength, of soil and hence stability and bearing capacity. It also reduces the compressibility and permeability if soil.
Consolidation also proves to be an effective ground improvement technique. The phenomena of gradual compression or reduction in volume resulting from a long term static load and consequent escape of water are known as consolidation.

Soil stabilization also represents an effective ground improvement technique, which makes the soil more stable. It is widely used for various types of engineering works, the most common application being in the construction of road, the main objective being to increase the stability of soil and to reduce the construction cost by using locally available materials.

2.2.2 Ground improvement by providing reinforcement in soil

The bearing capacity of soil can be enhanced by providing different types of reinforcements such as nets, synthetic, geogrids, polymer mashes, metal strips and etc.The provision of geo reinforcement imports anisotropic mechanical properties, increased stiffness, tensile strengths, increased bearing capacity. It also reduces the substantial base thickness and improves the performance of foundation.

The interaction between geogrid and soil is complex phenomena, Jewelle et al (1985) identified three main mechanisms of interaction between the soil and geogrid which are as follows:-
(i) Soil shearing on plane surfaces of the geogrids.
(ii) Soil bearing on lateral surfaces of the grids.
(iii) Soil shearing over soils through the apertures of the grids.

The first two are the skin friction and passive pressure resistance of the contact area between soils and grogrids. The third is the interfacial shear on the surface of the rapture zone created during shearing. The relative size of the soil particles to grid apertures has significant influence on the size of the rapture zone. As the ratio this relative size i.e. soil / grogrid increases the size of the rapture zone increases.

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Omar et al. **(**1993) conducted laboratory model test results for the ultimate bearing capacity of strip and square foundations supported by sand reinforced with geogrid layer. Based on their model tests, they determined the critical depth of reinforcement and dimensions of the geogrid layers for mobilizing the maximum bearing-capacity ratio. The following conclusions have been obtained from their model test results.
(i) For the development of maximum bearing capacity the effective depth of reinforcement is about 2B for strip foundations and 1.4B for square foundations.
(ii) Maximum width of reinforcement layers required for mobilization of maximum bearing capacity ratio is about 8B for strip foundations and 4.5B for square foundations.
(iii) The maximum depth of placement of the first layer geogrid should be less than about B to take advantage of reinforcement.
The influence of foundation size and scale effects has been investigated. They recommended that these findings cannot be directly transported to full-size foundations without additional verification.

Yetimoglu et al. (1994) investigated the bearing capacity of rectangular footings on geogrid reinforced sand by performing laboratory model tests as well as finite-element analysis. The effects of the depth to the first layer of reinforcement, vertical spacing of reinforcement layers, number of reinforcement layers and the size of reinforcement sheet on the bearing capacity were investigated. Both the experimental and analytical studies indicated that there was an optimum reinforcement embedment depth at which the bearing capacity was the highest when single-layer reinforcement was used. Also, there appeared to be optimum reinforcement spacing for multilayer reinforced sand. The bearing capacity of reinforced sand was also found to increase with reinforcement layer number and reinforcement size when the reinforcement was placed within a certain effective zone Both the analyses and tests clearly indicated that the bearing capacity of a : rectangular footings could be increased significantly by incorporating geo-grid reinforcement at strategic elevations in the foundation soil. However, the model tests indicated that the settlement at failure may not be affected significantly by the geogrid reinforcement. The reinforcement configuration, that is,
(i) The depth to the first layer of reinforcement, the vertical spacing of reinforcement layers, the size of reinforcement sheet, and especially the number of reinforcement layers can have a very significant effect on the bearing capacity of the reinforced foundation.

(ii) Maximum width of reinforcement layers required for mobilization of maximum bearing capacity ratio is about 8B for strip foundations and 4.5B for square foundations.
(iii) The maximum depth of placement of the first layer geogrid should be less than about B to take advantage of reinforcement.

The influence of foundation size and scale effects has been investigated. They recommended that these findings cannot be directly transported to full-size foundations without additional verification. For single-layer reinforced sand; there is an optimum embedment depth for the first reinforcement layer at which the bearing capacity is the highest. The tests indicated that the optimum embedment depth was approximately 0.3 of the footing width. The analyses indicated that the optimum depth would be somewhat larger for settlement ratios (settlement/footing width) greater than 6%. For multilayer reinforced sand, the highest bearing capacity occurs at an embedment depth of approximately 0.25B. for multilayer reinforced sand there is an optimum vertical spacing of reinforcement layers. The optimum spacing for the reinforced sand investigated is between 0.2B and 0.4B.

The bearing capacity of reinforced sand increases significantly with reinforcement size and reinforcement layer number within a certain effective zone. For the conditions investigated, the extent of the effective zone lies approximately within 1.5B from both the base and edges of the footing. Increasing reinforcement stiffness beyond a certain value would only result in small increases in the bearing capacity of reinforced sand. For the conditions investigated, that value is 1,000kN/m. It should be pointed out that since the influence of foundation size and the scale effects on the bearing capacity of reinforced soil foundations have not been investigated fully, the behavior of actual foundations is not well known. Hence, further studies are needed to establish more accurate design criteria for reinforced soil foundations.

Sharma & Balton (1996) explored the behavior of reinforced embankments on soft clay using the technique of centrifuge modeling. Controlled in-flight construction of the embankment was carried out in a geotechnical centrifuge over a soft clay layer reinforced with scaled-down and instrumented geogrid reinforcement and the behavior of the subsoil and the response of the geogrid were observed. These

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observations are compared with those from another centrifuge test in which a scaled-down woven geotextile was used instead of the geogrid. A new technique for measuring the tension induced in the reinforcement was developed and used in the centrifuge tests. It was found that a geogrid reinforcement that is placed directly on top of the clay layer may be not contribute significantly towards the stability of the embankment because of poor adhesion at the clay-reinforcement interface.

The behavior of reinforced embankments on soft clay was investigated using the technique of centrifuge modeling. Particular attention was given to the effectiveness of a geogrid reinforcement placed directly on top of the clay foundation. A new technique for measuring tension in the reinforcement was developed and used successfully in the centrifuge model tests. Controlled in flight embankment construction was carried out successfully in the centrifuge over a soft clay layer, and the behavior of the subsoil and the response of the reinforcement were observed.

A geogrid reinforcement placed directly on top of the clay foundation may not be very effective in preventing lateral deformation of the clay foundation and, therefore, may not contribute significantly towards the stability of the embankment. This may be due to the fact that such an installation inhibits the confinement of soil between the large apertures of the geogrid and as a result, hampers the geogrid from developing any passive resistance. In the absence of passive resistance, the geogrid has to rely on its adherence with clay in order to resist the lateral deformation of the foundation which can be fairly insignificant, because of the small surface area of the geogrid. A woven geotextile, on the other hand, performed satisfactorily when placed directly on top of the clay foundation. The magnitude of tension induced in the reinforcement was only of the order of lateral thrust in the embankment, but was enough to prevent the failure of the embankment. On the basis of the slip observed at the clay reinforcement interface and small tensions recorded in the reinforcement, it can be inferred that the stiffness and the surface characteristics of the reinforcement are more important than its ultimate strength.

In situations where the reinforcement has to be rolled directly on top of the clay foundation (e.g. marshy land which cannot support any earth moving equipment), it is better from the point of view of stability of the embankment to use geotextiles instead of geogrids. Although substantial savings can be made by using geogrids in place of geotextiles, the use of a geogrid would invariably require the placement of a granular fill over the clay foundation before the geogrid can be installed. The cost of placing a granular fill would significantly reduce the savings and in some situations may render the geogrid option more expensive. Biaxial geogrids have been shown to be an effective method of improving the ultimate bearing capacity of cohesion less soils. However, the amount of settlement required to mobilize tension in the geogrid is significant and hence, there is little difference in the initial portion of the bearing pressure versus settlement curve for unreinforced sands and those reinforced with biaxial geogrids.

Adams and Collin (1997) showed that using a single layer of reinforcement, the pressure producing a settlement of 0.50% of the footing diameter, B is between 92% and 119% of that for the unreinforced case. In this study, a newly developed strain-controlled loading system was used to investigate the performance of cohesion less soil reinforced multi-oriented geosynthetic inclusions, or geojacks placed over a biaxial geogrid. The investigation used 152 mm diameter rigid footings in a test 1.37 m diameter test pits. The soil was a uniformly graded 16-30 sand (>98% passing No. 16 sieve, <1% passing No. 30 sieve). As this is a preliminary study prior to full scale tests, the geogrid-type, depth of footing (not presented herein), and number of layers of reinforcement. The results indicate that the combined reinforcement of biaxial geogrids and geojacks improves the ultimate bearing capacity even beyond that obtained with a geogrid alone. Additionally, the settlement required to mobilize tension in the geogrid (and thereby enhance performance of the foundation system) is substantially reduced. Specifically, the pressure required to produce a settlement of 0.50% of the footing diameter, B is 230% of that using a geogrid alone and about 300% of that measured in the unreinforced case. Facilities constructed with spread footings on marginal foundation soils may be expected to undergo fairly large deformations and hence, modification of the foundation soil is essential. Geogrid reinforcement has been shown to increase significantly the bearing capacity of structural fills. However, allowable settlements, and not ultimate bearing capacity, generally dictate the design of spread foundations on cohesionless soils. To mobilize tensile forces in the geosynthetic material, vertical movements beneath the footing must occur and hence, there was often little or no improvement in the performance of these reinforced soils at design or working loads. This study used strain controlled laboratory tests to evaluate the performance of spread footings overlying

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cohesionless soil foundations reinforced with and without the use of geogrids supplemented with geojacks. It was discovered that the performance of geogrid-reinforced foundation systems is improved when supplemented with multi-oriented geosynthetic inclusions, or geojacks. The results of these tests indicated that the use of geojacks on top of the geogrid substantially improved the performance of the soil foundation and that the combination of geogrid and geojacks performed better than a combination of geogrid and gravel. This increased performance was observed not only at ultimate capacity, but also at smaller loads. This is significant because foundations in actual design situations are not taken to ultimate capacity, but to some fraction of ultimate (typically less than 1/3 for cohesionless soils).

Das et al (1998) Presented laboratory model test results for the settlement of a square surface foundation supported by geogrid reinforced sand and subjected to transient load. The tests were conducted on model foundation at one relative density of compaction using only one type of geogrid. Based on the model test results. It appears that geogrid reinforcement does reduce the settlement of the foundation. The settlement reduction factor is a function of the depth of reinforcement. The results of a number of laboratory model tests to determine the settlement of a square foundation supported by geogrid-reinforced sand and subjected to transient loading of short duration are presented. In all tests, the peak value of the transient load per unit area of the foundation exceeded the ultimate static bearing capacity of the foundation supported by unreinforced sand. Based on the model test results, the following conclusions can be drawn:
(1) Geogrid reinforcement reduces the settlement due to transient loading.
(2) The above conclusions are based on the tests conducted on sand at one relative density of compaction with only one type of geogrid reinforcement. More tests of this type are required to draw general conclusions.

Huang & Hong (2000) examined the applicability of a method for predicting 'bearing capacity increase" in reinforced sandy ground using tests performed under various test conditions. It was found that the present method predicted, with reasonable accuracy, the bearing capacity increase in sandy ground, reinforced with stiff reinforcement. This method may not be applicable for sandy ground reinforced with extensible reinforcement due to the unsuccessful formation of a semi-rigid zone under the footing. An investigation into the settlement of a footing on reinforced sandy ground, at ultimate footing load condition, suggested that the settlement of footing for reaching peak footing load may be correlated to the 'deep-footing' and the 'wide-slab' mechanisms. That is, the ultimate settlement ratio between reinforced and unreinforced model sandy ground, SR, may be linearly correlated to ' B C R D ' and ' B C R S \ which represent 'deep-footing' and 'wide-slab' effect, respectively, on the ultimate bearing capacity increase in reinforced sandy ground.

Applicability of a method for predicting the bearing capacity ratio of reinforced sandy ground at ultimate footing load condition was examined using two series of model tests. It was shown that this method gave reliable predictions of the ultimate bearing capacity increase for the footings on model sandy ground reinforced with high tensile stiffness reinforcement. This conclusion is valid only for the range of extensibilities of reinforcement investigated in the present study. When applying this method to the model sandy ground reinforced with extensible reinforcement, the "deep footing" mechanism may not function. In this case, the present method is not applicable. Settlement of reinforced ground at ultimate footing load condition was also investigated using a variety of model tests and centrifuge tests. Linear relationships between SR and BCR were found for all the tests in which a semi-rigid reinforced zone was successfully developed under ultimate footing load condition of SR for reinforced sandy ground may also be a linear function of BCRD and BCRs. This implies that the settlement of footing required for reaching the failure of the reinforced sandy ground may increase with the increase of the degrees of' deep-footing' and 'wide-slab' effects.
The present study focused on the load and settlement for reinforced ground at its ultimate condition. Further studies on the settlement characteristics of horizontal reinforced sandy ground under work load condition will be required to substantiate the practical application of the soil reinforcement technique. The model proposed in the present study is based on a limited number of reduced-scale model and centrifuge tests. Further studies into the accuracy of the proposed model considering the size effect of footings should be performed in the future.

S.T.Gnanedram,A.P.S.Selvadurai (2001) investigated the stabilizing force provided by a layer of geogrid reinforcement embedded in the body of sloped fill subjected to loading from a footing located near the crest through laboratory model study. This study indicates that the geogrid reinforcement could be instrumented more reliably with strain gauges installed in pairs, i.e. on top and bottom faces of the

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geogrid, at each location across the geogrid reinforcement and the use of the average strain minimizes the influence of flexural strains in the geogrid. If only one strain gauge per location is used, the tensile strain and geogrid force estimated on the basis of nominal stiffness would not be accurate particularly at low load levels and considerable caution is required when using such an approach. The study demonstrates that the accuracy of the estimated stabilizing force in the geogrid reinforcement could be enhanced by calibrating each pair gauges as installed in position since each gauge installed at different locations across a geogrid sample would behave differently. Details of a relatively simple tensile testing method developed for calibrating these gauges and the use of calibration results for assessing the gradual development of stabilizing force in the reinforcement in relation to the foundation load are discussed.

Performance of the geosynethetic in a reinforced soil structure is an important consideration for design and is usually assessed by monitoring the developed strain with electrical resistance strain gauges. Geosynthetic reinforcement contributes to the stability of soil structures primarily due to their tensile stiffness but changes in local strain measurements could occur due to the effects of bending as well. Therefore, the interpretation of the actual force developed in the geosynthestic reinforcement (i.e. the stabilizing force provided by the reinforcement to the soil structure) on the basis of measured strain in the reinforcing element requires careful consideration and forms the basis of this paper.

A small-scale laboratory study was conducted to evaluate the stabilizing force provided by a geogrid reinforcement layer to the sloped fill subjected to footing load. Electrical strain gauges were installed in pairs (i.e. on top and bottom faces of the geogrid) at each location across the geogrid reinforcement to account for the changes in geogrid strain due to the effects of bending. Since each gauge installed at different locations across a geogrid sample would behave differently, a reliable but simple method to perform tensile tests on a wide (i.e. on the entire 870 mm) sample of geogrid was developed for calibrating these gauges as installed positioned.

The study indicates that if only one strain gauges per location across the reinforcement is used the estimated geogrid force, on the basis of measured strain and nominal stiffness, would be in error especially at low load levels. Even if each gauge is calibrated as installed in position from a tensile test, it would not be possible to interpret the geogrid force from individual strain measurements accurately for these low load levels. Therefore, the use of single strain gauge at each location for the interpretation of geogrid loads is not advocated. This study presents the results of an experimental research program where strain gauges are installed in pairs on either face of the geogrid, in order to interpret the load development more accurately.

III.CONCLUSION

The following conclusion are drawn in the present study, based on the result and discussions presented in the previous section with regard to embedded foundations on sand reinforced with geogrids and also the effect of numbers of layers of geogrid.

Foundation on homogeneous sand in centrally loaded foundation on homogeneous sand bed, as the depth of the foundation is increased; the peak load at failure is increased.

Foundation on reinforced sand In centrally loaded foundations the load carrying capacity increases with increase in the depth of foundation-in surface footing providing geogrids in "four layers increases the load carrying capacity to 3.55 times where as providing there layers of geogrids above value reduces to 2.28 and for two layers the above value reduces to 1.82.The less number of geogrid layers decrease the load carrying capacity.

Provision of geogrid in strip foundations increases the load carrying capacity but decreases the settlement of the foundation.

IV.SCOPE FOR FURTHER STUDIES

Keeping in view the limitations of time, available laboratory facilities and its scope of present investigation, it is necessary to investigate the peak load at failure and the corresponding settlement in cohesive soil with geogrids as reinforcement. The load carrying capacity and the settlement behavior of centroidal footings observed need theoretical analysis.

Comprehensive investigation, both experimental and theoretical, of the problem with geogrid as reinforcement is desirable.

REFERENCES

[1] A. Guido, "Bearing Capacity of Reinforced Sand Sub grades," ASCE, Jr. of Geotechnical Engineering, Vol. 1 - 113, 1987.

[2] Adams & Collin, "Performance of Spread Footings on Sub grades Reinforced with geogrids & Geojacks, "Chi L i , Scott M-Merry, & Everkt C. Lawton (1997).

[3] Binquet & Lee, “Bearing Capacity of Reinforced earth Slabs," ASCE, Vol. - 1, G T - 1 2, P P - 1241 - 1255, Jan 1975.

ISSN: 2278 – 7798

[4] Bowles, E, "Foundation Analysis & Design" MC Graw Hill, Kogakusha, Ltd. (1977).

[5] Chummar A.V, "Bearing Capacity Theory from Experimental Results" Proc ASCE, Jr. Soil Mechanics & Foundation Division 1972.

[6] C.T.Gnanendran & A.P.S. Selvadurai, "Strain Measurement & Interpretation of Stabilizing force in a geogrid Reinforcement," Department of Civil Engineering & Applied Mechanics, MC Gil University, Montrel Canada (2001).

[7] Das et al., "Foundation of Geogrid Reinforced sand Effect of Transient Loading". California University, U.S.A. (1998).

[8] Fragaszy & Lawton, "Bearing Capacity of Reinforcement sand Sub grades." Jr.Geotechnical Engg, ASCE (1984).

[9] Henery Vidal, "The developments & Future of reinforced earth", ASCE Symposium on earth reinforcements (1978).

[10] Huang & Hong, "Ultimate bearing capacity & Settlement of footing on reinforced sandy ground." (2000).

[11] Indian Standard Institutions, "Code of Practice".
1498 - Classification & Identification on soils for general Engineering purposes,1888 - Methods of Load test and soils,2720 - Methods of tests on soils,PT - 111 - Determination of Specific Gravity,Pt - V - Grain Size analysis,Pt. - XIII - Direct Shear Test.

[12] Jewell et al, "Interaction between soil & geogrids," Symp. Polymer Grid Reinforcement in Civil Engg. London, England (1985).

[13] M.A. Mahmoud & F.M. Abdrabbo, "Bearing capacity tests on strip footing resting on reinforced sand subgreads, Canadian Geotechnical Journal. Vol - 26, No. 1 - 4, 1989.

[14] Meyerhof G.G., "The ultimate bearing capacity of foundations, Geotechnique, 2, No. - 4 (1951).

[15] Omar et al., "Ultimate bearing capacity of rectangular foundations on geogrid reinforced sand". Geotech (1993).

[16] Rhines, W. J, "Elastic - plastic foundations model for punching shear failure." * Proc. ASCE, Jr. of soil mechanics & foundations divisions Vol. 95, no. S m - 3, May 1967.

[17] Sharma & Bolton, "Centrifuge moddleing of Embankment on soft clay reinforced with geogrid," Cambridge University Engineering Department. (1996) reinforced soil & Geotextiles (1998).

[18] Sreekantiah H.R., "Stability of loaded footings on reinforced sand," Proc of FIGC on reinforced soil & Geotextiles Vol. - 1, (1988).

[19] Sridhran A, "Reinforced soil foundation on soft soil," Proc of FIGC on reinforced soil & Geotextiles. Vol. – 1 (1988).

[20] Terzaghi K, 'Theoretical soil mechanics," John Wiley & Sons inc, New York - 1943.

[21] Terzaghi & Peck, R.B., "Soil mechanics in Engineering Practice," John Wiley & Sons (1967).

[22] Vesic A.S., "Analysis of ultimate loads of shallow foundations." Proc of ASCE, Soil mechanics & Foundation division Vol. 99, Jan 1973.

[23] V.N.S. Murthy, "Soil mechanics & foundation Engineering" Dhanpat Rai & Sons (1988).

[24] Yetimoglu et al, "The bearing capacity of rectangular footings on reinforced sand," PhD, Thesis (1994).

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