International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 09 | Sep 2020 www.irjet.net p-ISSN: 2395-0072

Sensor Based Magnetic Extensometer for Monitoring Settlement of Soil Under Foundation

Vyshna Sushil T.M[1], Anju E.M[2]

[1]*PG Student , Department of Civil Engineering, IES College of Engineering, Kerala, India*
[2]*Assistant Professor, Department of Civil Engineering, IES College of Engineering, Kerala, India*

---***---

Abstract – *Foundation is the lower most part of civil structure which is in direct contact with the soil and transfer the load from super structure to the soil. Designing a foundation is often controlled by the settlement rather than bearing capacity. The sub soil or the soil under foundation may get weaken resulting in settlement due to several reasons such as heavy loading impact, earthquakes, flood and also due to disturbance caused by the nearby construction works such as excavation, pilling, digging, tunneling, mining etc. It may also lead to some natural hazards. Therefore, it is essential to monitor the causes of settlement and do the remedial measures Monitoring settlement of soil are usually carried out by extensometers strain gauge other similar devices for settlement monitoring of soils may get damaged due to sudden impacts or temperature variations etc. Considering all drawbacks, a new instrument set up is developed with minimum cost for monitoring the settlement of soil. Sensor based extensometer is developed for settlement monitoring of soil under pile. This paper deals with the designing of sensor based magnetic extensometer for monitoring the settlement of soil. An experimental set up is constructed and the settlement of sand under pile is monitored using sensor based magnetic extensometer by varying parameters such as relative density and pile length. In dense condition it is found to have a reduced settlement .It is found that as the pile length increases the settlement decreases, ie; In dense bed settlement of normal pile of length 30cm and diameter 2 cm is 14.64 mm and settlement of normal pile of length 40cm and pile diameter 6 cm is 8.89 mm. It is found that as the pile length increases the settlement decreases with an increase in load carrying capacity. Therefore as the pile dimension increases the settlement decreases. Application of sensor based magnetic extensometer is used in working sites to evaluate the settlement of the sub soil. Settlement of soil is monitored automatically by sensor based magnetic extensometer.*

Key Words: **Extensometer, Foundation, Pile dimensions, Sensor, Settlement**

1. INTRODUCTION

A civil structure includes a super structure and a foundation. Foundation is the part that is in direct contact with the soil and transfer all kinds of load to the soil from super structure. Foundations are generally classified into two shallow foundation and deep foundation. Deep foundation are necessary where the bearing capacity of the surface soil is not adequate to support the loads imposed by a structure and so those loads need to be transferred to deeper layers with higher bearing capacity. The design of the foundation must in cooperate different effects of construction on the environment. For example, the digging and piling works done for deep foundation may result in adverse disturbance to the nearby soil and structural foundation. These can sometimes cause the settlement issues of the nearby structure. Settlement of structures may arise due to deformation of the soil. Settlement of the soil leads to the failure of the entire structure. Settlement is often considered as the major factor in design of foundation rather than considering bearing capacity. Settlement is the downward movement of the ground caused by a load consolidating the soil below it or causing displacement of the soil. Monitoring for sub-surface settlement will provide an early indication of potential settlement or sinkhole formation at the ground surface. Currently, rod and magnetic extensometers may be used to monitor sub-surface settlement, strain gauges, settlement plates, vibrating wire gauges, liquid settlement system etc. are also used for monitoring sub surface settlement. Nowadays sensors are used for determining soil settlement. Considering all the limitations in settlement monitoring of soil beneath the foundation, a sensor based magnetic extensometer is introduced. Proposed sensor based magnetic extensometer is a fully/semi-automated system with automated data logging is desired to replace the existing practice of manual measurement of ground movement. The main parts of the proposed sensor based magnetic extensometer are sensor, sensor tube, and the permanent magnet with removable spider legs. In this paper designing of sensor based magnetic extensometer and its application is discussed.

1.1 Scope

Foundation is the important part of civil structure and the important function is to transfer the load from super structure to the soil safely. The soil beneath the foundation may settle due to various reason which may lead to collapse of entire structure. Hence the foundation design is often controlled by the settlement rather than bearing capacity. Therefore it is very essential to monitor the settlement of soil beneath foundations as well as adjacent sub soil nearby construction works. Usage of sensor based magnetic extensometer for monitoring settlement of soil under foundations.

1.2 Objectives

- To develop a sensor based magnetic extensometer for monitoring the settlement of soil under the foundation
- To determine the effect of relative density on settlement using sensor based magnetic extensometer
- To determine the effect of pile diameter on settlement using sensor based magnetic extensometer.
- To determine the effect of pile length on settlement using sensor based magnetic extensometer.
- To determine the field applications

2. MATERIALS USED

2.1 SENSOR TUBE

Acrylic glass is used to develop sensor tube. Fig.1 shows the acrylic glass sheets.

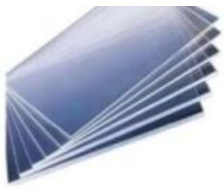

Fig.1- Acrylic glass

2.2 MAGNET

A permanent magnet used for the developing the instrument. Fig.2 shows permanent magnet used.

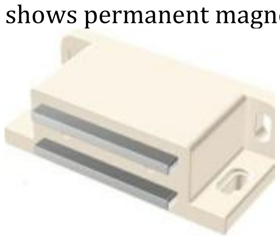

Fig.2- Permanent magnet

2.3 SENSOR

BNOO55 Orientation integrated circuit with MPU 6050 is the sensor used. Fig 3 shows sensor.

Fig.3- Sensor

2.4 SAND

Locally collected clean river sand was used in all experiments as a soil medium.

2.5 PILE

Mild steel pile of diameter 4, 6, 8 cm and length 30, 35, 40 cm are used.

2.6 TANK

A tank of size 1000x 1000x 800 mm is used

3. METHEDOLOGY

Includes development of sensor based magnetic extensometer, validation test, experimental study and finally the field analysis.

3.1 Designing of the instrument set up

There are mainly two parts for the proposed sensor based magnetic extensometer; one is the sensor tube, and another is the permanent magnet with removable spider legs. The sensor tube is made of transparent acrylic glass of thickness 3 mm consists of a cantilever acrylic glass beam and a sensor bonded on the cantilever beam. The sensor tube can be installed at a desired depth in the borehole or attached to the foundation. The magnet is attached to the outer surface of sensor tube in such a way that magnet can move along the sensor tube. The magnet is attached with the spider legs which anchor the magnet with the soil outside the sensor tube.

Fig.4-Developed Sensor Based Magnetic Extensometer

3.2 Experimental study – Load test

The experimental large scale model are designed for the representation of three dimensional field situation. Soil condition considered are medium condition. Normal piles with varrying parameters are considered and this can be modeled in two dimension if the width of the test tank is equal to five times the width of the tank. For conducting plate load test in field width of the test should not be less than five times the width of the plate so that the failure zones freely developed without any interference from sides. The dimensions of the test tank are fixed by considering the dimensions of footings and their influence zone. In order to represent the vertical concentric and eccentric loading static plate load tests were chosen and vertical deformations will be studied. Vertical deformation or the settlement of soil beneath the pile has been monitored using the newly developed sensor based magnetic extensometer. The calibration is done for the designed sensor based magnetic extensometer with dial gauge.

Fig.5-Experiment setup

3.3 Validation test

To check the accuracy of test set up a validation test was carried out .While conducting plate load test, vertical deformation of the pile due to the load acting up on it is monitored using sensor based magnetic extensometer attached to the pile and the dial gauge at a time. Comparing the readings of dial gauge and sensor based magnetic extensometer calibration of the sensor is done. Calibration process is illustrated in Fig.6

Fig.6- Validation test

4. TEST RESULTS

4.1 INDEX PROPERTIES

Basic properties of sand were determined as per the respective IS codes. Results of particle size distribution analysis, specific gravity, maximum and minimum densities, and angle of internal friction, permeability were tabulated in Table 1

Table 1: index properties

Properties	Value
Specific gravity	2.65
Uniform coefficient	2.4
Coefficient of curvature	0.77
Maximum dry density	1.819
Minimum dry density	1.766

4.2 PLATE LOAD TEST RESULT

1. Medium sand condition

For studying the influence of vertical loads on single normal pile, the test were carried out at various pile length (40cm, 35cm, 30cm) and constant diameter (2 cm).Load settlement curve is shown in Chart 1

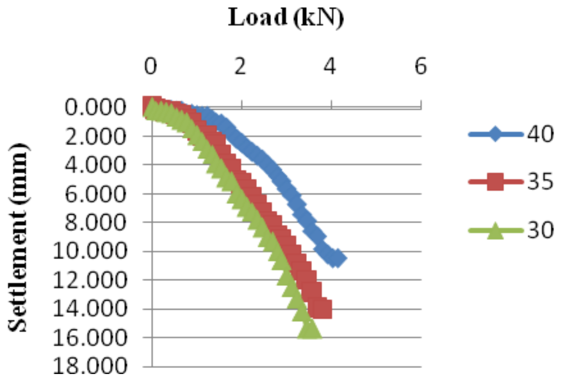

Chart 1--Load settlement curve

From the above graph it can be concluded that pile of 2 cm diameter and 40cm length have minimum settlement value and maximum load carrying capacity when compared with piles of 35 cm and 30 cm length. And pile with 30 cm length have maximum settlement and minimum load carrying capacity

The test were carried out at various pile length (40cm, 35cm, 30cm) and constant diameter (4 cm).Load settlement curve is shown in Chart 2

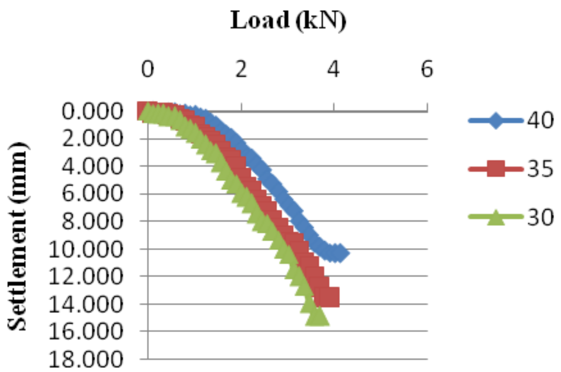

Chart 2 - Load settlement curve

It is found that as the pile length increases the settlement decreases and there by resulting into increases of load carrying capacity.

The test were carried out at various pile length (40cm, 35cm, 30cm) and constant diameter (6 cm).Load settlement curve is shown in Chart 3

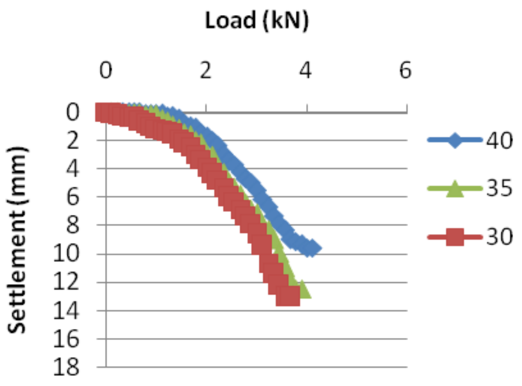

Chart 3 - Load settlement curve

It is found that as the pile length increases the settlement decreases and there by resulting into increases of load carrying capacity

For studying the influence of vertical loads on single normal pile of varying pile diameter (4cm, 6 cm) and constant length. Pile diameter Vs settlement graph is shown in Chart 4

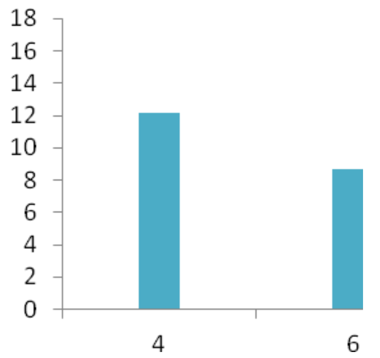

Chart 4 - Pile diameter Vs Settlement

From the graph its clear that as the pile diameter increases the settlement decreases with an increase in load carrying capacity

2. Dense sand condition

For studying the influence of vertical loads on single normal pile, the test was carried out at various pilelength(40cm, 35cm, 30cm) and constant diameter (2 cm).Load settlement curve is shown in Chart 5

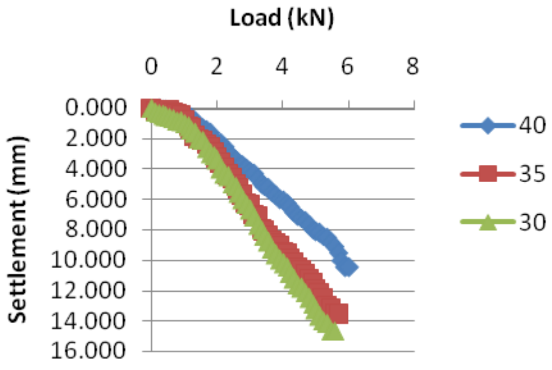

Chart 5 -Load settlement curve

It is found that as the pile length increases the settlement decreases and there by resulting into increases of load carrying capacity.

For studying the influence of vertical loads on single normal pile, the test was carried out at various pile length (40cm, 35cm, 30cm) and constant diameter (4 cm).Load settlement curve is shown in Chart 6

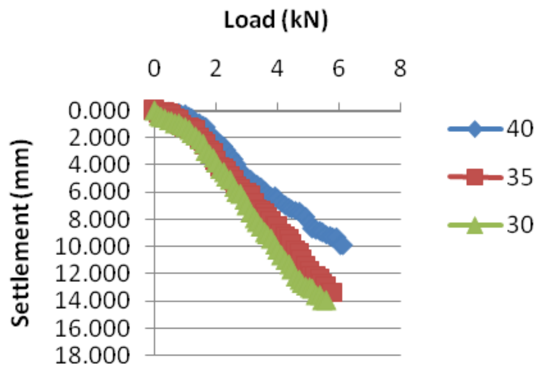

Chart 6- Load settlement curve

It is found that as the pile length increases the settlement decreases and there by resulting into increases of load carrying capacity.

For studying the influence of vertical loads on single normal pile, the test were carried out at various pile length (40cm, 35cm, 30cm) and constant diameter (6 cm). Load settlement curve is shown in Chart 7

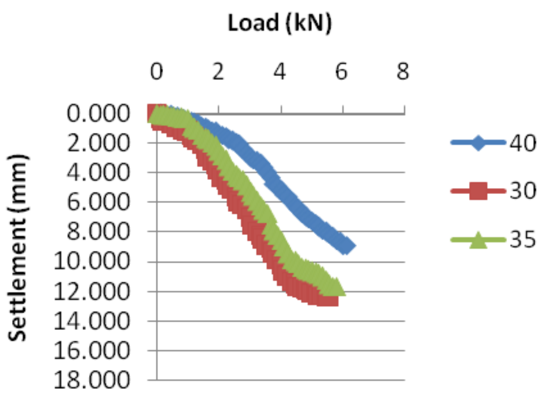

Chart 7- Load settlement curve

It is found that as the pile length increases the settlement decreases and there by resulting into increases of load carrying capacity

For studying the influence of vertical loads on single normal pile of varying pile diameter (4cm, 6 cm) and constant length. Pile diameter Vs settlement graph is shown in Chart 8

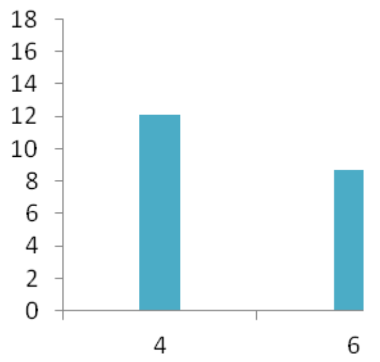

Chart 8 - Pile diameter Vs Settlement

From the graph its clear that as the pile diameter increases the settlement decreases with an increase in load carrying capacity

4.3 FIELD APPLICATION

Developed sensor based magnetic extensometer is used for field application. A sensor based magnetic extensometer is used to determine the settlement of sub soil due to disturbance caused by the nearby construction works such as excavation, pilling ,digging, tunnelling, mining, demolition and construction works etc. Field analysis was conducted at site where field levelling works were carried out. The instrument is placed at a shallow depth in the work site, by taking a shallow hole and placing the instrument set up roughly in to the hole. The instrument setup was connected to output LCD system externally. The Fig.7 shows the site where the instrument setup is placed.

Fig.7 -Site work

The output reading obtained in the output LCD system is shown in Fig 8

Fig.8- Output reading

Settlement of sub soil near to the excavation area using JCB is shown in the reader system. It is found to have a soil displacement of 13.17 mm. That means sub soil settlement is 13.17 mm.

5. CONCLUSIONS

- Sensor based magnetic extensometer is developed for settlement monitoring of soil under foundation
- Dense sand condition compared to medium condition, settlement decreases and thereby resulting into increase of load carrying capacity
- As the pile length increases, the settlement decreases and there by resulting into increase of load carrying capacity
- As the pile diameter increases, the settlement decreases and there by resulting into increase of load carrying capacity
- Sensor based magnetic extensometer can be applied in field for settlement monitoring

REFERENCES

[1] C.Schmidt-Hattenberger, Gunter Borm, Bragg grating extensometer rods (BGX) forgeotechnical strain measurements, Proc. SPIE. Int. Soc. Opt. Eng. 3483 (1998)214–217

[2] Kai-Qiang Sun, Bin Shi, Chao-Sheng Tang, Guang-Qin Wei, Hao Zeng, Luan Lin, Application of fiber bragg grating-based distributed optical fiber monitor in filled soillayered settlement, in: The 6th International Forum on Opto-Electronic Sensor-Based Monitoring in Geo-Engineering, Nanjing, China, 2017.

[3] Muneesh Maheshwaria,b, Yaowen Yanga,, Deepesh Upadrashtaa, Ean Seong Huangc,Koh Hun. Fiber Bragg Grating (FBG) based magnetic extensometer for groundsettlement monitoring,science direct (2019)

[4] Lei Gao; Han Long Liu; Xiangjuan Yu; Huidong Chen; and Ali H. Mahfouz .Application and Development of Dynamic Loading Model Test System of Pile Based on FBG ASCE,(2018)

[5] L. Briançon and B. Simon. Performance of Pile-Supported Embankment over Soft Soil: Full-Scale Experiment, *ASCE*,2012 .

[6] J. Brian Anderson, M.ASCE; F. C. Townsend, ASCE; and L. Rahelison. Load Testing and Settlement Prediction of Shallow Foundation .ASCE,(2007)

[7] Ravi Kant Mittal, Gourav Gill. Pressure settlement behaviour of strip footing resting on tire-chip reinforced sand International journal of geotechnical engineering,(2017)

[8] Hongwei An; Weidong Yao; Liang Cheng ; Scott Draper ; Ming Zhao . Detecting Local Scour Using Contact Image Sensors ASCE, (2016)

[9] Chengyu Hong, Yifan Zhang, Yuyao Yang, Yu Yuana. . A FBG based displacement transducer for small soil deformation measurement Science direct ,(2019)

[10] Aida Mehrpazhouh, Seyed Naser Moghadas Tafreshi , Mehdi Mirzabab. Impact of repeated loading on mechanical response of a reinforced sand ,Science Direct ,(2019)

[11] Ravi Kant Mittal, Gourav Gill. Pressure settlement behaviour of strip footing resting on tire-chip reinforced sand International journal of geotechnical engineering,(2017)

[12] Jia-Quan Wang , Liang-Liang Zhang, Jian-Feng ,Xue Yi Tang, Load-settlement response of shallow square footings on geogrid-reinforced sand under cyclic loading,science direct ,(2018)

[13] Ken Hoerethamp, Brendan Fitz Patrick, Settlement monitoring of discrete reinforced soil layer beneath mat foundation,Canadian journal (2007)

[14] Saeed Goodarzi, Habib Shahnazari, Strength enhancement of geotextile-reinforced carbonate sand ,Science Direct ,(2019)

[15] Mrs. Neetu B. Ramteke ; Prof. Anilkumar Saxena ; Prof. T. R. Arora, Effect of Geo-grid reinforcement on soil IJCEM ,(2014)

[16] Christopher Wong, Matteo Pedrotti, Gráinne El Mountassir, Rebecca J. Lunn, A study on the mechanical interaction between soil and colloidal silica gel for ground improvement, Science direct ,(2018)

[17] Gaofeng Rena, Taoyuan Lia, Zhongchun Hu, Congrui Zhang, Research on new FBG soil pressure sensor and its application in engineering Science direct ,(2019)

[18] Hisham T Eid, Bearing capacity and settlement of skirted shallow foundation on sand ,ASCE ,(2013)

[19] Marco Bonopera ; Kuo-Chun Chang ; Chun-Chung Chen; Zheng-Kuan Lee ; Yu-Chi Sung; and Nerio Tullini, Fiber Bragg Grating–Differential Settlement Measurement System for Bridge Displacement Monitoring: Case Study, ASCE,(2019)

[20] Pengpeng Ni ; Linhui Song ; Guoxiong Mei ; and Yanlin Zhao, Predicting Excavation-Induced Settlement for Embedded Footing: Case Study,ASCE,(2018)