PERFORMANCE OF ON-GRADE SLABS ON EXPANSIVE SOILS AT TABUK CITY – K.S.A.

BY

OSAMA MOSLEM MOHAMMED IBRAHIM

A Thesis Submitted to the

Faculty of Engineering at Cairo University

In Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

In

Civil Engineering - Public Works

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Under the Supervision of

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Title of Thesis:

PERFORMANCE OF ON-GRADE SLABS ON EXPANSIVE SOILS AT TABUK CITY – K.S.A.

Key Words:

Expansive soil, Swelling pressure, heave, granular anchor pile, slab.

Summary:

One of the techniques to reduce the heave problems is granular pile anchor foundation (GPAF). In this research, three slabs-on-grade are constructed at the field, the first slab as a regular slab-on-grade; the second was supported with granular pile anchor, while the third was supported on concrete pile anchor foundation (CPAF). The test area flooded by water for 64 days, the in situ swelling pressure measured as 49 KPa, Monitoring the performance of three slabs after wetting indicated that the CPAF and GPAF systems caused a 62% and 57% reduction in upward movement respectively. Furthermore, numerical models are analyzed, and a series of numerical models are constructed to study the effect of granular pile anchor in heave reduction at various lengths and diameters.

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List of Abbreviations:

A: Clay activity

C: Clay content

e: Void ratio

E: Young's modulus

ε: Strain

S: Swelling potential

P_s: Swelling pressure

C_s: Swelling Index

LL: Liquid limit

PI: Plasticity index

PL: Plastic limit

SL: Shrinkage limit

SI: Shrinkage index

EI: Expansion index

P_{ov}: Over burden pressure

S_p: Predicted swell percentage

FSI: Free swell index

CEC: Cation exchange capacity

GPA: Granular pile anchor

CPA: Concrete pile anchor

GPAF: Granular pile anchor foundation system

CPAF: Concrete pile anchor foundation system

MFSI: Modified free swell index

COLE: Coefficient of linear extensibility

ABSTRACT

Expansive soils in Saudi Arabia regions, such as Tabuk, Tymaa, Tabarjal, and Al Madina, have received wide attention in recent decades. This type of soil causes many problems and cracks in most structures and roads, which are constructed on it. The research is aimed at studying the performance of reinforced concrete slab which constructed on expansive soils at Tabuk city. The soil engineering properties were determined and compared with the soil which was classified as laminated weathered shale (CH). The swelling pressure and free swell index were 120 kPa and 105% respectively.

One of the techniques that are used to control the severity of distress caused to structures founded on expansive soils is the granular pile anchor foundation system (GPAF). It reduces heave behavior and improving the engineering behavior of expansive clay. Another technique is filling the pile holes by fresh concrete called in this research concrete pile anchor foundation system (CPAF). In this research, three full scale models have dimensions of (2.0 x 2.0 x 0.4 m) are constructed in-situ and tested as follow:

1- First slab is constructed directly on natural soil as a regular footing.
2- Second slab is constructed using GPAF system. The granular pile anchor (GPA), have length of 2.0 m and 20 cm diameter.
3- Third slab is founded on concrete pile anchors foundation (CPAF) connecting the slab-on-grade into the subsurface soil with 2.0 m length and 20 cm diameter concrete piles.

The field models are constructed to evaluate the efficiency of the granular pile anchor foundation (GPAF) system compared to the concrete pile anchor foundation (CPAF) system in reducing heave of slab-on-grade, resulting from the expansive soils. Field models site area is submerged with water for a period of 64 days. One borehole is drilled by compressed air to investigate the maximum depth of saturation measured during this period. Also, the maximum volumetric strain occurred in the saturated clay layer is determined. An earth pressure cell is fixed in contact with soil beneath center of GPAF model. At the end of test period, the measured field swelling pressure is 49 kPa. Due to the swelling action of expansive soil, the measured uplift displacement of three full scale models are 125 mm, 54 mm, and 47 mm, respectively. Stiffening the slab rested on expansive soil using granular pile anchors (GPA) or concrete pile anchors (CPA) are reduced the upward movement by 57%, and 62%, respectively. From the field measurements of swelling pressure, the force resisted by the Granular Pile Anchor was measured. Strain gages were installed on steel reinforcement steel bars of CPAF slab model and top of concrete pile anchor steel bar, it aimed at measuring the strains happened due to the soil swelling action and to determine the force resisted by the concrete pile anchors.

Finite element modeling is used to predict the heave of GPAF and CPAF models. PLAXIS 2D-Version 8.2 program is used in numerical modeling and analysis of the tested heave problems. The problem deals with footing have same characteristics of field model rested on expansive soil supported on GPA or CPA. The active zone of the expansive soil is similar to the wetted depth in the field models. A verification model is constructed to simulate observations in the field. In Plaxis model, definition of expansive soil is made by applying volume strain to the wetted surface layer with positive value. The obtained results of footing uplift displacement for three models are

55.6 mm for GPAF model, and 46.9 mm for CPAF model. Therefore, there is a good agreement between field observation data and finite element analysis. In addition, the model has been used to make sensitivity analysis as other finite element models are simulated for GPAF system to study the effect of pile diameter; depth and number on the foundations heave behavior. Finally, a design chart is presented to predict the heave that may be occurred for foundations at Tabuk city, kingdom of Saudi Arabia