Numerical Modeling of the Effects of Soil Reinforcement on Uplift Resistance of Buried Pipelines

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Extended Abstract

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Introduction

Recently, several studies on buried pipelines have been conducted to determine their uplift behavior as a function of burial depth, type of soil, and degree of compaction, using mathematical, numerical and experimental modeling.

One of the geosynthetics applications is the construction of a reinforced soil foundation to increase the bearing capacity of shallow spread footings. Recently, a new reinforcement element to improve the bearing capacity of soils has been introduced and numerically studied by Hatef et al. The main idea behind the new system is adding anchors to ordinary geogrid. This system has been named as Grid-Anchor (it is not a trade name yet). In this system, a foundation that is supported by the soil reinforced with Grid-Anchor is used; the anchors are made from 10×10×10 mm cubic elements. The obtained results indicate that the Grid-Anchor system of reinforcing can increase the bearing capacity 2.74 times greater than that for ordinary geogrid and 4.43 times greater than for non-reinforced sand.

This paper aims to investigate the enhancement effect of geogrid and Grid-Anchor incorporation on uplift resistance of buried pipelines in loose and dense sand, using the commercial finite deference software FLAC-3D. For enhancement of the uplift resistance of buried pipelines, the anchors must be installed below the geogrid. Figure 1 shows a schematic arrangement of the system. In this system the anchors assumed to be cylindrical plastic elements with 2.5 cm in diameter and 1 cm in height. The length of anchors is 8 cm.

Material and methods

The finite difference program "FLAC-3D" (version 5.0) was used to model the uplift capacity of pipelines buried in sand reinforced with geogrid and Grid-Anchor. 3D analysis was carried out to investigate the uplift behavior of circular pipelines to identify the effect of the most important parameters i.e. pipe diameter, soil saturation status, pipe burial depth, the location of reinforcement layers installation, soil density, as well as number of reinforcement layers and the width of reinforcement layers on the uplift resistance of sandy soils. The Mohr–Coulomb model was used for soil. Reinforcement layers and anchors were modeled using the option already built into the program. They are simulated by the use of special only tension elements with no bending stiffness. Parameters used in the analysis are tabulated in Table 1.

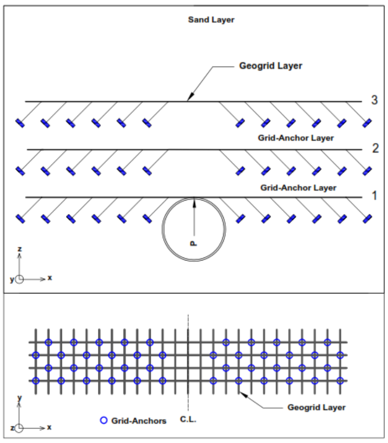

Figure 1. Schematic arrangement of the system

A total of 33 pullout models were conducted to determine the uplift resistance of buried pipes and the failure mechanism involved. Sand was reinforced by geogrid and Grid-Anchor system with a width of 3D, 5D and 8D that installed at top or bottom of pipe. No reinforcing system was used in some models; the pipe with a length of 100 cm was simply buried in sand with embedment ratio (h/D) of 1, 2 and 3. The pipes were pulled out of the soil using an uplift force. In order to model the pullout force, a point load was applied on the top and center of the pipe section. The backfill material consisted of dry and saturated sand at two different unit weights (13.5 and 18 kN/m^3).

Table 1. Parameters used in the analysis

Parameter	value
Soil Angle of internal friction	31^0 and 40^0
Cohesion (kPa)	0
Modulus of elasticity (kPa)	8000 and 12000
Poisson's ratio	0.3
Unit weight (kN/m^3)	13.5 and 18
Soil type	sand
Soil model	Mohr–Coulomb
Axial stiffness of geogrids (kN/m)	28
Axial stiffness of anchors (kN)	0.08
Pipe diameter (mm)	50, 100 and 200
Length of anchors (mm)	100
Anchor plates area(mm^2)	706
Horizontal angel of anchors	45^0

Results and discussion

To verify the effectiveness of Grid–Anchor system in improving the uplift capacity of pipelines, the behavior of pipelines buried in non-reinforced sand, sand reinforced with ordinary geogrid and sand reinforced with Grid-Anchor under the same conditions were investigated. Figure 2 shows the comparison between these three statuses. The effectiveness of using Grid-Anchor system as reinforcement elements in increasing the uplift capacity of pipelines is evident. As can be seen, the value of peak uplift resistance (PUR) is almost 3.7 times greater than that for non-reinforced sand and 2.3 times greater than that for ordinary geogrid in this case.

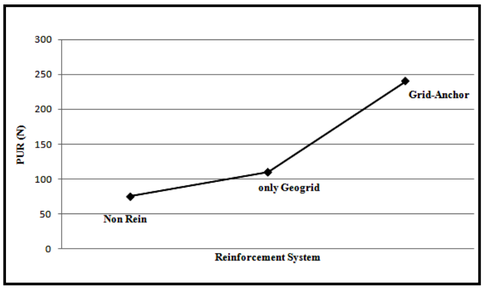

Figure 2. Variation of peak uplift resistance (PUR) with selected reinforcing system (D=50 mm, N=1, h/D=1, b= 250 mm and reinforcement layer installed at the bottom of the pipe)

Conclusions

A three dimensional finite difference parametric research was conducted to investigate the uplift capacity of buried pipelines to propose a new

anchoring system using geogrids and innovative Grid-Anchor as reinforcement element to improve as an alternative and to improve the uplift resistance and to prevent the upward movement of pipes, which can compromise pipeline operation. The study draws the following conclusions:

- Grid-Anchor system of reinforcing can increase the uplift capacity 2.3 times greater than that for ordinary geogrid and 3.70 times greater than for non-reinforced sand.
- Inclusion of Grid-Anchor system in a soil deposit significantly increases the uplift capacity due to developed longer failure surface.
- The efficiency of reinforcement layer inclusion for uplift resistance in dry sand is higher than saturated sand.
- In terms of pipeline uplift capacity, inclusion of one layer of reinforcement over the pipeline is more cost effective than sand reinforcement using multiple layers. The optimal location of one reinforcement inclusion is when it is resting directly on top of the pipeline.
- Increased soil density results in greater uplift capacity. But the efficiency of reinforcement layer inclusion for uplift resistance in loose sand is higher than dense sand; although, the amount of uplift resistance in dense sand is higher.
- Increased pipeline embedment ratio results in greater uplift capacity. But the efficiency of reinforcement layer inclusion for uplift resistance in lower embedment ratios is higher than higher embedment ratios; although, the amount of uplift resistance in higher embedment ratios is higher.
- For the pipelines buried in sand reinforced with Grid-Anchor system, increasing reinforcement width will increase the uplift resistance significantly.
- By increasing the pipe diameter, the efficiency of reinforcement layer inclusion will be lower. That is, inclusion of reinforcement layers will be more economic and effective only for small diameter pipelines.

Keywords: Uplift Resistance, Buried Pipelines, Numerical Modeling, Reinforced Sand, Geogrid, Grid-Anchor.

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