Geomechanics and Engineering, *Vol. 5, No. 3 (2013) 187-194*
DOI: http://dx.doi.org/10.12989/gae.2013.5.3.187

A review on uplift response of symmetrical anchor plates embedded in reinforced sand

Hamed Niroumand* and Khairul Anuar Kassim[a]

Department of geotechnical Engineering, Faculty of civil engineering, Universiti Teknologi Malaysia, Malaysia

(Received November 08, 2012, Revised January 03, 2013, Accepted February 20, 2013)

Abstract. The most soil anchor works have been concerned with the uplift problem on embedded in non-reinforced soils under pullout test. Symmetrical anchor plates are a foundation system that can be resisting tensile load with the support of around soil in which symmetrical anchor plate is embedded. Engineers and authors proved that the uplift response can be improved by grouping the symmetrical anchor plates, increasing the unit weight, embedment ratio and the size of symmetrical anchor plates. Innovation of geosynthetics in the field of geotechnical engineering as reinforcement materials found to be possible solution in symmetrical anchor plate responses. Unfortunately the importance of reinforcement in submergence has received very little attention by researchers. In this paper, provision of tensile reinforcement under embedded conditions has been studied through uplift experiments on symmetrical anchor plates by few researchers. From the test results it has been showed that the provision of geogrid reinforcement system enhances the uplift response substantially under uplift test although other results are such as increase the ultimate uplift response of symmetrical anchor plate embedded using geosynthetic and Grid Fixed Reinforced (GFR) and symmetrical anchor plate improvement is very dependent on geosynthetic layer length and increases significantly until the amount of beyond that further increase in the layer length does not show a significant contribution in the anchor response.

Keywords: uplift response; symmetrical anchor plates; geosynthetic; geogrid; reinforced sand

1. Introduction

Symmetrical anchor plates are a foundation system that can be resisting tensile load with the support of around soil in which symmetrical anchor plate is embedded. It is used by soil structures as a structural member, primarily to resist uplift loads and overturning moments and to ensure the structural stability. A wide variety of soil anchor systems (plate, soil hook system, grouted and helical anchors) have been developed in order to satisfy the increase in foundations to resist the uplift responses. Engineers and authors proved that the uplift response can be improved by grouping the symmetrical anchor plates, increasing the unit weight, embedment ratio and the size of symmetrical anchor plates. Innovation of geosynthetics in the field of civil engineering as reinforcement materials found to be possible solution in symmetrical anchor plate responses. Research into the uplift response of symmetrical anchor plates embedded in non-reinforced soil

*Corresponding author, Post-Doc, E-mail: ham.niroumand@yahoo.com
[a]Professor

http://www.techno-press.org/?journal=gae&subpage=7 ISSN: 2005-307X (Print), 2092-6219 (Online)

has been reported by Bala 1961, Meyerhof and Adams 1968, Vesic 1971, 1972, Hanna *et al*. 1972, Meyerhof 1973, Neely *et al*. 1973, Baset 1977, Das 1978, 1980, Rowe and Davis 1982, Saran *et al*. 1986, Dickin 1987, although research in the area of symmetrical anchor plates embedded in reinforced soil such as Johnston 1984, Subbarao *et al*. 1988, Singh 1992, Rajagopal and SriHari 1996, Niroumand *et al*. 2010 were less extensive. Its treatment on symmetrical anchor plate system was first documented by Subbarao *et al*. (1988). Selvadurai (1989) investigated the performance of geogrids for anchoring 150 mm diameter and 850 mm long pipelines embedded in sand. Andreadis and Harvey (1981), Ghaly *et al*. (1991), Krishnaswamy and Parashar (1992), Ilamaparuthi and Muthukrishnaiah (2001), Tian and Cassidy (2011) and Niroumand *et al*. (2011) were the few known researchers that worked ion reinforced sand under uplift test. Krishnaswamy and Parashar (1992) investigated the experimental test in reinforced sand bed and others in non-reinforced. A more extensive experimental study was carried out (Selvadurai 1993) to evaluate the treatment of a 215 mm diameter pipe with a length of 1610 mm embedded in sand beds reinforced. The inclusion of geogrids immediately above the pipeline in an inclined setup increased the uplift response by about 80%. This increased load was sustained for uplift displacements, mentioned extend of ductility. The uplift response of symmetrical anchor plates embedded in sand bed with geosynthetic reinforcement material was studied by Krishnaswamy and Parashar (1991). Krishnaswamy and Parashar (1994) investigated the uplift response of symmetrical anchor plates such as circular anchor plates (60 mm in diameter) and rectangular plates (53 mm wide with lengths varying from 23.8 to 53 mm) embedded in clay and sand with and without geosynthetics. Placing the geosynthetics directly on the symmetrical anchor plate was proved to be beneficial in achieving maximum increase in the uplift response although they founded that two layers of geogrid reinforcement does not increase the uplift capacity predominantly. Ilamparuthi and Dickin (2001) investigated an extensive study on the treatment of belled pile anchors in reinforced sand bed and formulated a hyperbolic method for the breakout factor. Ravichandran and Ilamparuthi (2004) evaluated the treatment of rectangular anchor plates in the non-reinforced and reinforced cohesionless soil bed. Kingshri *et al*. (2005) evaluated two series of experimental tests to understand the influence of stiffness and opening size of geosynthetic reinforcement materials on the uplift capacity of rectangular anchor plates. First series of tests were on combination of geocomposite and geogrid and the second series of tests were on two layers of geogrid as reinforcements and concluded that the performance of geocomposite & geogrid (two layer) combination was found to be effective in resisting uplift response than two combined layers of geogrids.

2. Symmetrical anchor plates in non-reinforced

The performance of symmetrical anchor plates worked by many researchers in non-reinforced sand but relatively little is known about the performance of symmetrical anchor plates in reinforced soil bed. Johnston (1986) investigated the pullout response of geogrids. Subbarao *et al*. (1988) evaluated the improvement in pullout load by using geotextiles as ties to symmetrical anchor plates embedded in sand. Experimental tests were conducted on reinforced concrete model symmetrical anchor plates of cylindrical and belled shape, polypropylene ties of width 55 mm and thickness 0.72 mm being used. Results showed that symmetrical anchor plates with geotextile ties offered greater uplift response than those without ties. Furthermore, the single layers of ties close to the symmetrical anchor plates were reported to be more effective than the use of multiple layers.

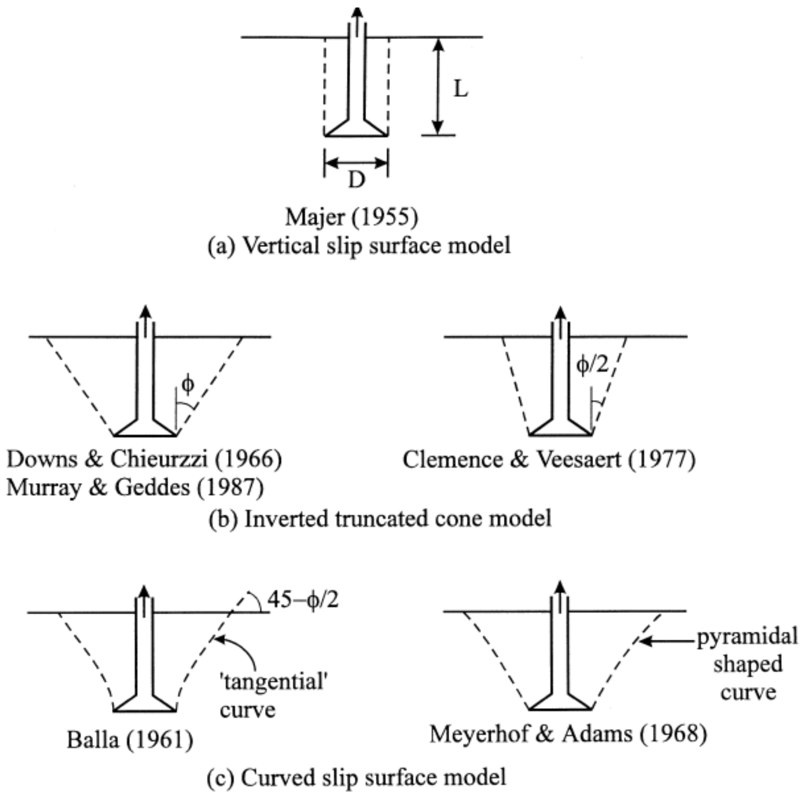

Fig. 1 Failure mechanism for various uplift design methods

Failure mechanism for various uplift design methods illustrated in Fig. 1.

3. Symmetrical anchor plates in reinforced

Increasing use of anchors to resist and sustain uplift forces may be achieved by increasing the size and depth of an anchor or the improvement of soil in which these anchors are embedded, or both. In restricted situations, increasing the size and depth of an anchor may not be economical compared with other alternatives. On the other hand, soil improvement can be attained by the inclusion of soil reinforcement to resist larger uplift forces. However, few investigations on the behavior of horizontal plates in a reinforced soil bed under uplift loads were reported. Subbarao *et al*. 1988 studied the improvement in pullout capacity by using geotextiles as ties to reinforced concrete model anchors embedded in sand. Selvadurai (1989, 1993) reported significant enhancement, of the order of 80 to 100%, in the uplift capacity of pipelines embedded in fine and coarse-grained soil beds reinforced by inclusion of geogrids immediately above the pipeline in an inclined configuration. Krishnaswamy and Parashar (1991, 1994) studied the uplift behavior of circular plates and rectangular plates embedded in cohesive and cohesionless soils with and without geosynthetic reinforcement and reported that the geocomposite reinforcement offered higher uplift resistance than both geogrid and geotextile reinforcement.

Ilamparuthi and Dickin (2001) investigated the behaviour of soil reinforcement on the uplift response of piles embedded in sand through model test with cylindrical gravel-filles geogrid sell was placed near pile base. Authors were reported increases the uplift response of piles with many factors such as diameter of the geogrid cell, sand density, pile bell diameter, and embedment as illustrated in Figs. 2 and 3.

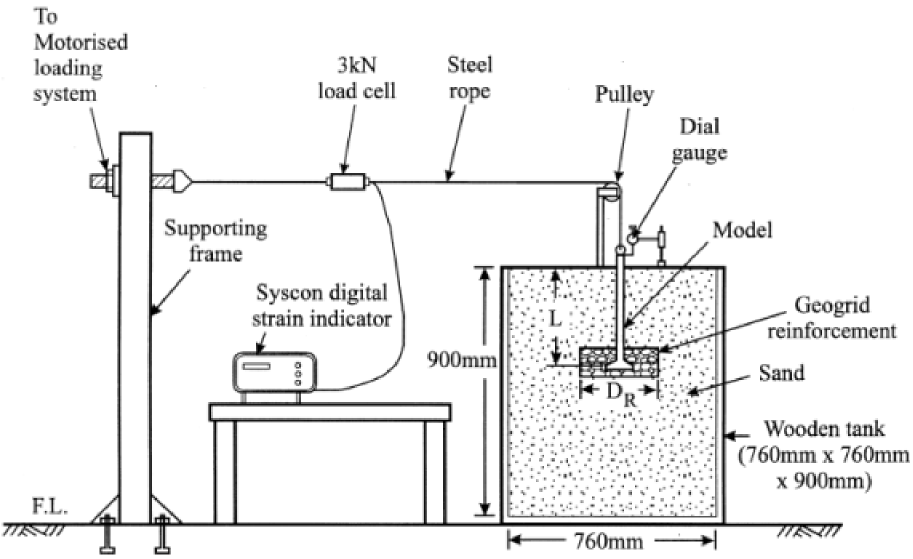

Fig. 2 Schematic diagram of experimental test by Ilamparuthi and Dickin (2001)

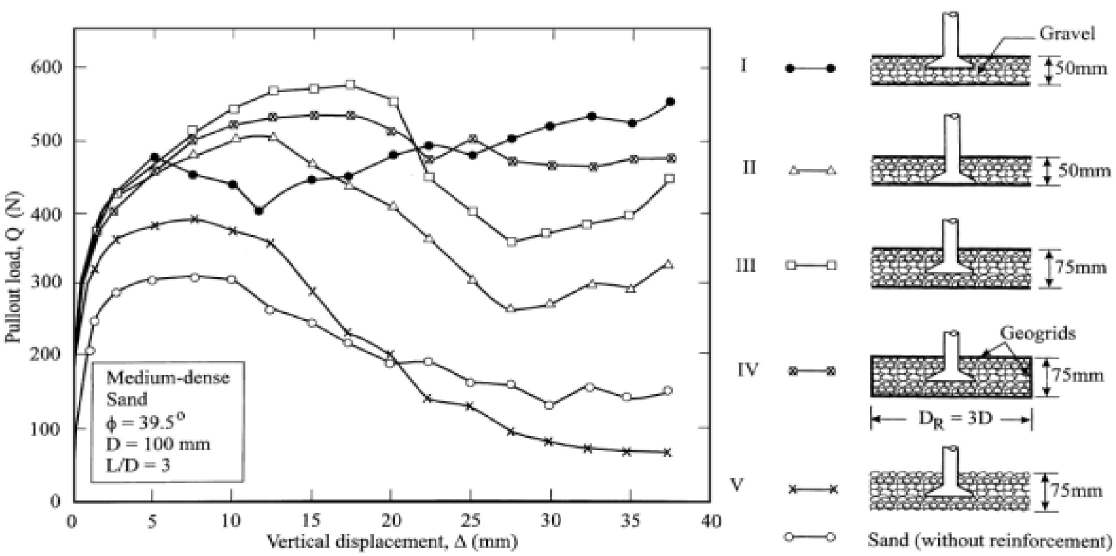

Fig. 3 Non-reinforced and reinforced results of symmetrical anchor plates under uplift test by Ilamparuthi and Dickin (2001)

4. Symmetrical anchor plates in geosynthetic multi - layers

El Sawwaf (2007) conducted a laboratory experimental investigation on strip anchor plate to investigate the uplift response in sand. Uplift response of symmetrical anchor plates located close sandy slopes with and without geosynthetic reinforcement has been evaluated in tests. Strip anchor plates were used in the experimental work to research the effect of soil reinforcement on the uplift behavior of anchor plates using plane strain. Strip anchor plates made of steel with 498 mm in length, 6.0 mm in thickness, and 80 mm in width were made with a special whole 3.0 mm in diameter in the center and used in the research. Authors found many conclusions such as increase the ultimate pullout response of an anchor plate embedded to the slope crest and anchor plate improvement is very dependent on geosynthetic layer length and increases significantly until the amount of beyond that further increase in the layer length does not show a significant contribution in the anchor resistance. Geosynthetic layers were placed to reinforced slope as shown in Fig. 4.

5. Symmetrical anchor plates in non-reinforced and reinforced

Ilamparuthi *et al*. (2008) investigated two series on the submerged sand effect of symmetrical anchor plates on uplift response of treated non-reinforced and reinforced sand. Influence factors such as embedment ratio, density and number of geofrid layers were investigated. Authors were reported the load - displacement behavior of non-reinforced and reinforced sand for a given density and embedment ratio were similar except higher peak and residual loads due to the geogrid materials as illustrated in Figs. 5 and 6. In the case of cyclic load, the displacement of symmetrical anchor plate was increased with decreasing rate and reached almost a constant value after 350 cycles.

6. Symmetrical anchor plates in GFR-reinforced

Niroumand *et al*. (2013) investigated the performance of symmetrical anchor plates in increasing uplift resistance of the sand at laboratory scales in Malaysia. Authors proposed new method for uplift response by new system, GFR. GFR is a new system to tie the geosynthetics into

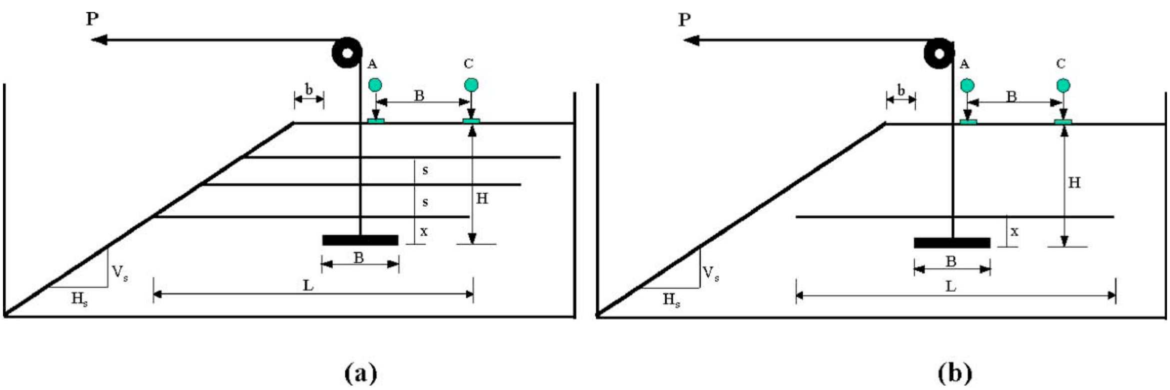

Fig. 4 Geometric parameters of reinforced slope by El Sawwaf (2007)

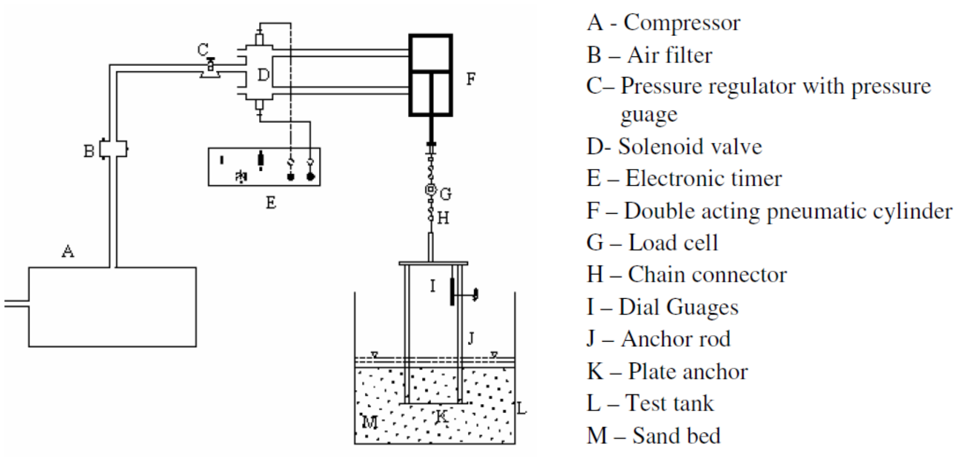

Fig. 5 Test set up for monotonic and cyclic loads by Ilamparuthi *et al*. (2008)

the ground GFR is made of Fiber Reinforcement Polymer (FRP). Authors increased uplift response of symmetrical anchor plates in reinforced sand. The research conducted ten series laboratory experimental investigation on symmetrical anchor plates such as squares, circulars and strips to investigate the uplift response in sand. Uplift response of symmetrical anchor plates located to sand box with and without geosynthetic reinforcement has been evaluated in tests. Symmetrical anchor plates were used in the experimental work to research the effect of soil reinforcement on the uplift behavior of anchor plates using plane strain. Authors found many conclusions such as increase the ultimate uplift response of anchor plate embedded using geosynthetic and GFR and anchor plate improvement is very dependent on geosynthetic layer length and increases significantly until the amount of beyond that further increase in the layer length does not show a significant contribution in the anchor resistance. Geosynthetic layers were placed to reinforced sand as shown in Fig. 7.

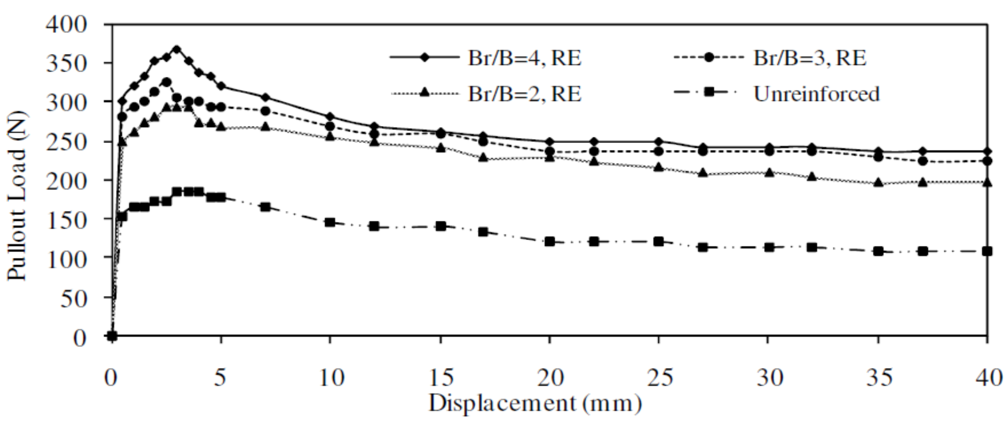

Fig. 6 Pullout response on symmetrical anchor plates in medium dense sand bed for H/B = 4 by Ilamparuthi *et al*. (2008)

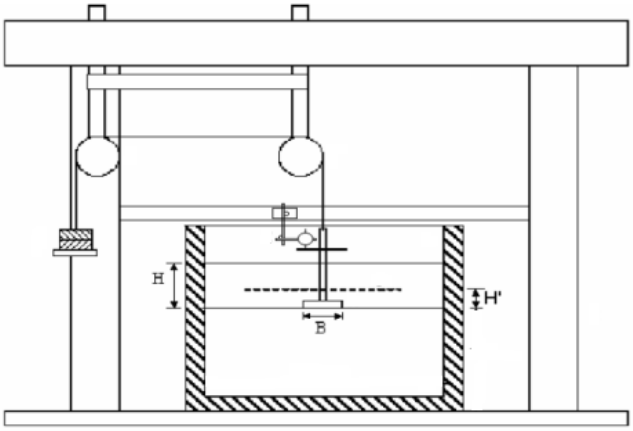

Fig. 7 Geometric parameters of reinforced sand by Niroumand *et al*. (2013)

7. Conclusions

The experimental works presented many results on a scale model of symmetrical anchor plates that are embedded to bed sand with and without geosynthetic reinforcement, the following conclusions are includes:

1. Increases the ultimate uplift response of symmetrical anchor plate embedded to sand.
2. Soil reinforcement can be considered as cost effective solution and can used to obtain the designed symmetrical anchor plates resistance instead of increasing the embedment depth or anchor sizes.
3. Based on experimental results, inclusion of one layer of geosynthetic on symmetrical anchor plate is more cost effective than soil reinforcement by multi layers.
4. Increase in the layer length does not show a significant contribution in the symmetrical anchor plate resistance
5. Increased sand density and embedment ratio data in greater uplift response without soil reinforcement.
6. GFR increased the uplift capacity for symmetrical anchor plates in sand.

Acknowledgments

The paper is prepared at Universiti Teknologi Malaysia, which is acknowledged.

References

Andreadis, A. and Harvey, R.C. (1981), “A design procedure for embedded anchors”, *Appl. Ocean Res.*, **3**(4), 117-182.

Chattopadhyay, B.C. and Pise, P.J. (1986), “Breakout resistance of horizontal anchors in sand”, *Soil. Found.*, **26**(4), 16-22.

Das, B.M. and Seeley, G.R. (1975a), “Inclined load resistance of anchors in sand”, *J. Geotech. Eng. Div.*,

101(GT9), 995-1008.
Das, B.M. and Seeley, G.R. (1975b), "Breakout resistance of shallow horizontal anchors", *J. Geotech. Eng. Div.*, **101**(9), 999-1003.
Dickin, E.A. (1988), "Uplift behavior of horizontal anchor plates in sand", *J. Geotech. Eng. Div.*, **114**(11), 1300-1317.
Dickin, E.A. and Leung, C.F. (1992), "The influence of foundation geometry on the uplift behavior of piles with enlarged bases in sand", *Can. Geotech. J.*, **29**(3), 498-505.
El Sawwaf, M.A. (2007), "Uplift behavior of horizontal anchor plates buried in geosynthetic reinforced slopes", *Geotech. Testing J.*, **30**(5), 418-426.
Ghaly, A.M., Hanna, A.M. and Hanna, M. (1991), "Uplift behaviour of screw anchors in sand II: Hydrostatic and flow conditions", *J. Geotech. Eng., ASCE*, **117**(5), 794-808.
Ilamparuthi, K. and Dickin, E.A. (2001a), "Predictions of the uplift response of model belled piles in geogrid-cell-reinforced sand", *Geotextiles Geomembr.*, **19**(2), 89-109.
Ilamparuthi, K. and Dickin, E.A. (2001b), "The influence of soil reinforcement on the uplift behaviour of belled piles embedded in sand bed", *Geotextiles Geomembr.*, **19**(1), 1-22.
Ilamparuthi, K. and Muthukrishnaiah, K. (2001), "Breakout capacity of seabed anchors due to snap loading", *Proceedings of International Conference in Ocean Engineering*, Chennai, India, September.
Kingshri, A., Ilamparuthi, K. and Ravichandran, P.T. (2005), "Enhancement of uplift capacity of anchors with Geocomposite", *Proceeding of National Symposium on Geotechnical prediction methods* (Geopredict 2005), IIT Madras, Chennai, India.
Krishnaswamy, N.R. and Parashar, S.P. (1994), "Uplift behaviour of plate anchors with Geosynthetics", *Geotextiles Geomembr.*, **13**(2), 67-89.
Krishnaswamy, N.R. and Parashar, S.P. (1992), "Effect of submergence on the uplift resistance of footings with geosynthetic inclusion", *Proceedings of Indian geotechnical conference*, Surat, India.
Meyerhof, G.G. (1973), "Uplift resistance of inclined anchors and piles", *Proceedings of the 8th International Conference on Soil Mechanics and Foundation Engineering*, 2, Moscow.
Meyerhof, G.G. and Adams, J.I. (1968), "The ultimate uplift capacity of foundations", *Can. Geotech. J.*, **5**(4), 225-244.
Murray, E.J. and Geddes, J.D. (1987), "Uplift of anchor plates in sand", *J. Geotech. Eng.*, **113**(3), 202-215.
Niroumand, H, Kassim, K.A. and Nazir, R. (2013), "The influence of soil reinforcement on the uplift response of symmetrical anchor plate embedded in sand", http://dx.doi.org/10.1016/j.measurement.2013.04.072
Niroumand, H., Kassim, K.A. and Nazir, R. (2010), "Uplift response of horizontal strip anchor plates in cohesionless soil", *Electron. J. Geotech. Eng.*, **15**, 1967-1975.
Niroumand, H. and Kassim, K.A. (2011), "Uplift response of square anchor plates in dense sand", *Int. J. Phys. Sci.*, **6**(16), 3938-3942.
Ovesen, N.K. (1981), "Centrifuge tests of the uplift capacity of anchors", *Proceedings of the 10th International Conference on Soil Mechanics and Foundation Engineering*, Stockholm, The Netherlands.
Selvadurai, A.P.S. (1993), "Uplift behaviour of strata-grid anchored pipelines embedded in granular soils." *Geotechnical Engineering*, **24**(1), 39-55.
Subbarao, C., Mukhopadhyay, S. and Sinha, J. (1988), "Geotextile ties to improve uplift resistance of anchors", *Proceedings of the First Indian Geotextile Conference on Reinforced Soil and Geotextiles*, Bombay, India.
Tagaya, K., Scott, R.F. and Aboshi, H. (1988), "Pull-out resistance of buried anchors in sand", *Soil. Found.*, **28**(3), 114-130.
Tian, Y. and Cassidy, M.J. (2011), "Incorporating uplift in the analysis of shallowly embedded pipelines", *Struct. Eng. Mech., Int. J.*, **40**(1), 29-40.
Trautmann, C.H., and Kulhawy, F.H. (1988), "Uplift load-displacement behavior of spread foundations", *J. Geotech. Eng. Div.*, **114**(2), 168-184.

CC