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Anchor Plates in Two-Layered Cohesion Less Soils

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Abstract: Problem statement: During the past few years a great number of experimental model and numerical analysis results on the uplift resistance of anchor plate embedded in homogeneous cohesion less soil has been reported by many researchers. A review of related literature shows that not much research has been done to analyze the performance of anchor plates in layered soils a problem, which is often encountered by the professional engineers in the field. **Approach:** This study presented the performance of the anchor plates in the cohesion less soil by different researchers. It was based on different previous researches, from the earliest till the most recent ones. The main aim of this research was focused on the prediction of the anchor plate's behavior and the force in the layered cohesion less soils. Few laboratory studies were conducted to investigate the uplift capacity behavior of cohesion less soil by previous researchers. **Results:** The experimental and numerical investigation included uplift test on cohesion less soil by last researchers. The embedment ratio and the effect of density on uplift response were evaluated. This analysis was investigated experimentally and numerically behavior of anchor plates buried in two layered cohesion less soil. Although earlier researchers developed experimentally expressions to estimate the uplift capacity of irregular anchor plates in layered cohesion less soils. **Conclusion:** The study observed that the ultimate uplift capacity is dependent on the relative strength of the two layers, the depth ratio of embedment and the upper layer thickness ratio.

Key words: Anchor plates, cohesion less soils, layered, break-out, ultimate pull-out capacity, uplift

INTRODUCTION

Based on a large number of laboratory model and large-scale test results many investigators reported the pullout resistance of anchor plates embedded in homogeneous soils, A review of related literature shows that not much work has been done to determine the ultimate pullout capacity in a two-layered soil, a problem that is often encountered in field. Figure 1 is shown the two-layered cohesion less soils for pullout loading of a layer of loose sand overlying dense sand.

Experiment, beginning from Bouazza and Finlay (1990) that they reported the behavior of an anchor plate buried in a two layered cohesion less soil. The testing program consisted of a 37.5 mm diameter circular anchor plate buried in dense sandy soil overlain by loose or medium dense sandy soil as shown in Fig. 2. The pullout tests were carried out on an anchor plate embedded at a depth D in a combination of layers of sand. The thickness of each layer was increased to a certain proportion of the anchor diameter and it was increased from 1-4 times the anchor diameter.

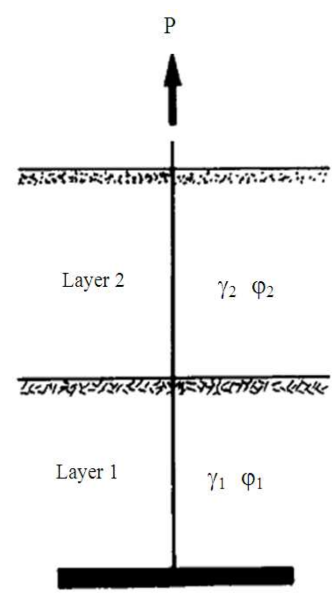

Fig. 1: Anchor plate under pullout load in two layered cohesion less soils

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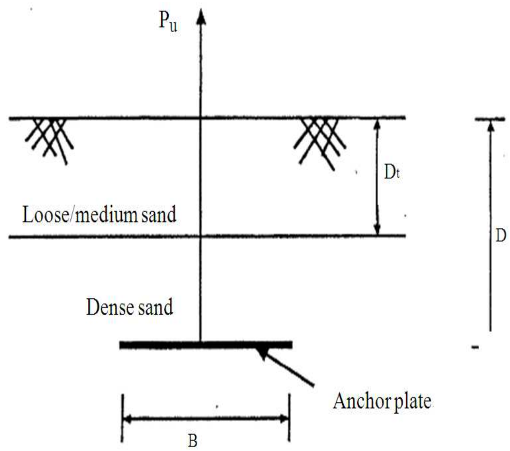

Fig. 2: Experimental investigations layered soil system used by Bouazza and Finlay (1990)

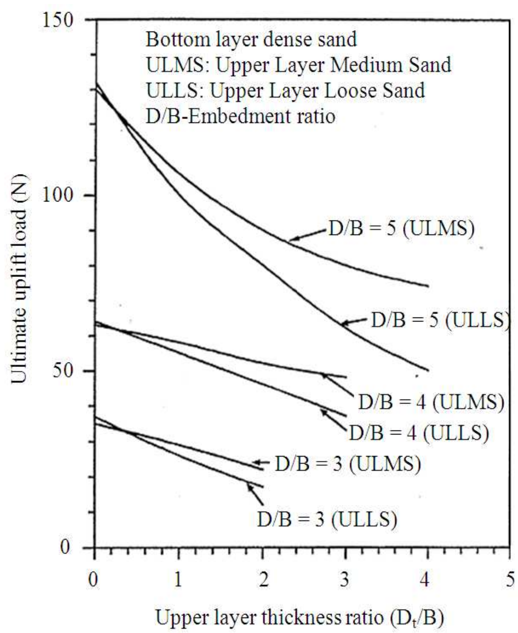

Fig. 3: Ultimate uplift capacity against ratio (Bouazza and Finlay, 1990)

It was reported that for upper layer thickness ratio of less than one and for a given embedment ratio, D/B there was no difference between the pulling an anchor plate from a dense-medium bed or a dense-loose bed. For a given D/B ratio and the upper layer thickness ratio of 1-4 a dense-medium bed gives a greater pullout than a dense-loose bed as shown in Fig. 3. It is observed that the ultimate uplift capacity is dependent on the relative strength of the two layers, the depth ratio of embedment and the upper layer thickness ratio.

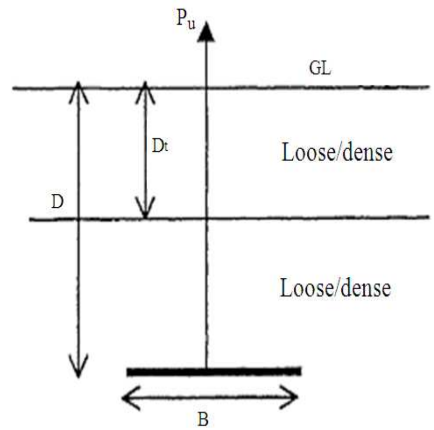

Fig. 4: Anchor plate analyzed by Krishna (2000)

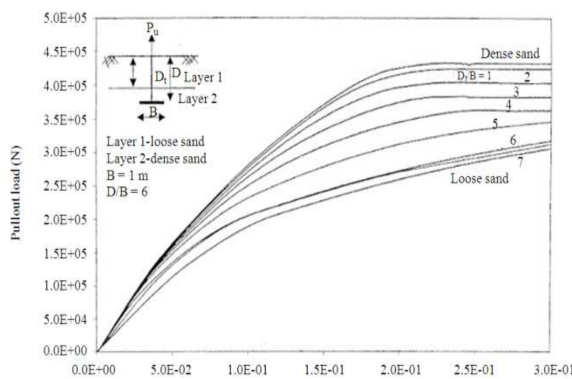

Fig. 5: Load-displacement curves used for the analysis in FLAC 2D by Krishna (2000)

Krishna (2000) reported the behavior of large size anchor plates in two layered cohesion less soil using an explicit two-dimensional finite difference program FLAC 2D. Soil is assumed to be a Mohr-coulomb strain softening/hardening material. The geotechnical properties of backfill of anchor foundations are very sensitive to construction and compaction methods. There is no satisfactory method to analyze the behavior of anchor plates in such inhomogeneous cohesion less soil conditions.

The two layered soil for this analysis consisted of two cases (a) a layer of loose sand overlaid by a dense sand layer and (b) a layer of dense sand overlaid by a loose sand layer that it is shown in Fig. 4.

For the present analysis he had chosen published properties of Chattahoochee River cohesion less soil both at dense and loose conditions (Vesic and Clough, 1968). The soil properties used for the analysis are shown in Table 1.

Table 1: The soil properties used for the analysis in FLAC 2D by Krishna (2000)

Property	Loose sand	Dense sand
γ	13.17 kN m^{-3}	15.43 kN m^{-3}
φ	32.5°	32.5°
ψ	0°	10°
E	6Mpa	19.6 Mpa

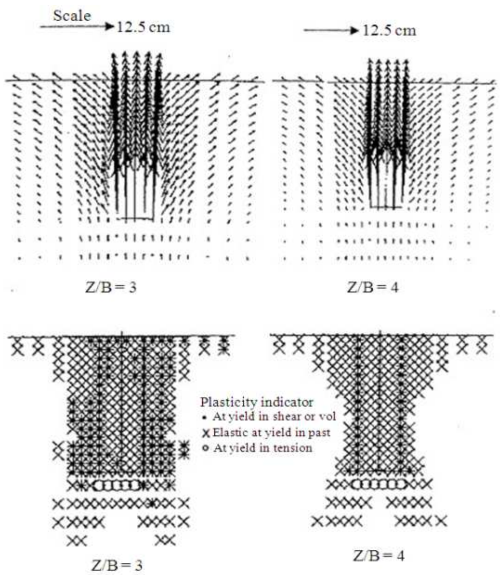

Fig. 6: Displacement vectors and plastic regions at failure for B = 1 m and embedment ratio, D/B = 4 in layered soils in FLAC 2D by Krishna (2000)

In the analyses, width of the anchor plate (B) is considered as one meter and the embedment ratio is varied from 2-8. The upper layer thickness (D) is varied from minimum of B to maximum of (D+2B). The material properties of the anchor plate are kept constant. It is assumed that the plate is sufficiently stiff as not to affect the pullout response. Figure 5 shows the variation of with for different D/B ratios. The ultimate pullout capacity is decreasing with increase in the case where bottom layer is dense sand and top layer is loose sand that Fig. 6 shows displacement vectors and plastic regions at failure in layered cohesion less soils.

Niroumand and Kassim (2010) reported the behavior of the irregular anchor plate buried in a two layered sandy soil. The testing program consisted of two 159 and 297 mm long irregular anchor plates buried in dense sandy soil overlain by loose sandy soil as shown in Fig. 7. The soil properties used for the experimental work are shown in Table 2. The pullout tests were carried out on an irregular anchor plate embedded at a depth D in a combination of layers of sand.

Table 2: The soil properties used for the experimental work by Niroumand and Kassim (2010)

Property	Loose sand	Dense sand
γ	14.90 kN m^{-3}	16.95 kN m^{-3}
φ	35°	42°
C	0	0

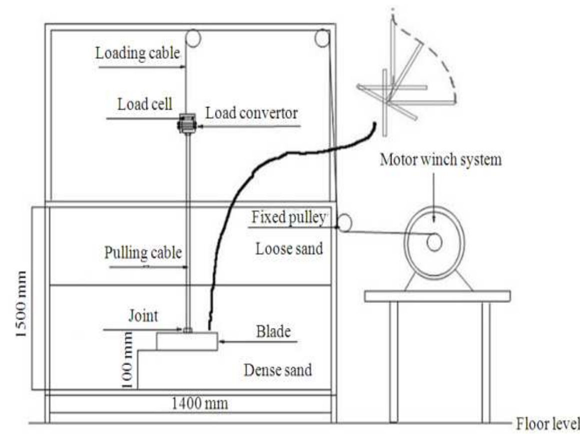

Fig. 7: Experimental investigations layered soil system used by Niroumand and Kassim (2010)

Fig. 8: Testing setup used by Niroumand and Kassim (2010)

The testing program consisted of the irregular anchor plates buried in dense sandy soil overlain by loose sandy soil as shown in Fig. 7. The thickness of each layer was increased to a certain proportion of the anchor long and it was increased from 1-4 and 1-7 times the long irregular anchor plates. It was reported that for upper layer thickness ratio of less than one and for a given ratio, D/B there was no difference between the pulling a plate anchor from a dense-loose bed. For a given D/B ratio and the upper layer embedment ratio of 1-4 a dense-loose bed in bigger irregular anchor plate (SHS2) gives a greater pullout than upper layer embedment ratio of 1-7 a dense-loose bed in smaller irregular anchor plate (SHS1), respectively in Table 3.

Table 3: Uplift response maximum values by Niroumand and Kassim (2010)

	D/B							
D/B	1	2	3	4	5	6	7	
1	614	-	-	-	-	-	-	PSHS1[1]
								PSHS2[2]
2	-	1089	-	-	-	-	-	PSHS1
								PSHS2
3	-	-	1509	-	-	-	-	PSHS1
								PSHS2
4	-	-	-	1997	-	-	-	PSHS1
	1307							PSHS2
5	-	-	-	-	2349	-	-	PSHS1
		2761						PSHS2
6	-	-	-	-	-	2813	-	PSHS1
			4216					PSHS2
7	-	-	-	-	-	-	3297	PSHS1
				5689				PSHS2

[1] SHS1: Irregular anchor plate with 159 mm in long; [2] SHS2: Irregular anchor plate with 297 mm in long

CONCLUSION

As a conclusion, this study shows that the last experimental tests and numerical analysis have been done regarding to performance of the anchor plate in layered cohesion less soil. Inevitably such a wide range of parameters will contribute to conflicting conclusions for the ultimate pullout load of the anchor plates. These researches have been done, using different regular/irregular anchor plates and soil parameters. Unfortunately, the results obtained from the laboratory tests are typically a specific problem and are difficult to extend and develop to field problems, due to the different materials or the geometric parameters used in the field scale. It is observed that the ultimate pullout capacity is dependent on the relative strength of the two layers, the depth of embedment ratio and the upper layer thickness ratio.

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