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The Soil-Anchors System Theories and Improvement: A Review Study

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ABSTRACT

In this paper, researchers have employed various methods and experimental ways to investigate the behavior of the soil-anchors system under the influence of varying load conditions. Also to focus on studying this system with improving the soil under loading with the anchor as a system. Therefore, the effect of soil geogrid improves the vertical anchor plates performance, and the test results show that the size, location, height, position, water content of the improved mass, and the variation of pullout load angle (0,25.45.60,90) degrees affect the resistance of the vertical anchor plate. But the improving the soil-anchors system with compaction the soil surrounding the anchor, adding the cement to soil, and improving with lime, that showed when the ratio of the improvement soil to the anchor-plate diameter be (D/d=1, D/d=1.5) with adding cement to soil and lime in other test in a percent less than 3%, the compaction test was the best in the evaluate the pull out of the soil-anchor system. If the percentage of the added cement to the soil is 6%, this will be more efficient in the strengthening process than compaction and lime. clayey layers above anchor plate, when loading the anchor plate by pull out in the physical model, the vertical displacement is increasing when increase the water content of the clay layer, also if the clayey layer in the solid state is above the sandy layer gives more displacement than the sandy layer above the clayey layer.

Keywords: Anchors, Mechanism of loading, Sandy soil, Failure mechanism.

1. INTRODUCTION

The anchors acutely mean a forming almost from a steel material used to stabilize any structure in any space. So, an anchor is a device normally made of metal used to secure a vessel to the bed of a body of water to prevent the craft from drifting due to wind or current. The word derives from Latin ancora, which itself comes from the Greek ἄγκυρα /ankȳra/ in Oxford dictionaries in general. But geotechnical engineering is used to stabilize walls, cracks, etc. Ground anchors have become an important component in modern construction modes. Large development plans are invested inbridges ando the use of anchors is beneficial with the construction of structures such as bridges and tunnels for supporting the structures and

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to prevent sudden failure. In the development of some special lightweight structures like towers and marine structures, it was remarkable to design, construct and analysis a special tension soil-anchors system, because of the wind loads causing reactions larger than the weight of the self-structure, Anchor plates are also used for avoiding the overturning of the structures (laterally, or uplift) loads. Anchor plates can be applied in many applications, like the stabilization systems in tunnels, aircraft mooring foundations to support the ships near the seaport, and to give the desired tension capacity for the retaining walls, sea walls. The tension capacity for the soil-anchor system is mainly derived from the passive force of the soil in front of the anchor plate **(Mors, 1959).** Even if the soil manner is stable, there will be some movement in the soil-anchor system. The anchor-plate system must be buried in undisturbed stable soil to withstand the required tension capacity. The pullout capacity of the vertical, horizontal, or inclined anchor-pile depends on the soil conditions. If the anchor is buried in loose soil, it will not give the required tension. The soil doesn't give any reliable tensile strength; therefore, it should be improved to avoid any sudden failure.
This paper has presented the principles of the mechanism for the anchors and the previous studies of the soil-anchors system. The objectives of this paper are to give a scope on the anchor-plate embedded within the soil layers under loading. Also, the improvement of the soil layer to overcome external loading, be increasing the weight of the soil layers or enhancing the contraction between the particles and the layers of the soil by using a chemical or physical precept. The understanding of the mechanism by which the load from the anchor plate to the soil depends upon the type of improvement of the soil, the shape of the anchor plate and whether the anchor is deep or shallow depth, according to the previous experimental studies.

2. SOIL-ANCHOR SYSTEM

Many studies have been carried out about the soil-anchor system until these days and all of them are trying to strengthen the capacity of the anchor to resist the pull-out forces due to external loading or via the structure itself through improving the soil that embeds the anchor. because the anchor is almost made from a material that has adequate resistance against tension (pull out), but the media that embrace the anchors is often soil, as we know it's brittle against pull out from it. In this way, the researchers investigated and tried to improve the soil.

2.1 The Theories of Failure for the Soil-anchors System

Many theories have been established to describe the failure of the plate anchor under pullout loading. In the present time period is a need to use the anchors in construction. Models studied the behavior of anchors.

2.1.1 Soil Cone Theory

The earliest theory that discussed the failure of plate anchor **(Downs and Chieurzzi, 1966)** described the failure in plate anchor by discussing the failure of shallow anchors, as a truncated cone with Angle $\theta = 90 + \text{Ø}/2$, as shown in **Fig. 1**.

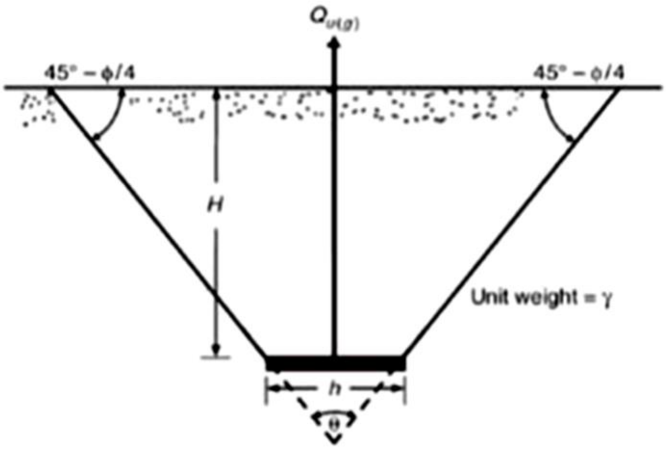


Figure 1. Soil Cone theory **(Downs and Chieurzzi, 1966).**

Then, the ultimate pull-out resistance of the plate anchor is assumed and equal to the volume of soil (v) above the anchor plate. That can be converted to the weight of the soil (Q_u) will be as in Eq. (1):

$$Q_u = \gamma * V \tag{1}$$

Where the (γ) is the unit weight of the soil that's lying above the plate anchor **(Downs and Chieurzzi, 1966).** After several years, they developed the same above theory and assumed (θ) to be (60 degrees) as illustrated in **Fig. 2**. These theories neglected the frictional shearing resistance between the particles of the soil along the failure surface.

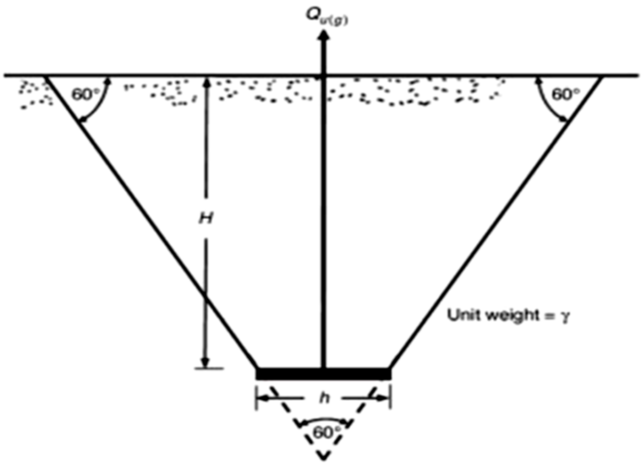


Figure 2. Developed Soil Cone Theory **(Downs and Chieurzzi, 1966).**

2.1.2 Friction Theory

One of the frictional theories for estimating the failure surface in plate anchors. The theory considers the failure envelope as a cylinder and the friction resistance along the perimeter as Eq. (2). This theory assumes the shape plate anchor is a circle **(Shukla and Das, 2013)** as shown in **Fig. 3**.

$$Q_u = \left(\frac{\pi h^2}{4}\right)(H \gamma) + \int_0^H \sigma 0 \tan \emptyset \, dz \tag{2}$$

Which (σo) is the effective stress, and ($\emptyset$) the friction angle, as in Eq. (3)

$$Q_u = \left(\frac{\pi H h^2 \gamma}{4}\right) + \frac{\pi}{2}\left(\gamma h H^2 K^{\circ} \tan Ø\right) \tag{3}$$

Which is (K_o) the effective earth pressure assumed (K_o= 0.5) for granular soil and (K_o= 0.4) or cohesion soil. Also, assumed (Ø) is equal to (30°) for granular soil and (20°) for cohesion soil.

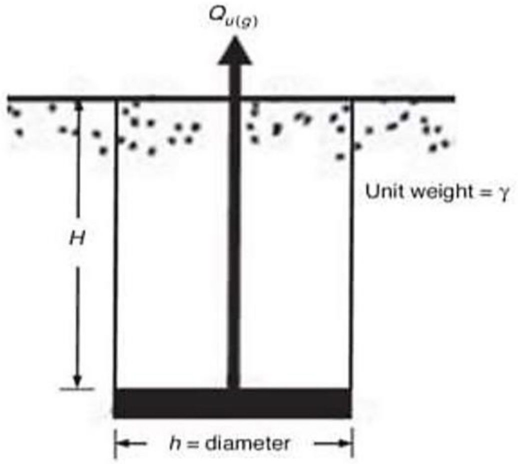


Figure 3. Friction Theory **(Shukla and Das, 2013)**.

2.1.3 Balla's Theory

(Balla, 1961) has developed an approach based on trials, by assuming the failure surface for shallow anchor plate to be a circle arc of the radius (r = H /sin(45+Ø/2)] **Fig. 4**. As a result, the resistance of pull-out loading was equal to the shear friction along the slip surface in addition to the weight of the soil in the failure surface.

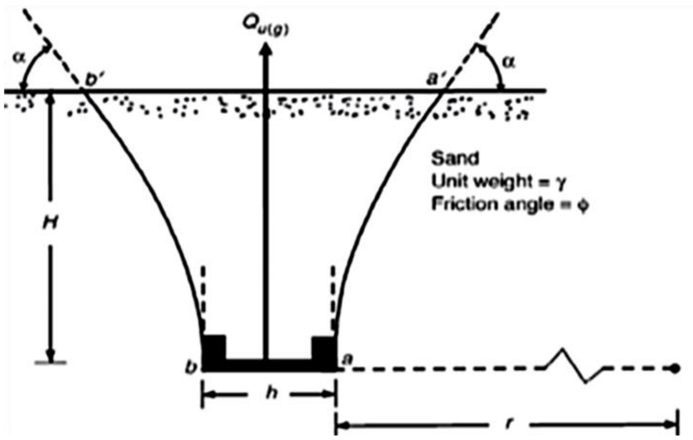


Figure 4. Balla's theory **(Balla, 1961)**.

The ultimate uplift pressure can be predicted as explained in Eq. (4)

$$Q_u = H^3 \gamma \left[F_1 (Ø, H h) + F_3 (Ø, H h)\right] \tag{4}$$

For the embedment ratio (H/h) and friction angle(Ø), the F1(Ø, H/h) and F3(Ø, H/h) are plotted in **Fig. 5**. At a ratio of embedment of (H/h ≤ 5), Balla's theory is consistent well with the pull out resistance of anchors embedded in dense sand. While overestimated values of uplift for anchors in loose and medium sand, Balla's theory overestimates the net pull-out capacity for (H/h > 5) even in dense sand.

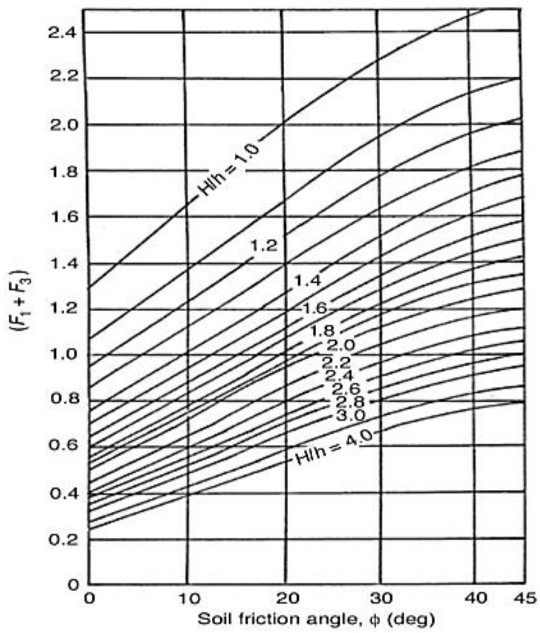


Figure 5. (F1 + F3) Variation Based on **(Balla, 1961)**.

2.1.4 Baker's and Kondner's Theory

Baker and Kondners have used a number of tests as a dimensional analysis. **(Baker and Konder, 1966)** proved Bella theory and proposed a formula for the research carried out for shallow and deep anchors. For shallow circular plate anchor as Eq. (5).

$$Q_U = C_1 L D^3 \gamma + C_2 D^3 \gamma \quad (5)$$

Deep circular plate anchor as Eq. (6).

$$Q_U = 170\ D3\ \gamma + C_3\ t\ D^2 \gamma + C_4 L D \quad (6)$$

Where(t): the thickness of plate anchor.
(C_1, C_2, C_3, and C_4): constants depending on the soil friction angle and the relative density of compaction.
(L): Impeded length.
(D): width of the anchor plate.

2.1.5 Mariupol'skii's Theory

(Mariupol'skii, 1965) suggested a mathematical calculation to describe the behavior of a circular plate anchor under pull out effect. The study has been carried out for the shallow and deep soil-anchors systems. Initial forces depended on the weight of the plate anchor and also on the weight of the soil above the plate anchor. The soil volume is a column with (D) diameter of plate anchor and (H) height of the soil or the depth of the embedded plate anchor. Friction and the cohesion of the soil has been affected along with the circumference of the plate. For a shallow circular plate anchor as described in Eq. (7) to calculate the ultimate uplift.

$$Q_U=\frac{\pi}{4}(D^2+d^2)\frac{\gamma\left(1-\left(\frac{d}{D}\right)^2+2K\left(\frac{L}{D}\right)tan\emptyset\right)+4C\left(\frac{L}{D}\right)}{1-\left(\frac{L}{D}\right)^2-2n\left(\frac{L}{D}\right)} \quad (7)$$

(K_0) lateral earth pressure coefficient,
(C) cohesion of the soil,
(n) 0.025Ø for frictional soil,
(d) diameter of anchor rod.
For deep circular plate anchor as Eq. (8).

$$Q_U=\frac{\pi q^\circ}{2}\left(\frac{D^2-d^2}{tan\emptyset}\right)+\int(\pi d)(L-(D-d)) \quad (8)$$

(q_0) radial pressure under which the cavity is expanded
(∫) unit skin friction along the stem of the anchor plate.
As shown in **Figs. 6 and 7,** respectively.

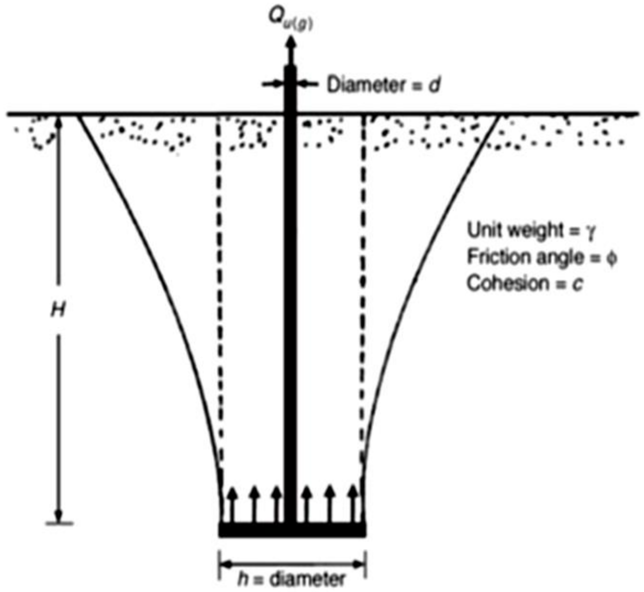


Figure 6. Mariupol failure theory shape for shallow anchor **(Mariupol'skii, 1965)**.

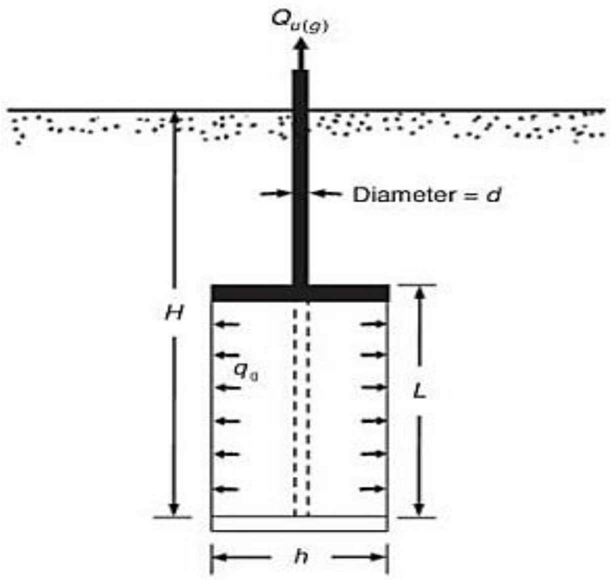


Figure 7. Mariupol failure theory shape for deep anchor **(Mariupol'skii,1965)**.

2.1.6 Vesic's Theory

(Vesic, 1965) been studied uplift loading as an explosion point appears to the surface as a spherical shape near the surface of the soil, homogeneous and isotropic as shown in **Fig. 8**. Suggested the pull-out as a vertical force in the cavity(P_V), also the internal force for the failure line surface (F_V). All forces have vertical components as Eq. (9) and Eq. (10).

$$P_v = N_q \gamma H \quad (9)$$

$$N_q=(1+A_1(H/0.5*h_1)+A_2(H/0.5*h_1)) \quad (10)$$

where:-
A_1: Area of the left as shown in **Fig. 8**
A_2: Area of the right as shown in **Fig. 8**
H: Embedded length to the center of the cavity.
$h_1/2$: The radius of the sphere.

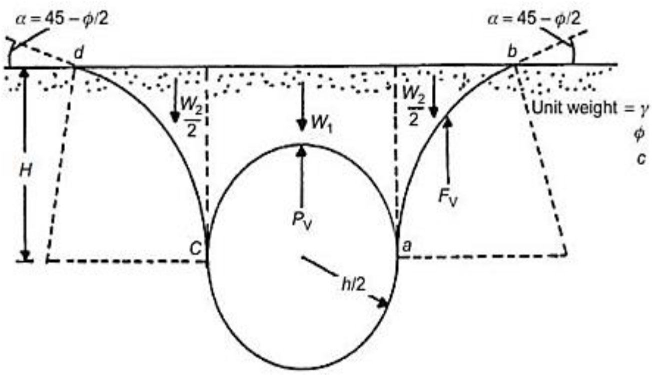


Figure 8. Vesic's theory of expansion of cavities **(Vesic, 1965)**.

2.1.7 Veesaert and Clemence's Theory.

(Veesaert and Clemence, 1977) suggested a list of laboratory tests for shallow circular anchor plates in order to estimate the failure surface. It has been assumed that the failure surface shape is formed as a cone with a cut tip and apex angle as shown in **Fig. 9**.

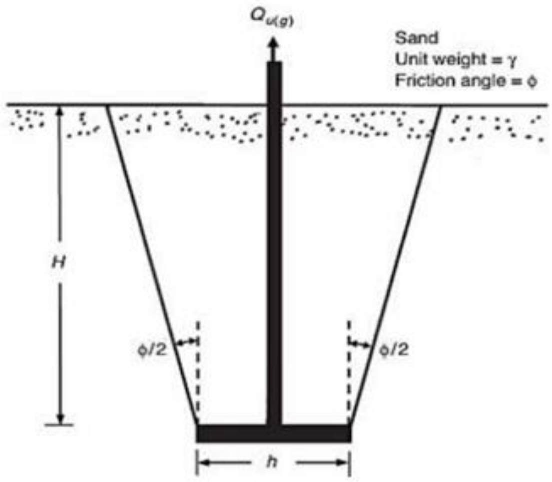


Figure 9. Failure surface for Veesaert and Clemence's theory **(Veesaert and Clemence, 1977)**.

The ultimate pullout resistance is given by as Eq. (11):

$$Q_u = ɣV + \pi ɣ\, K \tan \varnothing\, (Cos^2 \frac{\varnothing}{2})(\frac{H\string^2h}{2}+\frac{H\string^3+tan(\frac{\varnothing}{2})}{3}) \quad (11)$$

Where: V : The truncated cone volume above the anchor; K : The lateral earth pressure coefficient.

2.1.8 The Break-out Factor for Cohesionless Soil, Merifeild

(Veesaert and Clemence, 1977) showed that the uplift capacity for the anchors that are embedded in cohesionless soil is a function of the unit weight of the soil(ɣ) and the embedded length(H) of the anchor as expressed in Eq. (12) and viewed in **Fig. 10**.

$$F_q=\frac{Qu}{ɣAH} = \frac{Qu}{ɣ(\frac{\pi}{4h^2})H} \quad (12)$$

Where, (F_q) or ($N_ɣ$): Refer to the break out factor of the soil and represent the influence of the internal friction of the soil(Ø) and the embedded ratio of the anchor on the uplift capacity of the anchor. (H) is Embedded depth and (h) is Width of the plate.

The theories that derive and discuss the failure surface of the anchor plate are different from each other with the factor of safety and the dimensions of the physical model one of it is more conservative than the other, beside that a theory is a less reservation and it appears to me by taking a mathematical example to compare between the theories.

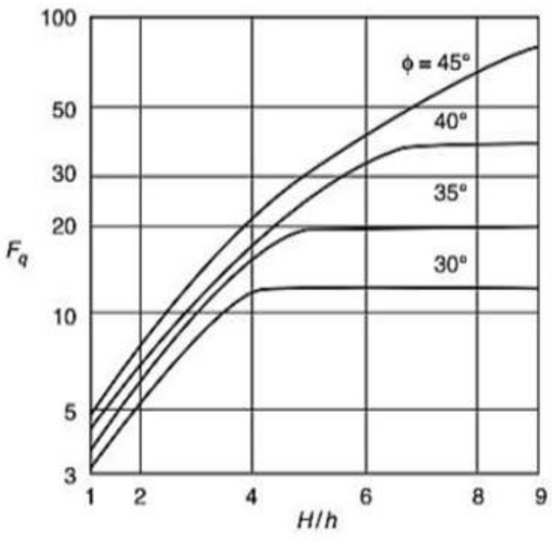


Figure 10. Variations of (F_q) for shallow circular anchor **(Veesaert and Clemence, 1977)**.

The theories that derive and discuss the failure surface of the anchor plate are different from each other, with the factor of safety and the dimensions of the physical model one of it is more conservative than the other as a Soil Cone Theory, beside that a theory is a less reservation as a Friction Theory.

3. ANCHORS IN GEOTECHNICAL

Many types of anchors depend on the geometrical shape and the path direction of the loading for the anchor elements that are used to support the structure to provide stabilization. The anchor elements are considered more economical to increase the efficiency of foundation resistance **(Kovacs and Blouin, 1975)**. The anchor provides a resistance for the structure to be stable against pull-out load **(Sabatini and Bachus, 1999)**. The overturning load and the pull-out load effect on structure because of external loads such as winds, earthquakes and inclined loads, that effect stability of the foundation and structure **(Hanna, 1982)**. Anchors represent one of the light elements supporting foundations by enhancing the resistance **(Catapult and ARUP, 2024)**. The field tests are most reliable for estimating load capacity **(Littlejohn and Mothersille, 2008; Ruggeri et al., 2013).**

3.1 Using Anchors in Practice

It's been used in structural facilities like as radar towers and energy towers transmission, ships moorings, submerged pipelines, tunnels, tieback earth retaining wall structures, waterfront structures, bends of pressure pipelines, and it is necessary to control thermal stress **(Niroumand and Kassim, 2016)**. And it seems to me that the classification of the anchor is based on many divisions, so the principle of the anchors mechanism by the load transferring from the structure toward the soil in fact every shape and type subjected to uplift loading is assumed to be anchors. Depending on the realization of the load transfer the strip footing with a column, if the column subjected to tension load the strip footing will be treated as anchor plate, also the buried pipes will have the same behavior. Depending on the above paragraph the resistance of the anchor plates against uplift loading derived from the weight of the anchor itself plus the weight of material-perhaps a soil above the anchor plate and the internal friction between the particles of the material _perhaps a soil_ in cohesionless soil. The usage of anchors has been developed for difficult soil conditions, such as the variation of the soil volume under different watering and drying phases, also in soft soil when the foundation is inside it to reduce the negative skin friction that can develop in the pile foundation **(FEMA, 2016)**. The structures that stabilize by using anchors whose own weight is less than the external loads to produce overturning or uplift pressure, the anchors provided a stabilization to such structures **(Sabatini et al., 1999)**. The cavities presence in the soil can cause problems affecting anchor capacity **(Al-Taie, 2004)**. Many reasons for cavities formation in the soil could be naturally or artificially **(Al-Mosawe and Al-Taie, 2007)**. Problematic soils such as Gypsum's soil change the properties of it. And the ability to cause collapses **(Seleam, 2006).**

3.2 Classification of The Anchors

Some classifications depend on the material that is made from steel or wood anchors **(Niroumand and Kassim, 2010)**. Anchors can also be classified into three types depending on the embedded depth to shallow, medium and deep anchors. Every type depends on the soil capacity and the loading path that affects it **(Shahriar and Jadid, 2020)**. Other categories, **(Niroumand and Kassim, 2016; Shukla and Das, 2013),** depending on the simple anchor, direct embedment anchor, helical Anchor, grouted anchor, anchor pile, drilled shift, suction caisson, drag anchors, and geo-anchors, the path of the loading may be vertical, horizontal and inclined loads as shown in **Fig. 12**.

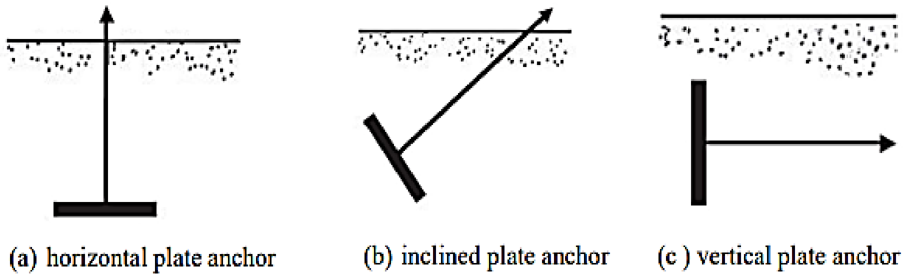


Figure 12. Different path loading **(Shukla and Das, 2013)**.

3.2.1 Helical Anchors

Considering the first types of anchors and widely used because of ease in installing via its shape like screw **(Tsuha et al., 2019)** helical plate connected to shift rod may be multiple as shown in **Fig. 13**.

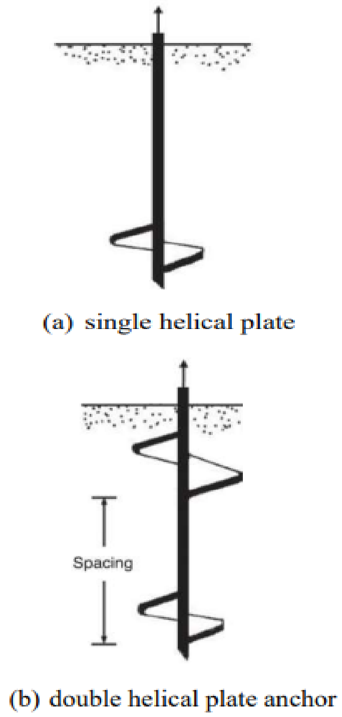


Figure13. Helical plate anchor **(Shukla and Das, 2013)**.

3.2.2 Grouted Anchors

Made from a rod drilled and embedded in the soil or cable and then filling the gaps around the rod by a grouting material such as cement this type is suitable for supporting sheet piles, and the structures that suffer overturning stresses. **Fig. 14** shows that **(Abdalftah and Omar, 2022)**. Depending upon the 500 tests that were carried out on the grouted anchors, which increased the strength of concrete in the strand (10%) every 7 MPa **(Stocker and Sozen, 1969)**. **(Littlejohn, 1979)** suggested that the minimum strength of the grouted material is 40 MPa to provide enough bonding and shear strength. In the presence of confined pressure with this type increases the pull-out capacity by using expansive cement **(Jarred and Haberfield, 1997; Benmokrane et al., 1995).** The applied load transfers from the grouted material to the ground by shear stresses **(Barley and Windsor, 2000).** While the distribution of stress along the grout-ground system was non-uniform along the bonding path **(Mastrantuono and Tomiolo, 1977; Sousa et al., 2021; Iten and Puzrin, 2010).** The failure surface of this anchor is a cylinder shape near the grouted mass **(Hobst and Zajíc, 1983; Su and Fragaszy, 1988).** The system has been stimulated numerically by using two dimensional symmetrical about an axis finite element model by software PLAXIS and ABAQUS **(Kim et al., 2006; Seo et al., 2019; Fabris et al., 2021).** For simplicity and for short time analyzing **(Seo and Pelecanos, 2017; Smet et al.,2019; Al-Baghdadi et al., 2022)** using a one-dimensional finite element model.

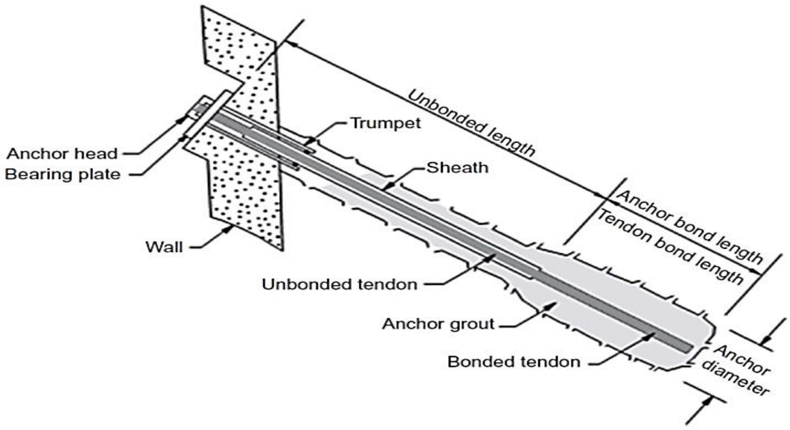


Figure 14. Grouted anchor **(Abdalftah and Omar, 2022)**.

3.2.3 Pile Anchor

There is another type of anchor that is used like a pile foundation via using an anchor plate and then filling it with concrete, and it will resist both tension and compression load exactly as a foundation **(O'Kelly et al., 2014)** or as a granular pile, **Fig. 15** explain that.

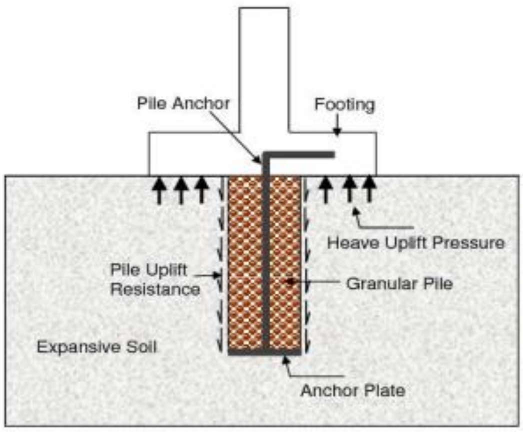


Figure 15. Pile Anchor **(Ismail, 2011)**.

3.2.4 Suction Caisson and Drag Anchors

(Abdalftah and Omar, 2022) Suction caisson and drag anchor commonly used in supporting the platform in sea as offshore. Consist from a wire or chain made from steel in usual connect to plate anchor which embedded to the seabed or connect buoyant platform.

3.2.5 Geo Anchors

It is type of anchors used to support the stability of ground slopes, reduce the lateral pressure on the retaining wall or to support the embankment on soft soil. It consists of geotextile material covering coarse sand or crushed stones. It's used in areas with high level water tables.

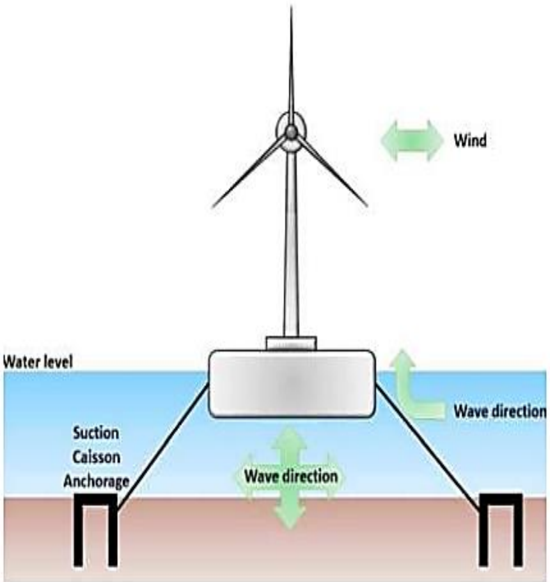


Figure16. Suction caisson anchor **(Abdalftah and Omar, 2022)**,

4. SOIL-ANCHORS SYSTEM IN A MULTI-LAYER

(Stewart, 1985) used two layers clay and sand of soil to enhance the capacity of the uplifting for the anchor-plate, in the test the overlaying a layer of the sand over a clayey layer enhance the capacity of the soil-anchors system, also the results were founded that the comparing loose sand overlying the clayey layer with a dense sandy layer show up a higher resistance for the pull out. In the other hand **(Bouazza and Finlay, 1990)**, used likewise two layers(cohesion-less) dense sand with loose or medium sand by installing a circular anchor plate in the layers of (37.5 mm) in diameter embedded in a depth (D) as shown in the **Fig. 17**.

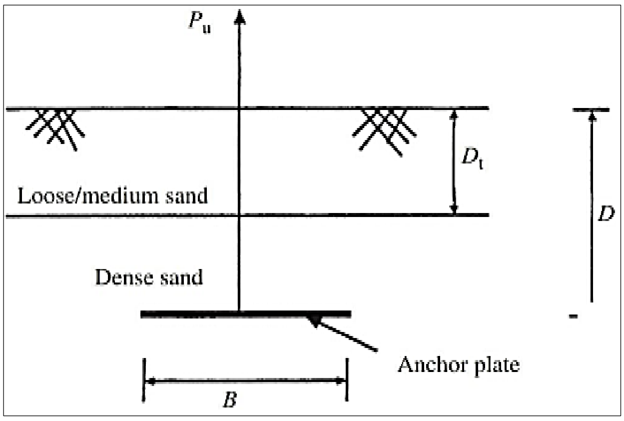


Figure 17. Experimental analysis of soil layered structure **(Bouazza and Finlay, 1990)**.

Throughout the tests there is no significant change in the pull-out capacity from using medium-dense sandy layers to using loose-sandy layers in the upper-layer thickness ratio less than (1) as the ratio(D/B). A significant effect was shown when using loose-dense layers have a little higher value in the pull out in the beginning of the curve (begin of the loading of the system) than the medium-dense layers but if the loading continuing for a few steps the two modes will equal together in the uplift then the medium-dense layers mode be higher resistance than other mode as illustrated in the **Fig.18**.

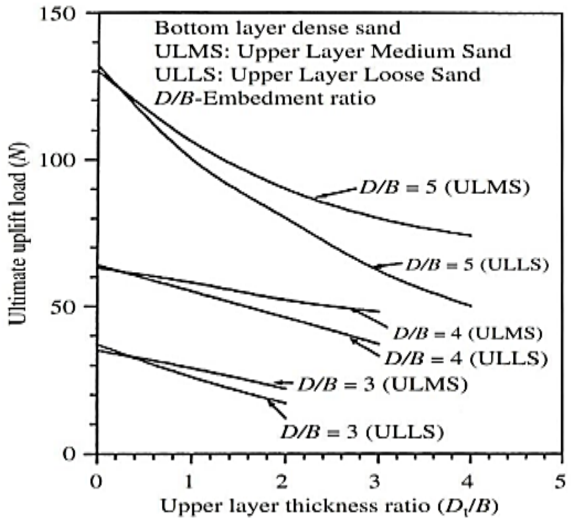


Figure 18. Illustrates the Ultimate capacity of uplift against the ratio **(Bouazza and Finlay, 1990)**.

Analytical programming by using finite difference (two-dimensional) with (FLAC 2D) to analyze an anchor-soil system behavior embedded in two-layered sandy soil. The model has been used as a strain hardening/softening Mohr-Coulomb material. The anchor plate was constructed in a geotechnical feature that depends on the compaction procedures. In these types of non- homogenous cohesion-less stratum conditions. As illustrated in **Fig.19**, the study of the soil (layered) in two stratifications: a loosely sandy layer above a densely sandy layer and a densely sandy layer above a loosely sandy layer. The soil used was taken from the "Chattahoochee River "The width of the anchor plate used was equal to (1m) while the embedment ratio was from 2 to 8. And the thickness of the upper layer ranged from (B) to (2B +D) values.

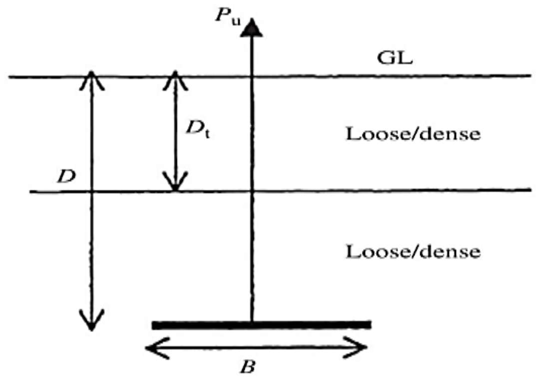


Figure 19. Analysis of the anchor plate **(Krishna, 2000)**.

The anchor plate's material properties were constant; the analysis found that when the bottom layer is dense sand and the top layer is loose sand, that will be an increment in the resistance of the anchor **(Krishna, 2000)**. **(Ali and Aziz, 2022)** the testing of the work of thirty-two tests are shown in **Fig. 20**. The curriculum has been subdivided into two aspects: The first part was with a layer of clay above a layer of sand when the properties of the clay layer is different in four states (solid, semi-solid, plastic and liquid) and then loading the system with and without adding the geogrid. The second way in the work concerned a layer of sand over a layer of Clay also loading the system with and without adding the geogrid. The samples of the soil were taken from An-Najaf (Iraq). The experimental work has been carried out by the cubic steel container model with dimension (70 cm x 70 cm x70cm). A circular steel plate anchor of (10cm) in a diameter was embedded at a constant depth of (30cm) from the surface of the soil. The relative density of sand is a constant at (60%).

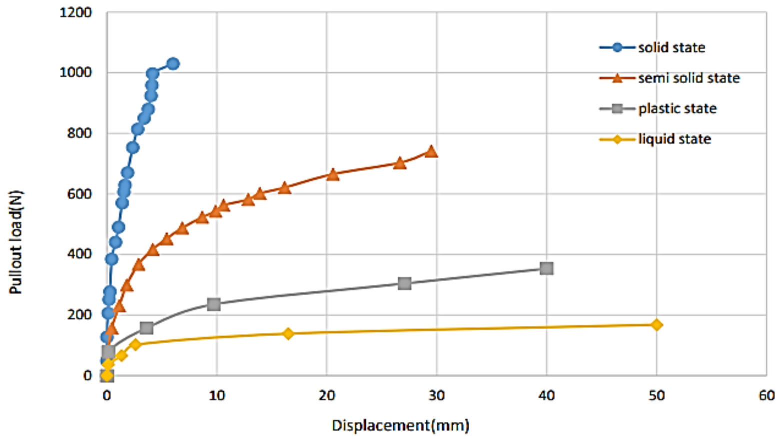


Figure 20. clay consistency for sand over clay layer **(Ali and Aziz, 2022)**.

But the clay layers were prepared in four cases (solid-state, semi-solid state, plastic state, and Liquid state) with densities of (14.8,14.6,11.6 and 9.8 kN/m^3) and water content of (11, 26.5, 46.65 and 62%) respectively. **Tables 1 and 2** show the failure load is maximum at solid state, and the treated soil results of clay over sand with geogrid at mid sand.

Table 1. Failure load for untreated soil when sand layer over the clay **(Ali and Aziz, 2022)**.

Untreated Soil state	Clay in solid-state	Clay in semi-solid state	Clay in plastic state	Clay in liquid-state
Failure load (N)	1030	740	360	170

Table 2. Failure load values for treated soil **(Ali and Aziz, 2022)**.

Clay over sand layer (clay in plastic state)		
Location of geogrid	**Failure load**	**Percentage of improvement %**
Untreated soil (N)	540	
Geogrid at mid sand (N)	845	56.48
Geogrid at mid clay (N)	577.8	7
Geogrid between layered soil (N)	654	21.11
Clay over sand layer (clay in liquid state)		
Location of geogrid	**Failure load**	**Percentage of improvement %**
Untreated soil (N)	320	
Geogrid at mid sand (N)	380	18.75
Geogrid at mid clay (N)	303	-5.31
Geogrid between layered soil (N)	348	8.75

The effects of the geogrid are clear when the sandy layer is above the clayey layer that when the solid state. On the other hand, the effect of laying one layer of geogrid is small when using a clayey soil at a plastic or liquid state for a clayey layer over the sandy layer. In the test of one layer of the geogrid, clayey soil with (semi-solid, plastic and liquid states) above sandy soil has a high magnitude of the anchor plate capacities and a low magnitude of the vertical displacements from the mode of sandy layer over clayey layer. As it appears when the sand layer is below the clay layer it gives a low capacity so the optimum location of the geogrid in the weaker layer and it is sand layer because it nears the plate.

5. SOIL-ANCHORS SYSTEM IN A MONOLAYER

The improvement of soil in horizontal anchor plate by using different mods (compaction, cement, and lime techniques), a physical model tests were carried out, percent of cement and lime material (1, 3, and 6%) were used in a different enhancement diameter, the ratio of the treated soil diameter to the anchor plate diameter be (1.0, 1.5 and 3.0) have been tested. The treated soil is placed into a steel model as shown in **Fig. 21**. Also, the anchor plate is embedded into the soil at a different depth ratio (h/T= 0.1, 0.2 and 0.3). Generally, the increase in ratio of the diameter of the soil treated to the anchor plate diameter (D/d) improves the capacity of the anchor plate **(Ali and Aziz, 2020)**. The pull-out resistance of the anchor plate increases with increasing embedded depth for the anchor plate. The result of the tests is shown in the curves below **Fig. 22 (Mahdi and Aziz, 2023)**.

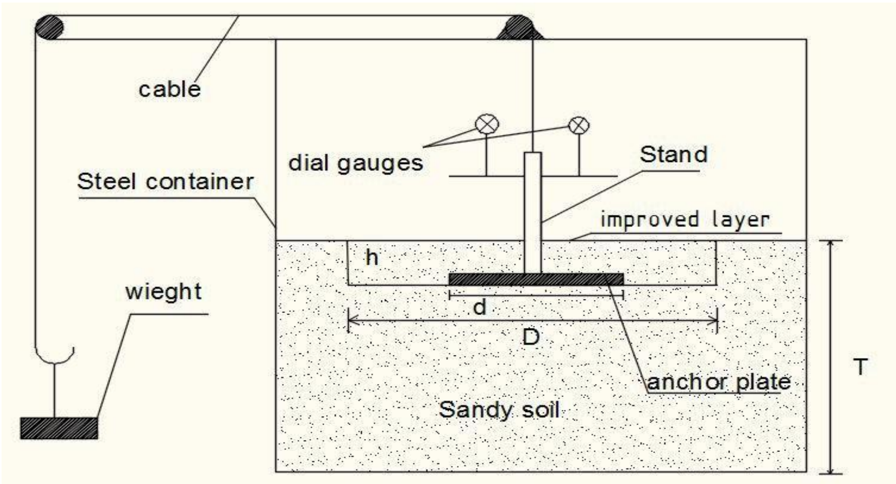
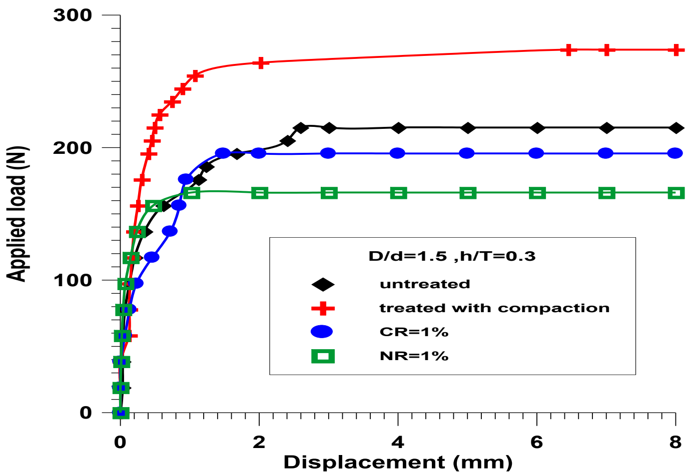


Figure 21. Tests program **(Ali and Aziz,2020)**.



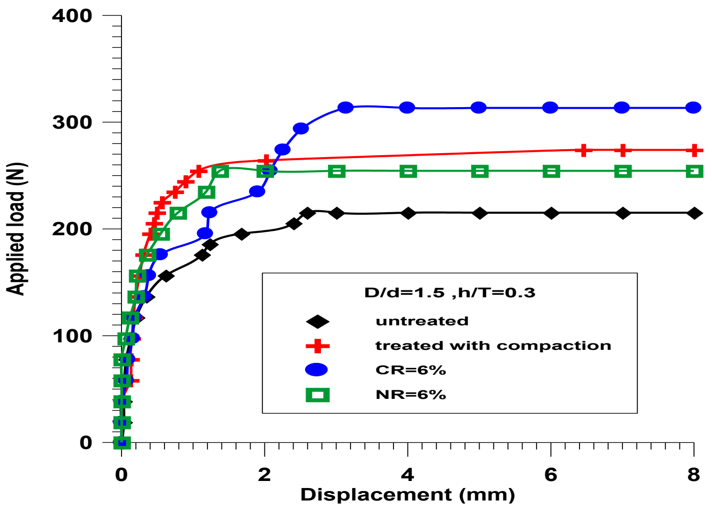


Figure 22. Effect of the improving of soil on the anchor pate capacity **(Ali and Aziz, 2020)**.

Using geogrid in sandy soil to enhance the soil-anchor system (anchor plate d=10cm) with different locations in various states (un-submerged step, and submerged) with different levels(h) during the loading by pull out as shown in **Fig. 23**. When the water levels tested in loading for untreated soil by geogrid were shown in **Fig. 24**. As the experimentations mentioned above, when the plate of the anchor is in a strong layer or in a layer that has a wide area of improving leads to increment of the resistance.

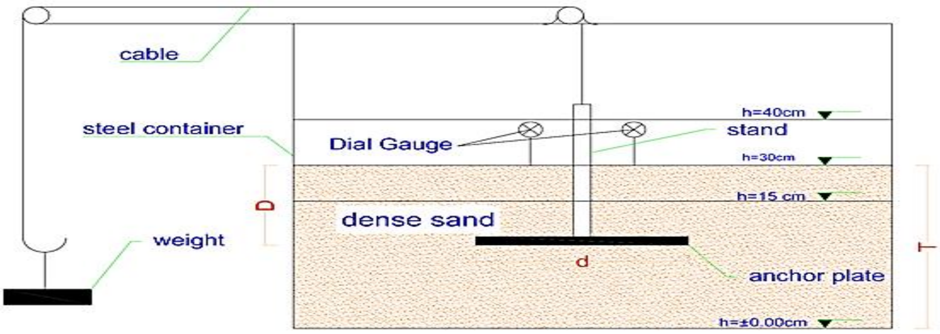


Figure 23. The sketch of the testing **(Mahdi and Aziz, 2023)**.

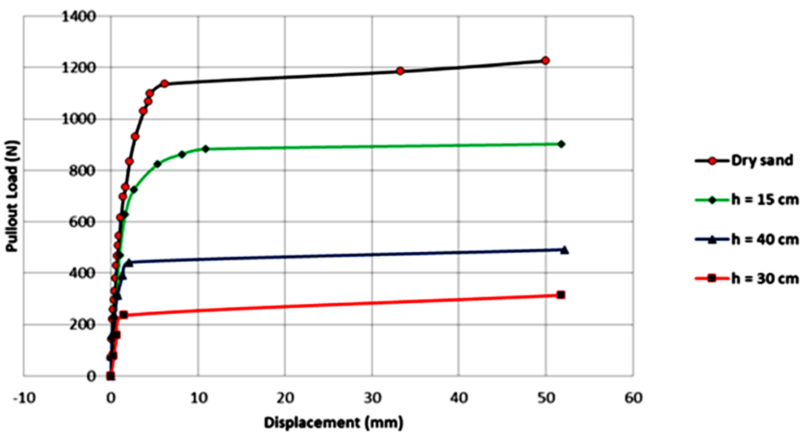


Figure 24. Effect embedded depth on the pull out **(Mahdi and Aziz, 2023)**.

(Kumar, 2003) was tested, the uplift resistance of shallow strip circular plate anchors embedded horizontally in sandy soils have been selected. The component of pull-out resistance due to the unit weight of the soil in dense sand beneath a loose sandy layer has been tested to be higher than the anchors embedded in loose sand under dense sandy stratum. **(Sakai and Tanaka, 2007)** tested the way of the shear path propagation, the pull-out resistance, also the scale effect of circular anchor horizontally at shallow depth embedded in two-layered sand by physical model as shown in **Fig. 25**. The shear path propagation direction depends on the sand unit weight density regardless of the location (upper layer or lower layer). The shear band became steeper with looser density, and the pull-out resistance increased with the depth of the dense layer over the medium bed.
(Ilamparuthi et al., 2008) Some load tests for anchor plates are also placed in submerged sand. The first testing was applied in submerged sand, while the second testing was conducted in submerged sand improved with a mono geogrid layer. Directly the geogrid has been placed on the anchor plate and the ratio (Br/B = 2, 3, and 4). The anchor embedment ratio (H/B=2, 3, and 4), the peak pullout load increases with the increasing the sand density and embedment ratio, and it's higher for the sand reinforced with geogrid than in untreated conditions regardless of embedment ratio and sand density.

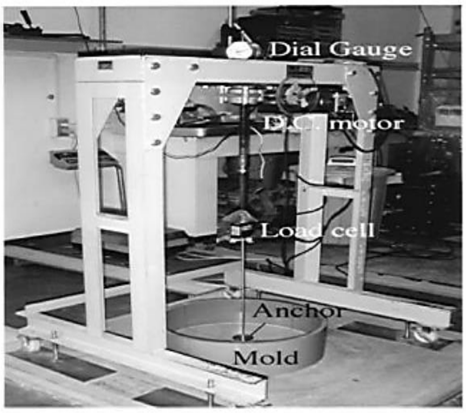


Figure 25. The practical apparatus **(Sakai and Tanaka, 2007)**.

(Emirler et al., 2016) For investigating the pull-out capability of a group anchors in sandy soil with and without enhancement by geogrid numerically and experimentally. The parameters that have been changed the number of geogrid layers and the effect of anchor embedment ratio, while the factors the separation distance among anchors, length of geogrid, the vertical separation distance of geogrid layers ratio, and the geogrid depth for the first layer were constant. Plaxis 3D, a finite element software, was used for modeling and analyzing experimental works. The pull-out capability of the plate increased by up to two-times of unreinforced sand, based on the reinforcement by geogrid as shown in **Fig. 26**.
(Choudhary et al., 2019) studied laboratory models tests, the studies have been carried out on the behavior of horizontally square plates in a sandy layer reinforced with geogrid. The untreated anchor plate groups showed a certain failure at the displacement ratio around (5%) from the anchor widths, while the reinforced groups showed a displacement ratio more than 45 % of the anchor widths, and a multiple improvement in pull out capability. For groups of two anchors, the optimum geogrid reinforcement width and length have been ranged to be (5) and (9.4) times the plate width, respectively.

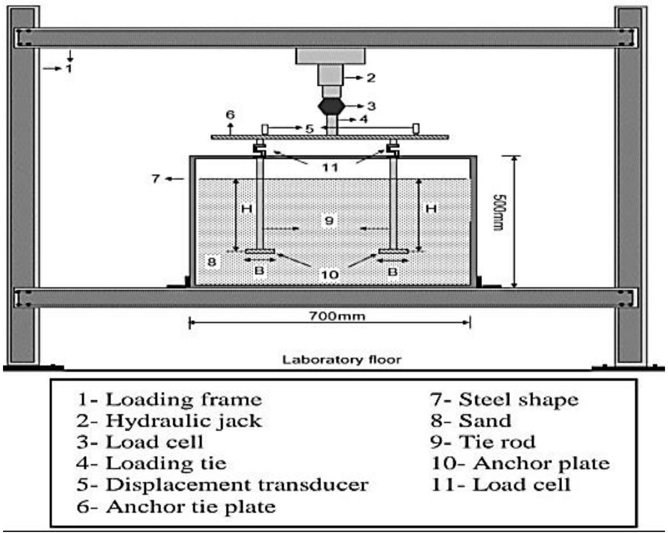


Figure 26. Test apparatus **(Emirler et al., 2016)**.

The showing of enhancement for solitary plates was shown to be the highest and will gradually decrease with the number of anchor plates increasing; however, this decrease is significantly smaller than in two to four. It has been found that in untreated sand, the optimal spacing between two anchor plates is (3.4) times the anchor plate width.

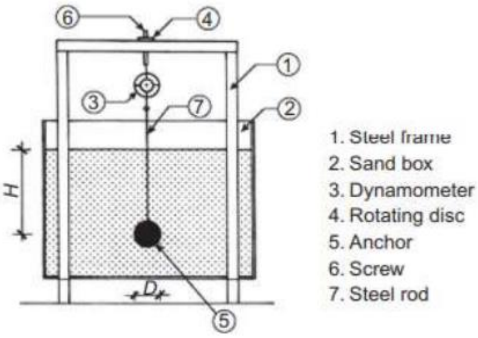


Figure 27. Experimental model skimp **(Frgic et al., 2004)**.

(Frgic et al., 2004) discuss the resistance of plate anchors, which suffer from the effect of pull out. In the models, the pull-out force was increased gradually while the displacement was measured in two directions perpendicular to each other. The models have taken the effects of several factors, such as embedment ratio and diameter ratio in the same soil and some conditions for the field and laboratory test, as shown in **Fig. 27**.

6. PERFECTION THE CAPACITY FOR SUNDRY SOILS WITH/WITHOUT ANCHOR PLATE

The enhancement of diverse soils with anchor types of foundations can be used the same manner with usage of the anchor plate. Below are some improvements to different soils and foundations.

6.1 Shallow Footing and Dune Sand

Fly ash has been used to improve the soft clay (Kaolin) bearing capacity by using a compacted layer of the fly ash under the footing, then noted a decrease in the settlement and increase in the bearing capacity, with a good ratio of improvement reached to 130**% (Al-**

Mosawe et al., 2011). **(Albusoda and Hessain, 2013)** have been tested the gypsum soil has been tested by replacing the soil with compacted dune sand, and during reinforcement of the replacing soil with geotextile and geogrid noticed that the bearing capacity increased (1.5-2) times on concentric load and (2.5-3) times during eccentric load. **(Albusoda and Salem, 2012)** has been stabilized the dune sand has been stabilised by using cement kiln dust CKD by preparing some laboratory tests on the dune sand mixed with the CKD and showed the results of the tests that the angle of the internal friction and the shear strength have been decreased and became almost constant after 14 days of curing. Gypsum soil is considered a problematic soil so in some studies such as (**Albusoda and Hessain, 2013)** this soil replaced by dune sand and reinforced the interface with a geotextile to improve the bearing capacity, so the results showed an increase from 2.5 to 3 times in the bearing capacity after replacing and reinforced.

Loose sandy soil has been enhancement during laboratory tests by **(Al Mosawe and Al Saidi, 2010)** to reinforce this type of soil by geogrid layers the researchers found that the bearing capacity of the soil reached to (22%) with using one layer of the geogrid and (47.5%) with no.=2 and depth ratio and vertical spacing between the geogrid layers (0.5B & 0.75B) respectively. The optimum spacing ratio and the number of the geogrid layers for soil subjected to inclined loading were studied in **(Bachay and Al-Saidi, 2022)**, The optimum spacing ratio was (0.5B) and percentage of the decreasing lateral displacement for the spacing ratio (0.5B, 0.75B,1B,1.25B) were (16%,10%,8%,7%) respectively and the percentage of the decreasing lateral displacement for the number geogrid layer (1,2,3,4) were (12%,16%,18%,20%), respectively.

6.2 Poly-Materials in Enhancement

The polymer-fiber has taken the chance to enhance the bearing capacity with length (3cm) in both directions and thickness (2.5 mm) of the sandy soil subjected loading from a square footing (5, 7.5, 19) cm, in the testing of the footings in the sand-polymer mixture the increasing of the bearing capacity were (1.4 to 2.5), (1.7 to 4.9), and (1.8 to 8) of footings (5, 7.5, and 10 cm), respectively **(Mekkiyah, 2013)**. The polyethylene high density when adding to the sandy soil it will change the characteristics of the soil so the **(Jasim et al., 2021)** tested that changes and showed that the adding of high-density from polyethylene (HDPE) to the soil with percent (0.1, 0.3, 0.6, 1, and 3%) caused reduction in the soil permeability (18%) and increase in angle of internal friction, the CBR, and shear strength (27.2%, 180.9%, and 38.6 %) respectively by using(1%) HDPE.

6.3 Geogrids in Enhancement

(Al-Mosawe and Al-Saidi, 2008) enhance the bearing capacity of the sandy soil by reinforcing the soil with Geogrid layers and find the optimum embedment depth. The increase of (z/B) above 1.5 has no effect on the bearing capacity, as shown in **Fig. 28**. While the **(Al Mosawe and Al Saidi, 2010)** improving the loose sandy soil by the same material in **(Al-Mosawe and Al-Saidi, 2008)** and the results for the bearing capacity increase by (21%) at one layer and (47.5%) for two layers as shown in **Fig. 29**. **(El Sawwaf, 2007)** used Geotextile layer as a reinforcement for the soil with anchor plate and showed the uplift increased significantly until reaching this ratio (L/B= 5.0), and then the increment in the uplift didn't show a clear value as illustrated in **Fig. 30**.

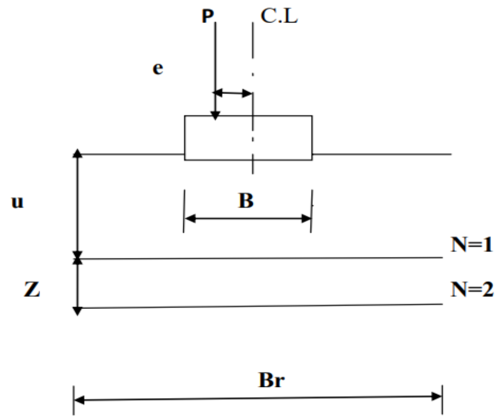


Figure 28. Geometric parameters of Reinforced Foundation **(Al-Mosawe and Al-Saidi, 2008)**

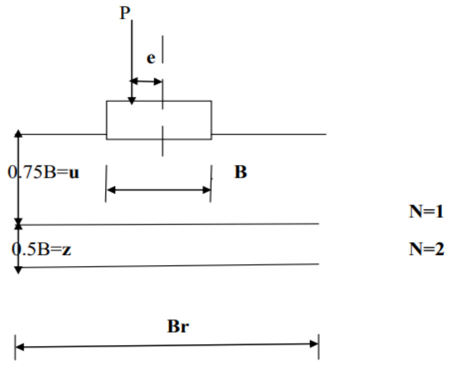


Figure 29. Geometric parameters of reinforced foundation **(Al Mosawe and Al Saidi, 2010)**.

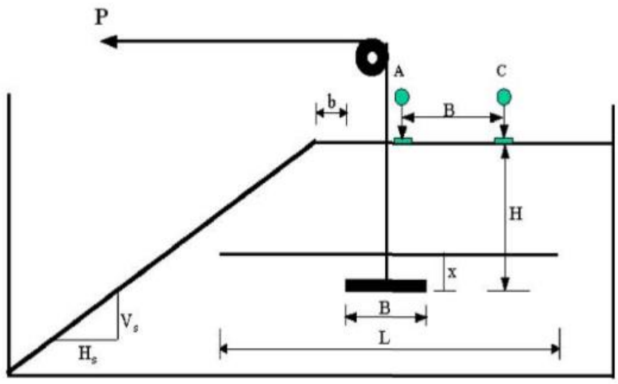


Figure 30. Geometric parametric of anchor plate reinforced sand slope model **(El Sawwaf, 2007)**.

In the other hand the experimental tests showed the large size anchor plate subjected to large pressure and had a significant effect of the displacement of the soil and then the force of anchor plate decreased while the soil force redistributed **(Zhang et al., 2022)**. Besides that **(Naji, 2022)** the effect of number and shape for cavities on the capacity of anchor plate, also the position and the diameter of the cavities. **(Yünkü and Gürbüz, 2022)** the shape of the failure on the soil surface was mildly curved concave in reinforcement with geocell and trapezoid failure surface without using of the geocell as shown in **Fig. 31**.

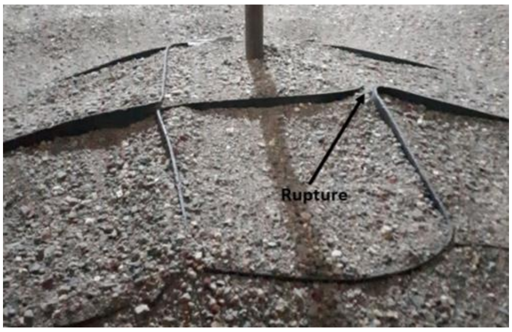


Figure 31. Failure surface of the geocell **(Yünkü and Gürbüz, 2022)**.

To understand the failure surface in general **(Choudhary and Dash, 2018)** obtained the shallow anchor plate (H/h≤5) the surface failure reached to the ground surface with general shear fiacre while deep anchor plate (H/h≥7) was localized around the anchor inside the soil as lined in **Fig. 32**.

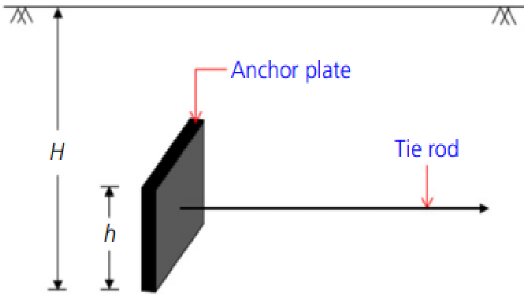


Figure 32. Diagram of the testing **(Choudhary and Dash, 2018)**.

Depending upon the improvement by geonets, the tests showed that the increase in the bearing capacity was 1.4 times more than without reinforcement of sandy soil **(Akbar and Parmar, 2021)**. The ultimate bearing capacity of a shallow horizontal anchor plate depends upon the summation of reaction force in surface failure (R_v) and the weight of soil above the anchor plate **(Deshmukh et al., 2010; Meyerhof and Adams, 1968; Murray and Geddes, 1987; Saeedy, 1987)**.

7. THE SHALLOW AND DEEP FAILURE MECHANISM OF THE ANCHORS.

(Guadin et al., 2014) founded from the numerical analysis that the transition embedded ratio from the shallow (breakaway) to the deep (no breakaway) is (H/D=2.5) for the dynamic embedded plate anchor (DEPLA) as illustrated in **Fig. 33** and **Fig. 34** by plotting the inclination angle of the anchor with the capacity factor (break-out factor).
From the previous studies **(Das, 1990; Ilamparuthi et al., 2002; Merifield and Sloan, 2006; Rowe and Davis, 1982; Su and Fragaszy, 1987; Baker and Kondner, 1966)** indicated that the difference between the shallow and depth anchors in a static state, the depth that the anchors transit from shallow to depth it's a critical depth with regards to the embedded ratio(H/B). However, many studies have suggested an approximate (H/B=6) at which the anchor change from shallow to deep. Another explanation for this phenomenon from **(Merifield et al., 1999)** depends on the surface failure with the shape of ground level when the anchor subjected to loading, so if the surface failure extends to the soil surface will be a shallow anchor, while the deep anchor will be as a balloon shape and didn't extend to the soil surface.

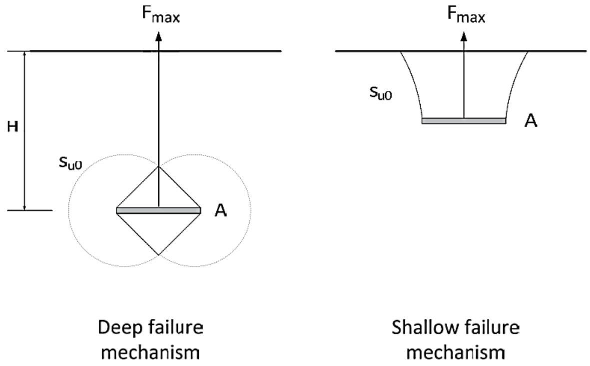


Figure 33. Anchor failure mechanism under no breakaway (deep) and breakaway (shallow) conditions **(Guadin et al., 2014)**.

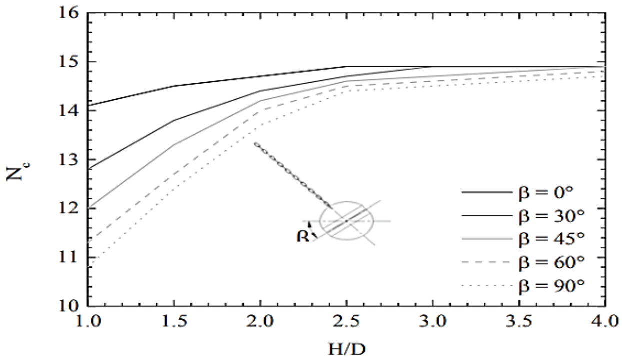


Figure 34. Variation of DEPLA capacity factor at different embedment depths and plate inclinations **(Guadin et al., 2014)**.

Whilst **(Vesic, 1971)** showed that by depending on the relative density of the soil in very loose sand and very soft clay be the depth (2D), for stiff clay (5D) and (10D) in very dense sand. Nevertheless **(Clemence and Veesaert, 1977)** suggested the critical depth (H/B=5) as a transitional ratio. **(Saran et al., 1986)** studied the states in a soft clay and depending on the size, shape of the anchor and the soil parameters in strip anchors (H/B=3), and for circular anchors (H/B=1.75). So that the critical depth depends on the angle of the internal friction unit weight and the relative density of the soil.

Table 3. Most of the previous studies

NO.	Work Experimental	Type of soil & improving	Final Description
1	**(Stewart, 1985)**	Two layers of clayey and sandy soil.	the sand over a clayey layer enhances the capacity of the soil-anchors system.
2	**(Bouazza and Finlay, 1990)**	Two layers(cohesion-less) dense sand with loose or medium sand.	no significant change in the pull-out capacity from using medium-dense sandy layers to using loose-sandy layers in the upper layer thickness ratio less than (1) as the ratio(D/B). A significant effect was shown when using loose-dense layers have a little higher value in the pull out.
3	**(Krishna, 2000)**	A loosely sandy layer and a densely sandy layer.	when the bottom layer is dense sand and the top layer is a loose sand that will be an increment in the resistance of the anchor.

4	**(Ali and Aziz, 2022)**	Sandy and clayey soil with geogrid.	the failure loads it be maximum at solid state, and the treated soil results of clay over sand with geogrid at mid sand.
5	**(Ali and Aziz,2020)**	Sandy soil with lime and cement percent.	the increase in ratio of the diameter of the soil treated to the anchor plate diameter (D/d) improves the capacity of the anchor plate.
6	**(Mahdi and AZIZ, 2023)**	Geogrid in sandy soil.	The pull out resistance of the anchor plate increases with the increasing of the embedded depth for the anchor plate.
7	**(Kumar, 2003)**	Dense and loose sandy soil.	The component of pull out resistance due to the unit weight of the soil in dense sand beneath a loose sandy layer has been tested to be higher than the anchors embedded in loose sand under dense sandy stratum.
8	**(Sakai and Tanaka, 2007)**	Sandy soil.	The shear path propagation direction depends on the sand unit weight density regardless of the location (upper layer or lower layer).
9	**(Ilamparuthi et al., 2008)**	Submerged sand with geogrid.	the peak pullout load increases with the increasing sand density and embedment ratio, and it's higher for the sand reinforced with geogrid than in untreated conditions regardless of embedment ratio and sand density.
10	**(Emirler et al., 2016)**	Sandy soil with multilayer of geogrid in group anchors.	The pull out capability of the plate increased by up to two- times of unreinforced sand, based on the reinforcement by geogrid.
11	**(Choudhary et al., 2019)**	Sandy soil with multilayer of geogrid in group anchors.	sandy layer reinforced with geogrid. The untreated anchor plate groups showed a certain failure at the displacement ratio around (5%) from the anchor widths, while the reinforced groups showed a displacement ratio more than (45 %) from the anchor widths, and a multiple improvement in pull out capability.
12	**(Frgic et al., 2004)**	Different embedment ratio and diameter ratio in sandy soil.	the pull out force increased gradually.
13	**(Al-Mosawe et al., 2011)**	Soft clay (Kaolin) by using a compacted layer of the fly ash under the footing.	the settlement and increase in the bearing capacity with a good ratio of improvement reached 130%.
14	**(Albusoda and Hessain, 2013)**	Gypsum soil by replacing the soil by compacting dune sand and reinforcement with geotextile and geogrid.	the bearing capacity has been increasing (1.5-2) times on concentric load and (2.5-3) during eccentric load.
15	**(Albusoda and Salem, 2012)**	Stabilizing the dune sand by using cement kiln dust CKD.	the angle of the internal friction and the shear strength have been decreased and became almost constant after (14) day of the curing.

16	**(Al Mosawe and Al Saidi, 2010)**	Loose sandy soil with geogrid layers.	the bearing capacity of the soil reached (22%) with using one layer of the geogrid and (47.5%) with no.=2.
17	**(Al-Mosawe and Al-Saidi, 2008)**	Sandy soil by reinforcement the soil by Geogrid layers.	The increase of (z/B) above 1.5 has no effect on the bearing capacity.
18	**(El Sawwaf, 2007)**	Sandy soil with Geotextile layer.	the uplift increased significantly until reaching this ratio (L/B= 5.0) and then the increment in the uplift didn't show a clear value.
19	**(Zhang et al., 2022)**	Large size of anchor plate with large applied pressure.	significant effect of the displacement of the soil and then the force of anchor plate decreased while the soil force redistributed.
20	**(Yünkü and Gürbüz, 2022)**	Sandy soil with geocell.	the shape of the failure on the soil surface was mildly curved concave in reinforcement with geocell and trapezoid failure surface without using of the geocell.
21	**(Choudhary and Dash, 2018)**	Shallow and deep anchor.	obtained the shallow anchor plate (H/h≤5) the surface failure reached to the ground surface with general shear fiacre while deep anchor plate (H/h≥7) was localized around the anchor inside the soil.

8. CONCLUSIONS

Depending on the previous studies can conclude the following:

1- Throughout the tests, there is no significant change in the pull out capacity from using medium-dense sandy layers to using loose-sandy layers in the upper layer thickness ratio less than 1, as the ratio(D/B).

2- When the bottom layer is dense sand and the top layer is loose sand, that will be an increment in the resistance of the anchor.

3- The effects of the geogrid are clear when the sandy layer is above the clayey layer, that when the solid state.

4- In the test of one layer of the geogrid, of clayey soil with (semi-solid, plastic and liquid states) above sandy soil has a high magnitude of the anchor plate capacities and a low magnitude of the vertical displacements from the mode of sandy layer over clayey layer.

5- The component of pull-out resistance due the unit weight of the soil in dense sand beneath a loose sandy layer has been tested to be higher than the anchors embedded in loose sand under dense sandy stratum.

6- The peak pullout load increases with the increasing sand density and embedment ratio, and it's higher for the sand reinforced with geogrid than in untreated conditions regardless of embedment ratio and sand density.

7- The pull-out capability of the plate increased by up to two- times of unreinforced sand, based on the reinforcement by geogrid.

8- The shape of the failure on the soil surface was mildly curved concave in reinforcement with a geocell and trapezoid failure surface without using the geocell.

9- The compaction test was the best in evaluating the pull out of the soil-anchor system.

10- To the future studies the improving by adding materials to the soil almost exhausted, it seems to me to improve the shapes of anchors to be more active.

NOMENCLATURE

Symbol	Description	Symbol	Description
θ	Angle of the failure surface	Q_u	Altitude angle, deg.
γ	Unit weight of soil	H	Embedded depth.
V	Volume of the soil	h	Width of the plate.
$\emptyset$	Angle of friction	σo	Effective stress
K_o	effective earth pressure	C	Cohesion of soil
q_0	radial pressure	A_1	Area of the right anchor
A_2	Area of the left anchor	K	The lateral earth pressure coefficient
R	radius of the arc	C_1 and C_3	Constants depending on the soil type, dimensionless
C_2	constants depending on the soil type, dimensionless	N_γ	break out factor of the soil
F_q	break out factor of the soil		

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Credit Authorship Contribution Statement

The authors have read and approved the manuscript. Ali R. Daibil, writing the original draft of the manuscript, A'amal A. Al-Saidi, reviewed and edited the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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نظام مراسي التربة، النظريات والتحسين: دراسة مراجعة

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الخلاصة

في هذا البحث استخدم العديد من الباحثين مختلف الطرق والأساليب التجريبية لدراسة سلوك نظام التربة–المرساة تحت تأثير ظروف الحمل المتغيرة. كما ركزوا على دراسة هذا النظام من خلال تحسين التربة تحت الحمل بالمرساة كنظام. وبالتالي فإن تأثير شبكة التربة على تحسين أداء ألواح المرساة العمودية، وقد أظهرت نتائج الاختبار أن حجم وارتفاع الموقع والموضع ومحتوى الماء للكتلة المحسنة وتغير زاوية حمل السحب (0،25.45.60،90) درجة تؤثر على مقاومة لوح المرساة العمودي. ولكن تحسين نظام التربة–المرساة من خلال ضغط التربة المحيطة بالمرساة وإضافة الأسمنت إلى التربة وتحسينها بالجير، أظهر أنه عندما تكون نسبة التربة المحسنة إلى قطر لوح المرساة (D/d=1، D/d=1.5) مع إضافة الأسمنت إلى التربة والجير في الاختبارات الأخرى بنسبة أقل من 3٪، كان اختبار الضغط هو الأفضل في تقييم سحب نظام التربة–المرساة. إذا كانت نسبة إضافة الأسمنت إلى التربة 6% فإن ذلك يكون أكثر كفاءة في عملية التقوية من الرص وأضافة الجير. طبقات الطين فوق صفيحة المرساة، عند تحميل صفيحة المرساة بالسحب للخارج في النموذج الفيزيائي فإن الإزاحة الرأسية تتزايد عندما تزيد نسبة الماء في طبقة الطين، أيضاً إذا كانت الطبقة الطينية في الحالة الصلبة فوق الطبقة الرملية تعطي إزاحة أكبر من الطبقة الرملية فوق الطبقة الطينية.

الكلمات المفتاحية: المراسي، آلية التحميل، التربة الرملية، آلية الفشل.