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Simulation of Torpedo-Shaped Anchor (without Fins) for Submersible Offshore Platforms under Tensile Force

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ABSTRACT

Due to the increasing use of submersible semi-submersible floating platform in deep water and using connecting equipment (anchors) to connect the seabed and platforms by mooring lines and immobilize platforms.
In this research, torpedo-shaped anchors is modeled under tensile force and it is drawn out from inside for this purpose, the method was used to determine is the specific location change in soil. Finite element modeling software is used to show soil and a torpedo-shaped behaviors. And finally capacities that they are obtained by calculating (the forces and capabilities) were compared using API Regulations. For torpedo-shaped anchor obtained capacity is increased. The output results can be seen by examining the capacities obtained by modeling finite element software capacity and the calculation formulas are reasonably consistent API Regulations.
KEYWORDS: Torpedo-shaped Anchor, floating platform, numerical modeling

1. INTRODUCTION

In recent years, due to the limited energy resources of the land and that about 30% of the world's hydrocarbon resources are located in offshore, new method to obtain energy, people are drawn to extract hydrocarbon resources from the sea and ocean. After decades of construction of the first oil rigs today there are more than 7,400 oil and gas platforms in the world [1].

In the past, the float rigs in sea water developed to a depth of 18 meters and consists of one or more base that kept the top of the podium with the columns. Those floating platforms were transferred to the operating area and then set up in the water by pumping the water into the base columns of the platform, they were placed on the sea floor and began digging. During this floating time, it is found that this type of structures in response to stimulation of the waves move slightly. This property was used in the design stage of semi- submersible. These platforms should be connected to the sea floor by anchors for preventing the movement of the platform under forces. Those devices are called Anchors. Environmental loads, including loads are caused by natural phenomena such as wind, water, waves, earthquakes and ice or iceberg. Environmental forces also involves changes in hydrostatic pressure and buoyancy force members are platform. Changes in level of water is caused by waves and tides occur and these forces through inhibition of anchor by mooring lines.

The loads on the platform

Loads on the platform can include environmental loads, wave forces, wind forces, the force of the ice (in the Arctic) and sludge load on the parts attached to the seabed. The wave loads on a platform are dynamic. Analyzers often apply dynamic mode for analyzing water depths. For deeper water or where the platform is more likely to be flexible these loads can suitably be replaced by an equivalent static loads.

Static analysis may not properly represent the dynamic loading imposed on the platform. For correct analysis of such platforms dynamic performance must be considered. In this paper, instead of shifting the anchor in soil in specified time or it will be withdrawn in specific time.

Previous research

Since the implementation of the offshore structures, offshore foundations has been changed radically after 1947. Previous offshore structure that were in shallow waters for primary offshore structures and foundations followed generalization of the use of land or in onshore. Frist they installed by hammer force and they used as bases for other part of platforms. Nowadays platforms shift to the deep water and become bigger and bigger. After that they need bigger piles and new hammer that they can operate under water. For example: in Cognac platform in 313 m deep water and 2.15 m diameter, 190 m length and 137 m penetration in the soil[2].

Torpedo anchor due to low cost, easy to install and easy to build and run the install has been more attention. They used for fixing the submersible semi-submersible floating platform by mooring lines. Torpedo -shaped anchor is able to withstand the constant loads. (Medeiros et al., 2006) [3] reported that the torpedo shape anchor in January 2000 Rasin Campos, Brazilian Sea company Petro bras over ninety inhibition torpedo shape anchor without fins (finless) with dimensions of 0.76 m in diameter and 12 meters length and 240 kN weight for anchoring system are used. (Aguiar et al., 2009) [4] in another project, used the torpedo –shaped anchors with a diameter and length of the same , but with a weight of 421 kN with 4 fins that were attached along the main cylinder. They installed by free-fall method for

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establishing one FPSO in the water more than 1400 m. The other 6 torpedo -shaped anchor diameter of 1.07 m, 17 m length and 961 kN weigh were used to inhibit each unit [4]. Movement and the torpedo -shaped anchor in the water are studied by (Raie , 2009) [5].

Table 1- is contained the number of research projects about torpedo shape anchors.

Table-1: A number of research projects conducted on torpedo anchors

conclusion	test	size	weight	company	scale	year	project
Pulling capacity (based on API RP2) is conservative and verifiable.	1.penetration test 2. Verification Methods of implementation 3.Pull out capacity	L = 4.4m, W = 1.3m	2.75 Te	Statoil	1:3	2003-2006	**Trondheimsfjorden**
Excellent coordination analysis	1. Showing entering the DPA again in Soil 2.Vertical Capacity 3.Pull out capacity	L = 4.4m, W = 1.3m	2.75 Te	StatoilHydro	1:3	2008-2009	**Troll A2**
Excellent conclusion	1.Quality parameters anchor penetration	L = 13m, W = 4m	80 Te	Gj&A Licensing Group	1:1	2009	**Gj&A**

The loading test to measure the capacity for six installed torpedo shape anchor in RasinCampos Brazil Sea (Porto et al., 2009) [6], that it possible to evaluate the statistics model of uncertainty associated with model-based software components of the proposed limited (Aguiar et al, 2009) [4] as well as authorized in this article by Working Stress Design (WSD) and Load and Resistance Factor Design (LRFD) (partially resistant) has been investigated. The results show that the structural safety of LRFD uniform designs based ones, which are based on allowable stress method [7].

Using the stiffness matrix formulas

$$[\Delta\sigma] = [D_{ep}].[\Delta\varepsilon] \qquad (1)$$

In this equation, stress and strain Vectors are :

$$[\Delta\sigma] = [\Delta\sigma_{xx}\ \ \Delta\sigma_{yy}\ \ \Delta\sigma_{zz}\ \ \Delta\tau_{xy}\ \Delta\tau_{xz}\ \Delta\tau_{yz}\ \ ]^T$$

$$[\Delta\varepsilon] - [\Delta\varepsilon_{xx}\ \ \Delta\varepsilon_{yy}\ \ \Delta\varepsilon_{zz}\ \Delta\varepsilon_{xy}\ \Delta\varepsilon_{xz}\ \Delta\varepsilon_{yz}\ \ ]^T$$

$[D_{ep}]$ Dependents on Elastoplastic matrix by (Potts and, Zdravkovic 1999) using below equations. [8]

$$[D_{ep}] = [D] - \frac{[D].\left\{\frac{\partial P([\sigma],[m])}{\partial\sigma}\right\}.\left\{\frac{\partial F([\sigma],[K])}{\partial\sigma}\right\}^T.[D]}{\left\{\frac{\partial F([\sigma],[K])}{\partial\sigma}\right\}^T.[D].\left\{\frac{\partial P([\sigma],[m])}{\partial\sigma}\right\}} \qquad (2)$$

$$[D] = [D_{eff}].[D_{pore}] \qquad (3)$$

The formula is also using the matrix strain and tension in ultimate mode.

$$[\mathbf{D}_{\mathrm{eff}}] = \begin{bmatrix} K_s + \frac{4}{3}\cdot G & K_s - \frac{2}{3}\cdot G & K_s - \frac{2}{3}\cdot G & 0 & 0 & 0 \\ & K_s + \frac{4}{3}\cdot G & K_s - \frac{2}{3}\cdot G & 0 & 0 & 0 \\ & & K_s + \frac{4}{3}\cdot G & 0 & 0 & 0 \\ & \text{symmetric} & & G & 0 & 0 \\ & & & & G & 0 \\ & & & & & G \end{bmatrix} \qquad (4)$$

D_{eff} = Effective stress resulting from the matrix (4)

D_{pore} = pore water pressure

Loading

The loads, including concentrated nodal forces, the forces of volume or surface. The nodal forces can be focused directly on relevant equations in the matrix of forces agreement. First the surface and volume forces must be converted to the equivalent nodal forces. Body force of gravity is the most common force in geotechnical researches.

A stress- strain relationship should be model the properties of the soil in the following manner:

- Compression of soil particles to each other, means, increase σ_m or decrease the spacing (e), volume compressibility modulus (k) increases.
- Shear modulus is increased when the particles of soil come closer together, and it is decreased by distortion of soil's particles.
- Mohr -Coulomb yield criterion or similar criteria should be established. This requirement is the tangential shear modulus submit to zero.

Modeling

According to the convenience of the application, less the number of parameters and the ability to justify the results of the theory of Mohr -Coulomb modelling soil is recommended. It should be noted that the Mohr -Coulomb model doesn't allow the soil elements to tolerance tension stress and in software there isn't any capacity for tension force and when the soil's elements suffer software operation will be stop [9].

Table-2: Torpedo anchor and soil specifications

Weight of anchor	Diagonal of anchor	Length of anchor	Tangential stiffness	Normal stiffness
2500 Kgr	3.8 m	3.5m	10 kpa	10 Kpa

And other soil characteristics are listed below:

Soil density: ρ = 2000-2800 $Kg/_{m^3}$

Normal stiffness coefficient ϵ_t = 0.01
Tangential stiffness coefficient ϵ_n = 0.01
Mohr –Coulomb coefficient μ = 0. 8

ϵ_n =Normal restitution coefficient
ϵ_t = Tangential restitution coefficient

Calculated according to API

In API section 5-6 (2007edited) it is noted that the tensile capacity can be less than or equal Q_f (Sleeve resistance) and the weight of the float should be considered.[10]

$$Q_d = Q_f + Q_p = fA_s + qA_p \quad (5)$$

Q_d = Tensile load bearing capacity of the pile, Q_f = Resistance caused by the friction of the parietal, Q_p = Resistance comes from the bottom of the pile, A_s = Sectional area of the parietal (m^2), A_p= Surface area of the bottom of the pile (m^2), D_p = Length of the pile (m)
f = Frictional resistance coefficient outer shell pile (Kp)

Calculated f

$$f = \alpha c \quad (6)$$

α = Dimensionless factor, C = Untrained shear strength of the soil at the point

$$\alpha = 0.5\Psi^{-0.5} \quad \Psi < 1.0$$
$$\alpha = 0.5\Psi^{-0.25} \quad \Psi > 1.0 \quad (7)$$
$$\alpha \leq 1.0$$

In the absence of Ψ = $\alpha \leq 1.0$ in specific point
p'_0 = Overburden pressure at specific point

For piles in cohesive soils q=9c and to calculate Ψ overhead pressure in length of a torpedo anchor for γ =2000 m^3/Kg and 3.5 m length of pile and 3.5 m deep is calculated. The centroid point is determined and for that point P'_0 =10900 kg/m^3 then Ψ=0.4587 and in equation (2) α =0.738 then C in sea soil between 50-100 Kpa, conclusions are listed in table 3.

Tensile comparison between the model and the calculated bearing capacity

1. For torpedo anchor with Lagrange soil condition and a considering the torpedo -shaped anchor is placed in the soil and then pulls out as much as 2 meters in 2 seconds. Force and displacement diagram is showed in Figure 1 and Figure 2 is a figure without dimension curve (diameter to displacement and force to weight, diameter)

Table-3: Calculating the bearing capacity of the deep foundation with specifications of torpedo anchor by API equations $T_u = Q_d$ (KN)

Q_d (KN)	W_a (KN)	f_s	α	Ψ	c	area of pile m^2	As	area of fins m^2	Radius R (m)	Length D_p (m)	Specification of torpedo anchor
339.35	31.14	73.80	0.74	0.46	100.00	0.11	1.19	0.00	0.19	3.5	**Without fins**

2. Euler model by taking the first, the torpedo -shaped anchor is fixed and then pulls out as much as 2 meters in 2 seconds. Force and displacement diagram in Figure 3 and Figure 4 is a figure without dimension curve (diameter to displacement and force to weight, diameter)

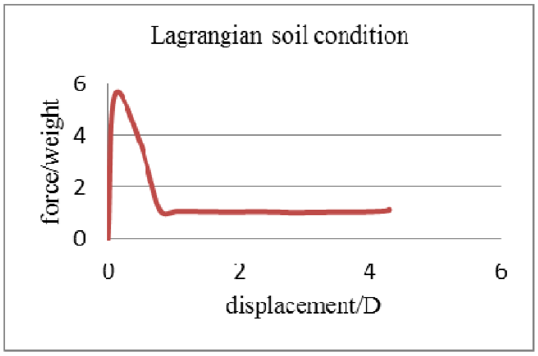

Figure 2: without dimension curves in Lagrangian soil condition

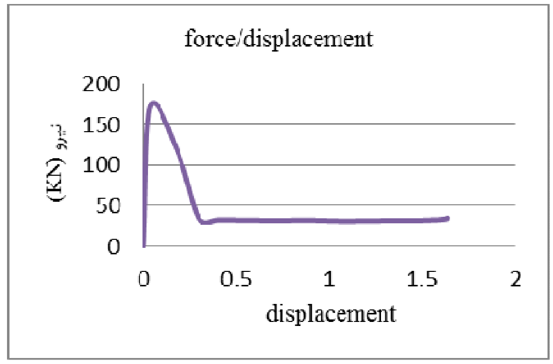

Figure 1: force, displacement diagram for torpedo -shaped anchor without fins in Lagrangian soil condition

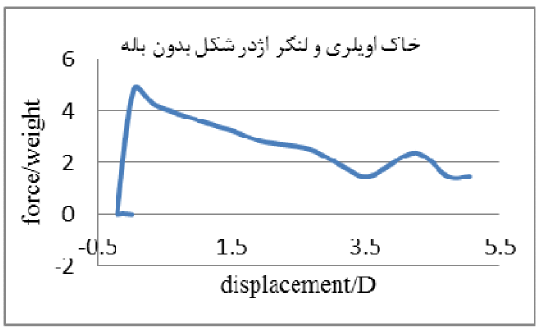

Figure 4: without dimension curves in Euler soil condition

Figure 3: force, displacement diagram for torpedo -shaped anchor without fins in Euler soil condition

CONCLUSIONS AND RESULTS

By examining the output results and the results of modeling the soil Euler and Lagrange in Tables 4 and 5. It is observe that the capacity obtained from modeling by Finite Element software components with capabilities and forces that are calculated Regulations API formulas are acceptable and reliable. And results of modeling by Euler soil are more reasonable and reliable.

Due to the torpedo -shaped anchor figure in soil Euler and Lagrange soil condition modeling it is clearly that the results for the 0.5 m displacement in both of Lagrangian and Eulerian soil condition closer together. And the maximum capacity (KN) 1.27, and difference in the remaining amount of force is 7.98 (KN).

In Figure. 5 outputs of Lagrangian soil modeling, in Figure 6 installing a torpedo anchor and in Figure -7 a torpedo anchor with lower fins are illustrated [11] , [12].

Table 4: Comparison of the capacity and force torpedo anchor modeling with Eulerian and Lagrangian soil condition modeling

maximum displacement/ D	maximum force/weight	Than the maximum capacity of the model obtained from the API method	Displacement when the maximum force is occurred(m)	The remaining force in torpedo model (KN	Maximum of force in whole of torpedo anchor (KN)	Time of Maximum Force (s)	Specification of torpedo anchor
0.05263	4,77	0.87	0.012	82.74	297.16	0.013	Torpedo anchor without fins in Lagrangian soil
0.0228	4.791	0.88	0.009	90.72	298.43	0.025	Torpedo anchor without fins in Eulerian soil

Table 5: results of without dimension curves

Displacement when the maximum force is occurred (m)	The remaining force in whole torpedo model(KN	The remaining force in half of torpedo model (KN)	Maximum of force in whole of torpedo anchor (KN)	Maximum of force in half of torpedo anchor (KN)	Time of Maximum Force (s)	Specification of torpedo anchor and soil	Row
0.036	63.64	31.82	346.11	173.05	0.021	Torpedo anchor without fins in Lagrangian soil	1
0.012	82.74	41.37	297.16	148.58	0.013	Torpedo anchor without fins in Eulerian soil	2

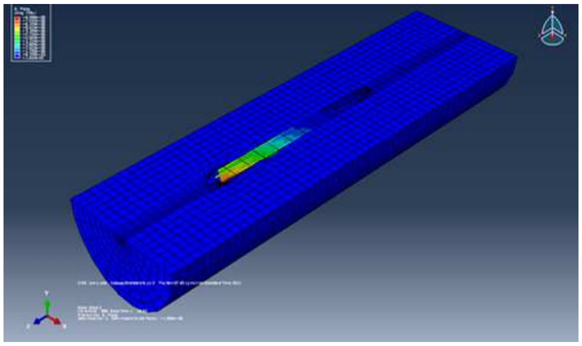

Figure 6: installation of torpedo anchor

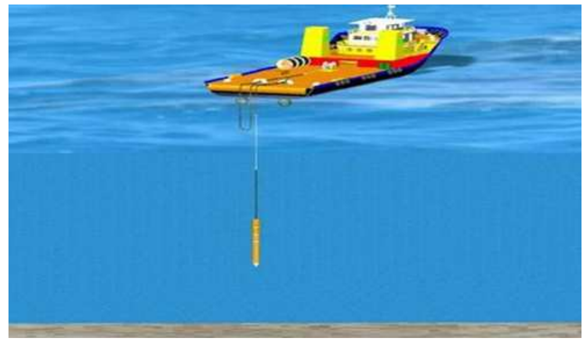

Figure 5: figure of output result of software in Lagrangian soil condition

Figure 7: figure of output result of software in Lagrangian soil condition

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