Using Concrete Caissons as a Foundation for Double- Circuit 230 KV Transmission Line, Qeshm Island, Iran

Abdolhamid Kamali, Bandar Abbas, Iran
(bandar_52@yahoo.com)
Majid Simrakh, Bandar Abbas, Iran
(simrakh@gmail.com)

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Name of the Presenter: Abdolhamid Kamali

Abstract:

In the past 50 years, there have been many attempts to design and construct a way for transferring energy, water, etc. to Qeshm Island. The most suitable location for this purpose is near Qeshm Strait, located between "Bandar-e-Pohl" and "Bandar-e- Laft", which is about 2200 meters long. Various methods have been considered for transmitting power to the Qeshm Island through a Double- Circuit 230 KV Transmission Line, including: constructing a basement in the seabed at depth of 20m using concrete imbedded piles or floating concrete foundations; constructing two high columns in both sides of the strait and using undersea cables. Although these methods were possible, they were not economically feasible. Therefore, floating concrete caissons were preferred. Because the lateral forces arising from water flow and wind can twist and rotate the foundation, it is very dangerous to use tension concrete piles in the sand layer. So, concrete caissons (Dimensions: 32*32m, Height: 8m) were selected to maintain concrete basements (Diameter: 5m; Height: 18m). Since it is not possible to construct this caisson in the site, they should be constructed in a proper place in coastal area and be floated in the sea, transported to the installation site, drowned, and then be installed in the seabed. This paper considers imposing forces to a caisson including water flow, rotation and torsional moments and their effects on stability of the structure.

Key words: Floating Basement, Caisson, Concrete Piles, Qeshm Island

1- Introduction

"Qeshm Island" is the biggest island in the Persian Gulf near the straits of Hormoz. It is also a free trade zone, which has made the island very important due to international trade and national security. In the past 50 years, there have been many attempts to design and construct a way to transfer energy, water or even vehicles to this island. The most suitable location for this purpose is near Qeshm Strait, located between "Bandar-e-Pohl" in the coast of the mainland and the north of "Bandar-e- Laft" in Qeshm Island, which is about 2200 meters long. (Fig.1)

Fig.1: Qeshm Strait located between “Bandar-e-Pohl” and “Bandar-e- Laft”

Various methods have been considered for transmitting power to the Qeshm Island through a Double- Circuit 230 KV Transmission Line, including: constructing a basement in the seabed at depth of 20m using concrete imbedded piles or floating concrete foundations; constructing two high columns in both sides of the strait and using undersea cables. Although these methods were possible, they were not economically feasible. Therefore, floating concrete caissons were preferred.

2- Exploratory excavations and the characteristics of soil layers in “Qeshm Strait”

To identify the characteristics of soil layers, four 30-meter-depth holes were drilled near “Bandar-e-Pohl” and four other holes with the same depth were drilled near the north-east of “Bandar-e- Laft”. Then, they were sampled and tested.

In order to do geotechnical excavations in the middle of “Qeshm Strait”, it was needed to design, construct and install a “jack up platform” (water depth up to 22m). Considering the water flow intensity, which reaches 1.8 m/sec in maximum tide, a 10*10 platform with 48 tones capacity was designed and constructed. (fig.2)

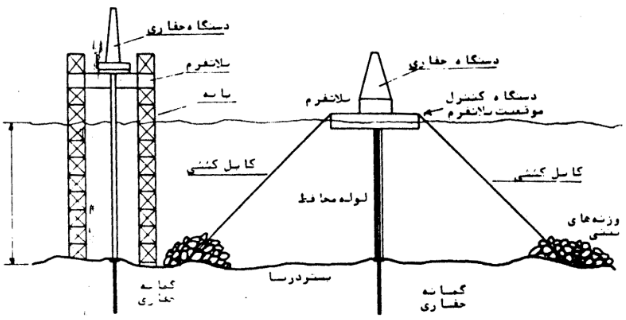

Fig.2: floating platform installation using (a) tension cables, (b) high columns

Research showed that in the northern part of the strait located in “Bandar-e-Pohl”, there are repeated layers of sandstones and marl and the layers are adapted with geological characteristics of the northern region. On the other hand, in the southern part of the strait located in “Bandar-e-Laft”, there are repeated layers of clay-stones and marl and the layers are adapted with geological characteristics of the southern region. As a result, we predicted that there should be a similar pattern in the middle of the strait. But, practically observed that seabed especially around the undersea hill has remarkably different soil layers in comparison with both sides of the strait. (fig.3)

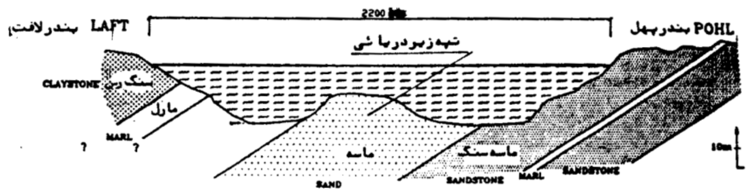

Fig.3: soil layers in "Qeshm Strait"

Four different layers were observed in all 5 holes. Consisting of floating sand, the upper layer doesn't have any stability and displaces with intense water flows. The seabed consists of a stable dense sand layer with carbonate joins (1.5 m thick) called "Beach Rock". Under the "Beach Rock", there is a 4-meter-thick layer of brown sand following a layer of gray sand to the depth of 30m. There are 1- to 2-centimeter-thick sub layers of dense clay in the gray sand layer in a very strict zone. Table 1 briefly represents the physical and mechanical characteristics of the soil layers.

Item	Layer	Density (t/m^3)	Friction angle (°)	Cohesion factor (KPa)	Elasticity factor of the soil (KPa)
1	Beach stone	1.95	32	80	385
2	Brown sand	1.92	35	0	75
3	Gray sand	1.93	38	0	85
4	Dense clay	1.87	20	0	8

Table 1: physical and mechanical characteristics of the soil layers

3- Foundation profile for constructing the basement in the middle of "Qeshm Strait"

Generally, two kinds of basements can be designed and installed on the undersea hill in the middle of "Qeshm Strait". If the constructed columns were high and influenced by rotation moments, the big part of foundation would be under tension. Weigh foundation or caisson should be used in this case. If vertical forces were remarkably higher than rotation moments, using imbedded piles would be suitable.

Considering the soil layers, due to the density of the sand layer, it is not possible to install precast piles. The approximate forces resulted by wind, water, structure, and foundation for the basement of a cantilever with 80-meter spans and 210-meter power towers are presented in table 2.

Item	Description	80-meter span cantilever basement	210-meter power tower
1	Vertical forces	6000 ton	180 ton
2	Foundation weight	12000 ton	8000 ton
3	Structure rotation moments	240 ton-m	11400 ton-m
4	Water flow rotation moments	380 ton-m	380 ton-m
5	Water flow torsional moments	120 ton-m	120 ton-m

Table2: Imposed forces to the caisson in order to construct the basement of cantilever or power towers in "Qeshm Strait" without considering the wave effects

Because the lateral forces arising from water flow and wind can twist and rotate the foundation, it is very dangerous to use tension concrete piles in the sand layer. So, concrete caissons (Dimensions: 32*32m, Height: 8m) were selected to maintain concrete basements (Diameter: 5m; Height: 18m). Since it is not possible to construct this caisson in the site, they should be constructed in a proper place in coastal area and be floated in the sea, transported to the installation site, drowned, and then be installed in the seabed.

4- Design fundamentals for floating concrete caissons

Water flow intensity along with static and dynamic loads arising from wind and earthquake can cause rotation and torsional moments in different directions. When the tide is ebbed, water flow is from "Bandar-e-Abbas" towards "Bandar-e-Khamir", causing an increase in rotation moments on the installed caisson.

In this case, as fig.1 represents, a part of water flow comes towards Qeshm Island via "Bandar-e-Khamir" and another part via "Bandar-e-Laft". The angle between two flows is considerable (70°) and results in twist. Therefore, the caisson is affected by rotation moments twice a day (anticlockwise). These one directional repeated rotation moments should be considered in stability calculations (fig.4).

Notice that the undersea hill increases the water flow velocity on the seabed. Studies show that 5 to 10 meters above the undersea hill, the water flow velocity is about 80% more than the seabed. Fig.5 shows the imposed forces on the caisson in different conditions before installation of any structures (e.g. cantilever, power tower, etc.).

Overall, one of the critical conditions for the stability of the structure is the case that no other structure is installed on the basement, so the concrete foundation, which is not under vertical pressure, moves horizontally and displaces due to water pressure. After the installation of another structure on the basement, the critical conditions occur when earthquakes happen or a cable is torn and lateral forces would turn the tower. In both cases, it is necessary to design the basement dimensions according to the forces affecting the structures. Values of forces and moments during and after the installation a cantilever with 110- meter spans are mentioned in table 3.

Item	Description	during the installation	after the installation
1	Vertical forces	V=7800 tons	V=16600 tons
2	Shearing force (X)	R_x=36 tons	R_x=36 tons
3	Shearing force (Y)	R_y=0 tons	R_y=0.800 tons
4	Rotation moment (X)	M_x=487 ton.m	M_x= 487 ton.m
5	Rotation moment (Y)	M_y=0 ton.m	M_y=25600 ton.m
6	torsional moment	T=88 ton.m	T=12888 ton.m

Table 3: Values of forces and moments during and after the installation

Although the torsional moments is negligible in comparison with those moments arising from torn cables or any non-homogeneous collapse of the cantilever span when an earthquake occurs, but the value of the torsional moments is considerable during the installation of the basement and before loading the structure. Results show that despite the very high lateral forces, the caisson has a considerable stability.

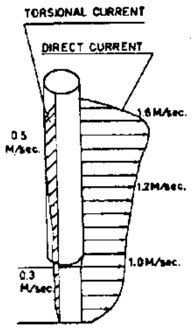

Fig.4: water flow velocity distribution when the tide is ebbed

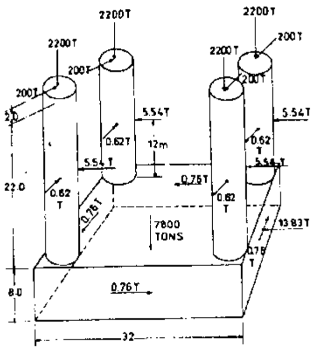

Fig.5: imposed forces on the caisson before installation

The maximum pressures on the sides in critical conditions are 1.54 and 1.70 kg/cm. The least friction coefficient between concrete and sand layer of about *tan u=0.36* results in horizontal force to vertical force ratio of about 0.05, which is far less than the critical value.

When considering the stability, the most important evaluation includes the effects of bending moment, shear and torsional moment in the soil under the foundation. Integration of moments causes torsional soil cracks and thus makes the soil lose its firmness and strength. The assumptions can be made for the stability of torsional cracks in concrete under bending moment in certain conditions.

5- Required data for design

5-1- Overview

The designed caisson dimensions is 32 ×32 m2 , consisting of 4.6 × 4.6 ×6.05 m cells separating from each other with 30-centimeter-thick walls. The basement for the transmission line consists of four hollow reinforced concrete columns attached to the caisson as a rigid console. The final form of the top of the column will be designed according to the body of the columns and the caisson in the next stage. The caisson is located on a foundation of crushed stone with a thickness of 0.80 m in the depth of 15m. (fig.6)

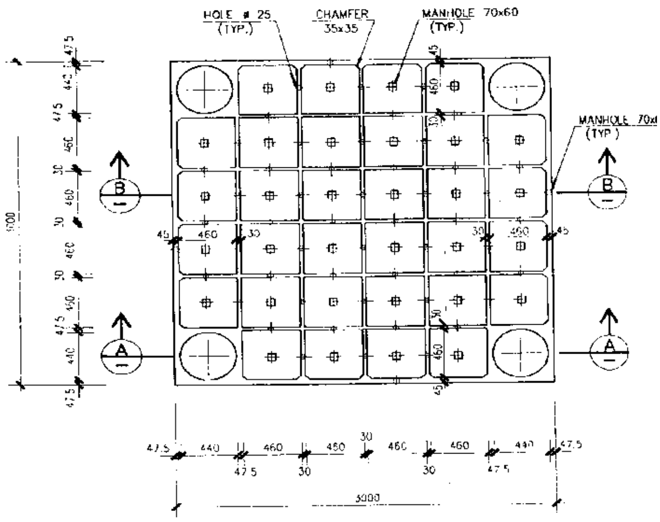

Fig.6: Basement Plan

5-2- Design Data

1 - Reference standard: ACI 357R; ACJ 318

2 - Materials: Portland Pozzolanic Cement: ACTM C595; and micro silica: fc=350 kg/cm^2

3 - Reinforcement: ribbed bars: ASTM A 615 grade 60

4 - Minimum concrete cover: 50 mm

5-3-Loads and Load combinations

Effective loads imposed on the structure of foundation in design process are:

FD: Permanent loads (dead)

FL: Imposed Loads (live)

FW: Waves (frequent waves with up to 1.0 m and lateral waves with up to 5.0 m height)

F_{wi}: Winds (frequent winds with up to 25 m/s and lateral winds with up to 52 m/s speed)

FCu: Water flow (speed: 1.5 m/s)

FEu: Earthquake (0.2 g)

TU: Final Load (considering the factor of the load of the tower)

TS: Service Load (without considering the factor of the load of the tower)

6- Caisson floatation

One of the characteristics of floating concrete caissons is that they can be constructed on land and floated. After concrete works ended in “Persian Gulf Shipbuilding Co”, the 8000-ton caisson was floated in a basin to be balanced. Then it can be transported 76 kilometers to the basement and be drowned in a certain method. Large pieces of stone are required to be attached to the sides of the caisson to prevent lateral movements and keep the balance.

Different factors including bearing capacity, chlorine erosion effect, and especial weight of the concrete should be considered. If the weight of the concrete is more on one side than the other, sand replacement should be done to make the structure stable. (fig.7)

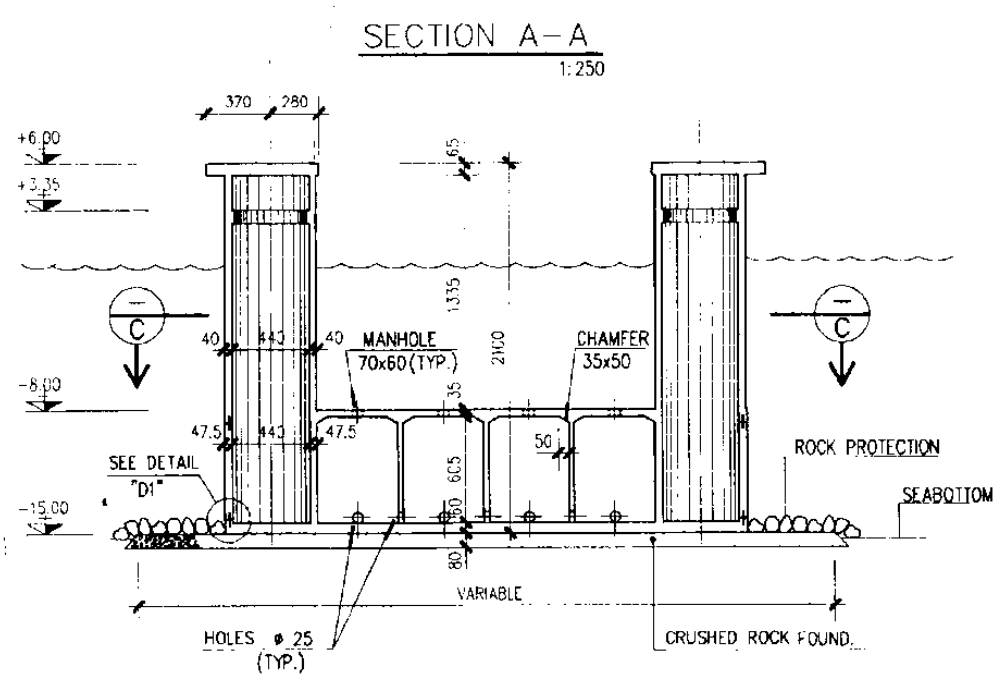

Fig.7: section A-A (Caisson installed on the seabed)

The weight of the caisson should be 20% less than the weight of the water with the same volume as the cubic basement of the caisson. The surface of the caisson in this case, is always 40 to 50 cm above the sea level. (Fig. 8 and 9)

Fig.8: the caisson floating in a basin in “Persian Gulf Shipbuilding Co”

Fig.9: The caisson is brought out of the basin by a tugboat

7- Drowning the caisson

Drowning is one of the most sensitive and important parts of the installation of a caisson. To install the caisson without any damage, we can use the experience of installation of the floating platform. It was observed that the best way to overcome the water flow arising from tide is to act like landing a plane or flying a kite. First, to stabilize the caisson against horizontal pressure, it should be tilted. Then, as the water flow decreases and water comes up, the caisson is drowned due to its weight. (Fig. 10 and 11)

Fig.10: the caisson is located in the installation site and it is ready to be drowned

Fig.11: the drowning caisson

8- conclusions:

- It is possible to construct floating concrete caissons for installation of power towers, cantilevers or pipelines up to 35 m depth and it can be developed for 40 to 50 m depth.
- "Qeshm strait" has its certain conditions and water flow distribution, water flow intensity, and eddy flows causing rotation and bending should be considered in any constructing operation.
- Geotechnical studies showed that many misleading initial data was related to the certain characteristics of "Qeshm strait" rather than the testing procedure.
- Floating caissons can be used to construct a communication way such as a railway. Constructing imbedded concrete piles is difficult due to the intense water flow, and impossibility of locating a tugboat in a certain location the site during excavation. Floating caissons are one of the practical solutions in this case.

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