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ABSTRACT

This paper summarizes the execution of an on-going ice protection barrier construction project in the Northern Caspian Sea, Kazakhstan. The Project started in May, 2001 and a total of five artificial islands for oil drilling activities were completed until November, 2007. Ice protection structures consist of stronghold and barrier heads distributed around oil drilling islands (with dimensions of 90 m by 110 m to 90 m by 160 m) in order to protect the island from drifting ice ridges. These cofferdams consist of sheet piles and steel pipe piles with various dimensions. The piles were driven by vibro hammers and drop hammers. The construction site is located in an extremely sensitive environmental area designated as "Specially Protected Zone" where the water depths typically range from approximately 1.5 m to 6 m. The subsoil conditions at the construction site consist of fine sandy clay and silt marine sediments overlaying predominantly firm to stiff clay layers. Activities within this region are subject to stringent controls, therefore a strict HSE and Quality Control / Quality Assurance Programs are implemented in the construction works.

INTRODUCTION

On-going construction of "Artificial Islands Project" lies on the largest oil field discovered in the North Caspian Sea, Kazakhstan. It is located 80 kilometers south of Atyrau and extends over a surface of approximately 45 km by 55 km. (Fig.1) It is currently estimated that there are 38 billion barrels of oil-in-place, which gives the region the property to be the largest oil field discovered over the last thirty years worldwide.

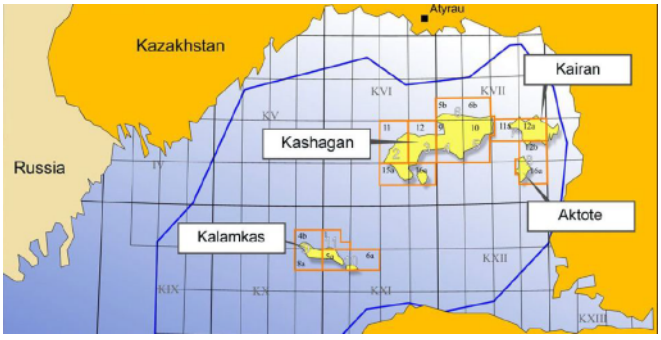

Fig.1 "Artificial Islands Project" in the North Caspian Sea

Its development represents one of the greatest current challenges of the petroleum industry due to the following characteristics of the project:

- Deep, high-pressure reservoir,
- High (16-20 %) sulphur content with associated production of hydrogen sulfide,
- Shallow water depth that ranges from 3 to 4 meters and freezing from November to March,
- Wide temperature variations from -30^0C to $+40^0$C
- A very sensitive environment with a variety of internationally protected species

OFF SHORE GROUND INVESTIGATION PROGRAM

Off-shore ground investigation works were performed in 1997 in the region that the artificial islands are planned to be constructed in the North-eastern Caspian Sea. In the whole ground investigation works, the consequent aim was to determine the soil conditions and the engineering characteristics of the soil strata and to decide the type of design of the artificial island (whether to use steel or gravity structures). The off-shore soil investigation works were carried out in the following manner:

Drilling Works

20 no of 280 meters of drilling works in total with varying length from 5 meter to 90 meter were carried out from a spud-barge. Off-shore geotechnical borings were generally drilled without the use of a riser and consequently the unsupported drill string only provides limited reaction for down hole operations. In order to obtain better horizontal and vertical control over the drill string, the SEACLAM method was used.

The SEACLAM was lowered down to the seabed at the designated borehole location. Then the drill string was spudded along the lifting wires into the wide smooth sided funnel, by means of a guide frame. In a continuous manner, down to the bottom drilling level piezo-cone penetrometer test is performed and with a WISON/WIP 76 mm diameter XP samples were gathered. (Figure 2a) (Fugro, 1997)

Piezo-Cone Penetrometer (CPTU) Works

48 no of piezo-cone penetrometer (CPTU) tests were performed from the top of a jack-up platform. Initially, a jack-up platform containing a GPS System went near the testing site. Later on, after the testing site was checked, its four legs were fixed to the seabed and measurements were taken by a piezo-cone meter (CPTU) fixed to the platform. (Figure 2b)

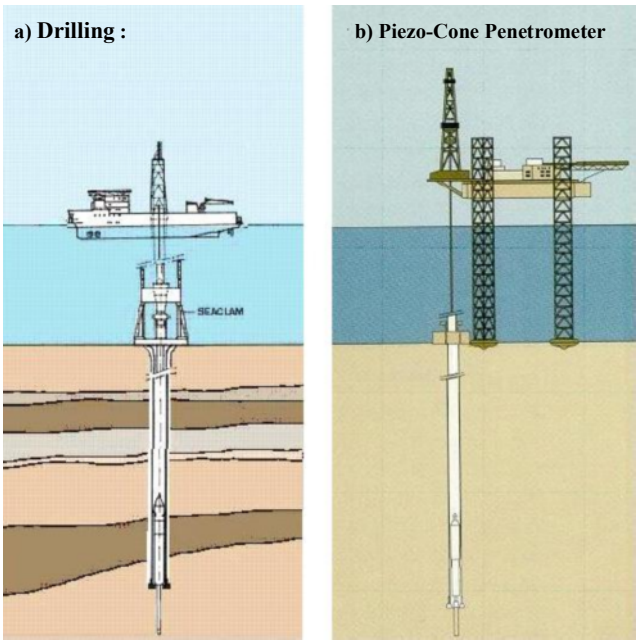

Fig. 2. Off-Shore Tests in the Context of Ground Investigation

GROUND PROPERTIES IN THE PROJECT SITE

Ground Properties

During the field tests disturbed and non-disturbed soil samples were regularly taken. Laboratory tests (Particle-size distribution, hydrometer analysis, carbon content determination, microscopic analysis and Atterberg Limits, etc.) were performed on samples. Shear strength parameters of clayey soil strata were computed using triaxial stress tests, off-shore torvane and pocket penetrometer. Properties of the soil layers were summarized in Table 1.

Table 1. Ground Properties

Depth	Soil Description	q_c (MPa)	c_u (kPa)
1.0	Shell Beds	0-1	-
3.7	CLAY/SAND, some organic matter and shell fragments	1-4	5-30
20.5	CALCAREOUS CLAY	3-8	10-42
3.2	CALCAREOUS SILT/SAND, medium dense to very dense	4-12	-
36.2	CALCAREOUS CLAY, very stiff to hard	3-7	152-341
50.0	CALCILUTITE, weak to moderately weak	50+	-

In general, the seabed in the project site was a smooth plane and the water depths change between 4 to 6 meters. At the top, there are 1 meter thick shell beds. Beneath this layer a soft clay layer extends for about 3 to 4 meters, where on the southwest of the site loose sand exists. It was observed that the c_u value of this soft clay varies between 5-15, 15-20 and 20-30kPa in three different regions.

Below this soft clay layer, very stiff calcerous clay and dense silty sand layer extends for a wide range of 20-25 meters. In addition, there are some gypsum crystals in the sand. Below this sand layer a stiff to very stiff, 35 m thick clay layer extends. In this clay layer, there are laminations of silt and sand with locally some gypsum crystals. Below this layer, there exists calcilutite layer.

Coastal Morphology

The North Caspian hinterland is characterized by the presence of three coastal flats. Immediately bordering the sea lies, a first accumulative plain, marked by its frequent partial flooding. Here, the boundary between water and land is arbitrary and varies on a daily basis. Up-country, this plain is bordered by a low gradient bench, marking the beginning of the second plain. This somewhat higher located terrace again is nearly horizontal, and terminates stepwise, marking the beginning of the third surface. All these plains extend for some 10 km to over a 100 km. Several rivers (Volga, Ural and Emba), dissect the flat landscape. The space between the Volga and Ural delta is fringed with dense reed beds, whereas between the Ural and former Emba delta many small salline depressions exist. Furthermore, near the first and the second surface frontier

Baer knolls are often encountered, east to west oriented hills go up to 10 meters high.

Seabed Morphology and Bathymetry

The North Caspian is a gently sloping shallow plane. The water depth gradually increases towards the south. Observed features include relict river beds and contemporaneous storm surge erosion rills. Furthermore, near the Ural delta submarine bars are present parallel to the shoreline. Small flat islands consisting of accumulated marine shell deposits and often capped by vegetation remnants exist among shoreline from Emba delta to the Komsomolets Gulf.

Many of them are currently drowned by the recent rise in water level. In the western part of the North Caspian Sea present day relief is governed by the Volga. The fore-delta of Volga river is marked by a series of hollows separated by rises, formation of islands, banks and spits. Old channels and terraces of the Paleo-Volga rivers are tracked by north-east of Chechen Island. Maximum depths within these channels could reach 17.5 meters.

Tectonics

The North Caspian Sea floor is dissected by a number of major deep faults which divide the area into large basins. The Pre-Caspian basin of the Russian Platform in the north-east in which the study area is located, is characterized by the presence of many Permian salt domes.

CLIMATIC AND ENVIRONMENTAL CONDITIONS

Like the air temperature, water temperature varies according to the season. In summer time water temperature in shallow regions exceeds 27^{o} C. A regular winter lasts long and cold and when the air temperature goes below -25^{o} C (generally starts from November) the part of the Caspian Sea from estuary of Volga to Bautino completely freezes.

All the activities in the Northern Caspian Sea is strictly controlled from April to 15th of July and for the entire month of October, whereas seals living in Caspian Sea carry on with their nutrition and reproduction activities on the ice in winter.

ARTIFICIAL ISLAND CONSTRUCTION (2001 to 2005)

Sheet pile and steel pipe pile driving works within the context of “Artificial Island Project” have been under construction since May, 2001 and the project is planned to be completed by the year 2009.

The project consists of islands with operational areas of 90 x 110 m to 90 x 160 m so as to explore oil in Caspian Sea. The island embankments are protected with limestone rock and steel sheet pile walls. Suitable local seabed sand was not available as fill material. The islands have therefore been constructed from limestone quarry run, shipped from Bautino by barges.

The island embankments are protected with limestone rock and steel sheetpile walls. The island topside facilities, drilling rigs, associated utilities and the living quarters are founded on prefabricated concrete slabs.

The artificial islands are closed box structures, whose front walls composed of 15 m to 17 m long sheet piles are tied to the rear sheet pile wall composed of 5 to 7 m long sheet piles by tie-rods. (Fig.3, 4 and 5)

Fig.3. Artificial Island named Aktote constructed in 2002

Between the years of 2001 and 2005, the construction of 3 no. of artificial islands was completed and drilling of oil exploration works was commenced in the year 2005.

Fig.4. Artificial Island named Kairan constructed in 2002

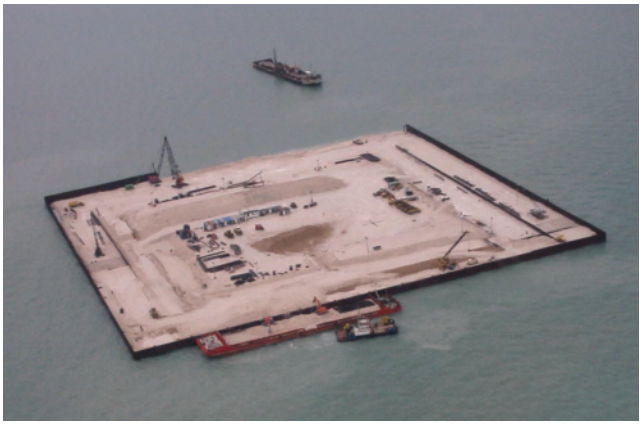

Fig.5. Artificial Island named D-Isalnd constructed in 2003

ICE RIDGES IN WINTER PERIOD

The islands were exposed 0.5 meter to 10.0 meter high ice ridges originated from piling up of drifting ice, which are due to freezing of Caspian Sea from estuary of Volga to Bautino in winter season. Heavy construction equipments were used to prevent huge drifting ice from getting close to the island and continue drilling activities without any interruption during winter seasons of 2002 and 2003. However, this method of protection did not work. Neither oil exploration works could be continued nor the drilling team could be accommodated at the exploration island during the winter season. (Fig.6. shows 8-9 meter high ice ridges approaching to an oil exploration island)

Fig.6. Ice ridges (8-9 meter high) approaching to islands

For this reason in the year 2005, it was decided to monitor and verify the effectiveness of the strengthening of rock fill barriers by ice protection structures so as to protect the island complex from ice ridges and to enhance the continuity of oil production activities without any interruption during winter season.

A number of trial cofferdams (2 no. of strongholds and 1 no. of barrier head as shown in Fig.7 were constructed in the summer of 2005 around the largest oil drilling island complex (D-Island Complex). The complex is the center for the main processing and re-injection facilities together with production and re-injection wells. It includes oil separation and pumping, gas dehydration, gas re-injection, utilities, living quarters and helicopter landing facilities.

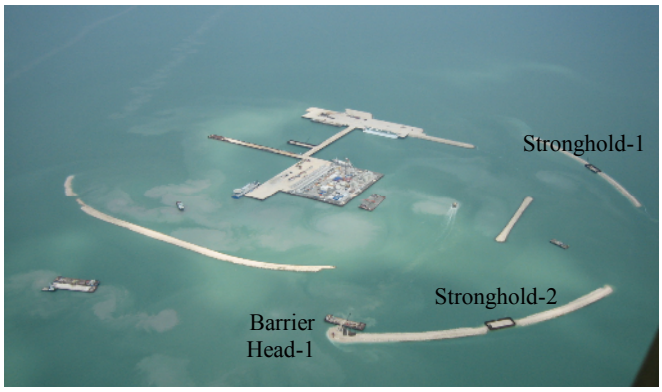

Fig.7. Trial cofferdams at the D-Island Complex

The ice ridge at the D-Island Complex can be clearly seen from the following photograph (Fig.8.) taken in February 2006. During the winter season of 2006, the performance of these trial ice protection structures was monitored by a detailed surveying technique.

Fig.8. Ice ridge around the trial cofferdams at D-Island Complex

As a result of the monitoring program carried out in 2006, it was encountered that the measured displacements and deformations of the sheet piled ice barrier structures caused by the drifting ice are within the tolerances as stipulated in the specification of the Project. Thus, it was decided to continue the construction works with the ice barriers as shown in Fig.9 without any changes.

- Octagonal shape Barrier Heads consist of sheet piles and steel pipe piles at each end of the rock fill barriers,

- Various no. of rectangular shape Strongholds consist of sheet piles along the longitudinal section of the rock fill barriers,

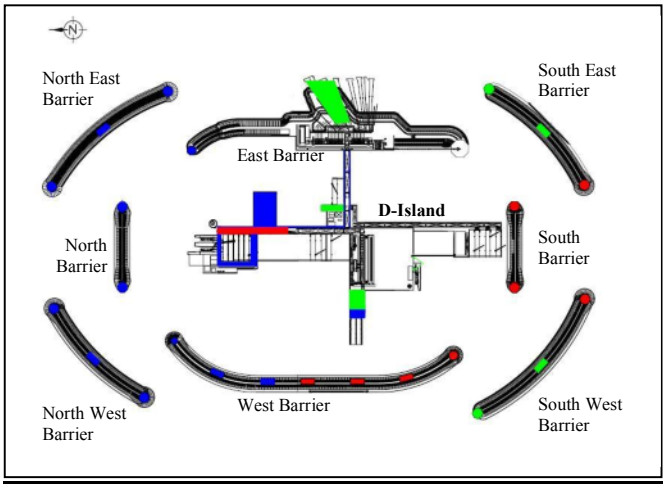

Fig.9. Ice Protection Barriers around the D-Island Complex

ICE PROTECTION BARRIERS (2005 – 2007)

In addition to construction of artificial islands, ice protection barriers and auxiliary cofferdams have been installed since the year 2005.

Each year there is 8 month long off-shore working period and 4 month long on-shore stand-by period. It should be noted that these durations are estimated approximately depending upon the ice break up period on Caspian Sea depending on the intensity of the winter. (Fig.10.)

Through an annular season, sheet pile driving progress was mainly depended on;

- Soil conditions encountered,
- Weather Conditions,
- Efficiency of Piling Machinery & Equipment,
- Supply of permanent materials,
- Marine and logistic support,

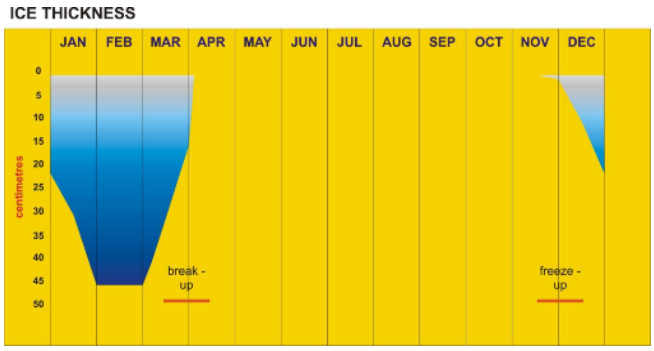

Fig. 10. Ice Thickness at Kashagan Field

Each year mobilization to the off-shore working areas and commencement of the site works are depended on the ice break up in the Northern Caspian Sea. The satellite aerial photographs are used for monitoring the actual situation of the ice break up around the islands.

A satellite photograph (Fig.11.) taken in March, 2007 shows that the ice break up on the Caspian Sea is sufficient for commencement of the mobilization to the off-shore working areas in the beginning of April, 2007.

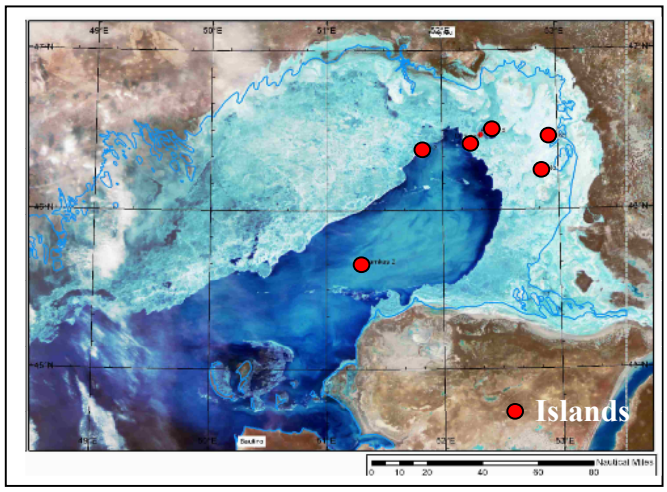

Fig.11. Ice break up on the Northern Caspian Sea (As of March 2007)

In adddition to D-Island Complex, steel pipe pile and sheet pile driving works; tie-rod, cap beam installation works have been successfully carried out at the following locations between 2005 and 2007:

- Extension of D-Island Complex, remaining ice barriers, wellheads and auxiliary cofferdams,
- 2 no. of new artificial islands and their ice barriers,
- New Loading Jetty,

Between the years 2001 and 2007; a total of ~200,000 m^2 of sheet pile and steel pipe piles were driven and a total ~6,000,000 tons of rock material was hauled successfully.

The work sequence within the context of project is as follows:

Earthworks

All fill and core materials are supplied from Bautino Base for island construction. Materials were loaded from loading jetty to barges. Fill or core materials were dumped into the sea by excavators from the barges. Earthwork operations continued until the island reached its designed level and dimensions.

Guide Installation

So as to drive the sheet piles and steel pipe piles of the front sheet pile wall at the correct designated location and level, a special manufactured steel guides were used. (Fig.12.) These steel guides are distinctly manufactured for octagonal cofferdams composed of sheet piles & steel pipe piles and rectangular cofferdams composed of sheet piles.

Fig.12. Specially manufactured steel guide frame

Sheet Piling & Pipe Pile Driving

Stronghold

The Stronghold is a rectangular shape sheet piled cofferdam. The structure is incorporated into the barrier. Tie-rods connect the two sheet pile walls parallel to the barrier axis to each other. (Fig.13.) Various numbers of rectangular cofferdams (50m x 20m) composed of sheet piles, tie-rods were designed within the barrier depending on the length of the barrier.

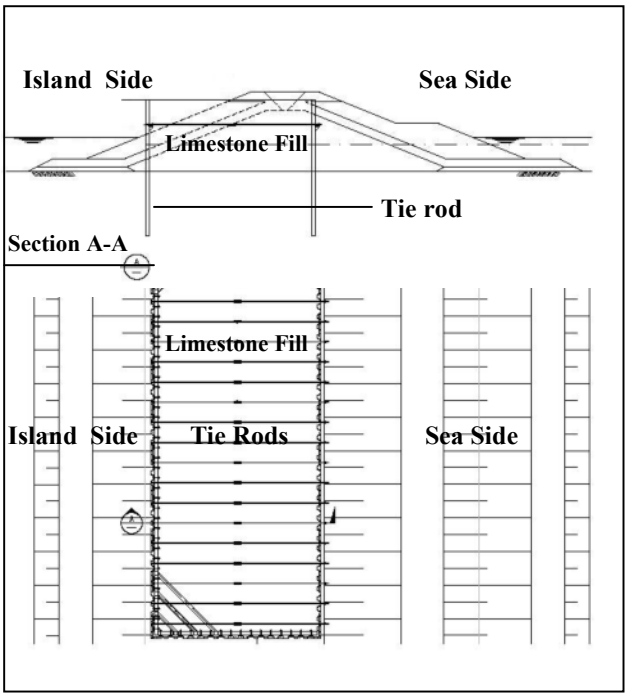

Figure 13. Plan view and cross section of Stronghold

After specially manufactured steel guide frame was placed, sheet pile driving operation was conducted by using a vibratory hammer till the designated level. (Fig.14) Water jetting was used in case hard to very hard clay layer was encountered at the construction site. After sheet pile driving work was completed, the cofferdam was filled by limestone fill material and it was compacted with 98% modified proctor.

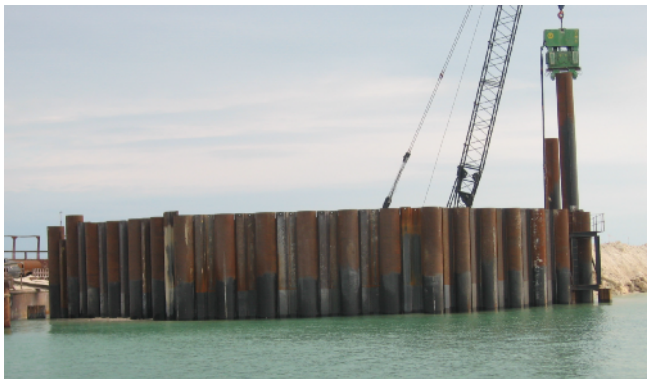

Fig. 14. Sheet pile driving works at Stronghold

Barrier Head

The Barrier Head is a combined wall composed of steel pipe piles and sheet piles. The barrier head is an octagonal shape cofferdam. The sheet piles are tied to each other by four layers of tie-rods. (Fig.15) The infill consists of limestone and it was filled with 98% modified proctor tight limestone. (Fig.16.)

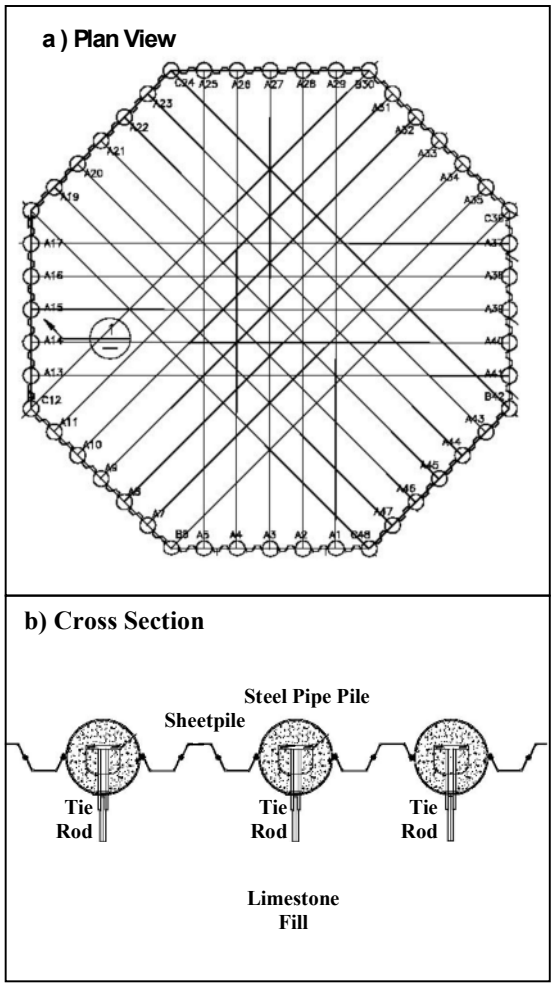

Figure 15. Plan view and cross section of Barrier Head

The octagonal combiwall consists of 19 meter long steel pipe piles and sheet piles. The steel pipe piles and sheet piles were connected to each other by channels, which were welded on both sides of the pipe piles. Since the pipe piles are protected against corrosion, special precautions are taken not to cause any harm while driving these pipe piles.

After specially manufactured steel guide frame was placed, pile driving operation was conducted by using a vibro hammer till a certain level. Then vibratory hammer was replaced with a crane suspended hydraulic hammer with helmet and pile driving operation was continued till the designed level. The number of blows was counted while driving the pile and the penetration was recorded in meters by the marks pointed on the piles.

Fig.16. Steel pipe pile driving works at Barrier Head

In case any obstacle or hard layer was encountered along the pile length, appropriate method of driving was decided on-site. After steel pipe piles were driven, drilling inside the steel pipe piles was carried out by using a clampshell. The fill inside the cofferdam, consists of limestone was compacted to 98% modified proctor by using a deep vibration method. (Fig.17.)

Waling Beam & Tie-rod Installation

After completion of sheet pile driving and excavation works, waling beams and tie-rods were installed in accordance with the technical specification of the Project.

LOGISTIC OF THE PROJECT

The logistic works for the site have been carried out from the main office, established in Bautino, which is the closest urban village in the region and is approximately 350 km away from the construction site. Therefore, the transportation to the construction site is carried out by ships and usually takes 28-30 hours depending on the weather conditions. Transportation from island to the base is carried out by two freighters.

Since water level in the vicinity of the island was very low, the accommodation ship could not reach the island and had to anchor far away from the island. Therefore, the journey by a small boat from the accommodation ship to the island takes maximum 2 to 2.5 hours depending on the weather conditions.

HSE PROGRAM

The artifical islands project has been undertaken by fully complying with the very strict HSE regulations stipulated in the project and achieving the “Safety Excellence and the Zero Accident Philosophy”. All work were conducted by using PPE (personnel protective equipment); such as hard helmet, gloves,

safety glasses, life jacket for all personnel on site and safety belts for the piling workers, which are working on the specially manufactured guides.

The proposed site is in an extremely sensitive environmental area designated as “Specially Protected Zone”. Activities within this region are subject to stringent controls during the periods, April 1 to July 15 and the whole month of October. Therefore, strict HSE and Quality Control / Quality Assurance Programs are implemented in the construction works.

CONCLUSION

In this article, information related to on-going artificial island and ice protection barrier construction project in Northern Caspian Sea is summarized. Cofferdams composed of sheet piles and steel pipe piles with various dimensions were constructed. These cofferdams are distributed around the island so as to protect the island complex from drifting ice ridges in winter season.

Despite the construction site being extremely sensitive environmental area designated as “Specific Ecological Region” and “Specially Protected Zone”, hard nature conditions, adverse weather conditions and all the problems faced during construction, strict HSE and Quality Control / Quality Assurance Programs are implemented in the construction works.

This project is an important model, which verifies that geotechnical engineers can manage to use the highest technology for the construction of the most challenging off-shore structures even in the hard nature conditions.

ACKNOWLEDGMENT

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