MOORING-BUOY SYSTEMS AT DIEGO GARCIA POL PIER

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ABSTRACT

The U.S. Navy Construction Forces have installed two buoy-mooring systems at Diego Garcia POL Pier. These buoys are to assist the mooring and maneuvering of capital class vessels berthing at the pier. The operational requirements, installation constraints and environmental considerations required the use of propellant embedment anchors and a high tension shallow water configuration.

Hardware components were acquired from Government inventories, inspected, preassembled and shipped to Diego Garcia. On the island, Naval Construction Forces (Underwater Construction Team 2) surveyed the installation sites, placed embedment anchors and connected mooring legs on the sea floor. Connections to the buoys were made by sinking the buoys and making the final hookup underwater. The buoys were re-floated, establishing a pretension condition in the chains to reduce the buoy excursion under ship loads.

1. INTRODUCTION

This paper pertains to the design and installation of the two buoy-mooring systems at the Petroleum-Oil-Lubricant (POL) Pier Project at Diego Garcia, Chagos Archipelago, B.I.O.T. The pier mainly consists of an approach trestle, a main loading platform and two mooring buoys. The berthing face is aligned in a northwesterly-southeasterly direction located within the lagoon of Diego Garcia parallel to and 30 feet seaward from the toe of the dredged turning basin, and its trestle connects with an existing causeway, as shown in Fig. 1.

The two mooring buoys serve the purpose of securing bow and stern lines of capital ships and are located at the two ends of the pier 175 feet from the ends of the pier and set back 60 feet (in shore) from the pier face. The two buoy-mooring systems consist each of a single modified peg top buoy and 5 sets of leg chains, sinkers and propellant embedment anchors.

Design of the buoy-mooring system for the Diego Garcia POL pier was driven by operational requirements, installation constraints and environmental considerations which make the moorings quite different from standard Navy Fleet Moorings. These differences make the installation of the moorings more critical in some respects than conventional fleet moorings.

2. MOORING SYSTEM DESIGN

Standard Navy Fleet Moorings. Figure 2 shows the operating characteristics of catenary legs equivalent to those of a DM-26 CLASS C riser-buoy type fleet mooring for 50,100, and 150 ft. of water depths. CLASS C meets the Diego Garcia requirement of 100,000 lbs horizontal load per leg. This load includes a 1.33 factor for dynamic loading. The curves shown in the figure are for a single leg of a free-swinging riser-type mooring without sinker.

Unique Design Constraints. The importance of Fig. 2 is to show the critical aspects of shallow water moors compared to deeper water moors; and to show the magnitude of the horizontal span of the legs. The cross-over point of the three curves reflects a maximum dynamic loading criteria of 0° up-angle on the anchor shank, chain safety factor of 4:1 and a 'Slack' of 0.6 feet minimum. 'Slack' is defined here as the excess of total catenary leg and riser length over a "tautline" length from the anchor to the buoy. Slack is therefore a measure of the mooring's capability to absorb oscillatory motion of the ship mooring bitt around its maximum static load excursion. From Fig. 2 it can be seen that the spring rate (stiffness) of a shallow water mooring is greater than for the deeper water moorings. Also, the spring rate of moorings in the working load region are much less than those in the overload region. This shows the necessity of avoiding working in the overload region where small ship motions develop high loads very rapidly. Also, in the working load region, it can be seen that the higher spring rate of the shallow water moors tolerates substantially less ship oscillatory motion, for the same dynamic load factor, than is the case for the deeper water moors.

Although the Diego Garcia installation cannot accommodate the large horizontal span of the DM-26 fleet mooring design, the necessity for maintaining most of the design criteria and characteristics of the standard fleet moorings is recognized. This is particularly true with regard to providing at least the minimum chain slack criteria for the shallow water moors. Motion which cannot be accommodated by the chain must be absorbed by the elasticity of the ship's hawser lines to the buoy.
Embend Anchors. The Diego Garcia lagoon has a highly variable and unpredictable subbottom consisting of spotty coral and coralline sediments. Past performance of drag type anchors has been unreliable in the lagoon soils. Embend anchors are the best choice for permanent moorings in the coral seafloor at Diego Garcia. CEL 100K lbs anchors have been installed and utilized there successfully for several years. The shallow water in conjunction with limited horizontal span, involves high up-angles of the chain at the anchor-point. The embedment anchor is not limited by the 30° up-angle limitation for burial anchors that is shown by Fig. 2.

The high up-angles would have forced the system to work past the knee of the characteristics curve and up into the low-sack, chain snapping overload region unless relatively large sinkers were used. Figure 3 shows the influence of sinker weight on slack for the final configuration. This accounts for the use of 20K pound sinker weights on the main loading legs of the moorings.

Equally significant is the difference in failure mode between embedment anchors and burial anchors. The burial anchor may drag if over-loaded but it may either dig in deeper, or it may rebury on future dragging. However, if the embedment anchor is overloaded, it starts to break-out of the soil and becomes less resistant to further overloading (if it does break-out entirely). It cannot be depended on to recover such lost holding power.

Application of embedment anchors to this mooring design has reflected these design considerations in the emphasis placed on anchor load sharing provision and tailoring the design to the bathymetry. In addition, methods for underwater measurement and adjustment of each leg assembly have been developed to assure load sharing balance and buoy location.

Leg Span and Array Angles. The horizontal span and the angular orientation of the legs of each mooring is determined by bathymetry, the proximity of the pier to the mooring buoys and by the location of the POL lines at the south end of the pier, as shown in Fig. 1. The embedment anchors, when used at the minimum 30 feet of water depth, require the use of the heavy-mass launcher for firing. As shown in Fig. 1, the bathymetry is such that the horizontal span of the main legs for the south array is limited to approximately 130 feet. The angular orientation to these 30-foot contour pockets, and clearance around the POL lines is also shown in the figure. The north mooring is made identical in scope of chain and component selection to the south mooring for the purpose of commonality.

Mooring Leg Design Characteristics. The characteristics of the final mooring leg design are shown in Fig. 4. The maximum static load (75,000 lbs) and the maximum dynamic load with 1.33 factor (100,000 lbs) are shown to fall below the knee of the operating curve.

3. CONSTRUCTION AND INSTALLATION

Hardware Procurement, Assemblage and Shipment. The 31st Naval Construction Regiment, Port Hueneme, CA, procured all components of the required hardware from the Government inventories. The hardware components were inspected and preassembled into 5 sets of mooring legs for each of the buoy systems. Each mooring leg was then packaged into a single pallet for shipment to Diego Garcia and installation on site.

Site Survey. Stations A, B and C were established on the approach trestle, as shown in Fig. 1. Stations A, B and C are in a straight line and parallel to the existing bench marks. Station A is set back 5 feet from the south face of the pier and set back 10 feet from the east face of the pier. Stations B and C are 200 feet and 500 feet, respectively, from the Station A.

The south mooring buoy survey used Stations A and B for all survey points. The bearings from Station A were read from line AB counterclockwise. The bearings from Station B were read from line BA clockwise.

The north mooring buoy survey used Stations B and C to establish survey points for the mooring legs and for the construction mooring anchors. The bearings from Station A were read from line AB clockwise. The bearings from Stations B and C were read from CB counterclockwise.

Propellant Embedment Anchors. A total of ten propellant embedment anchors were installed at the designated marker buoys. Installation of the anchors was accomplished as follows:

- Explosives and primer for the placement of embedment anchors were stored on the barge.
- Assembly of the launch vehicle.
- The barge was positioned, using the LCM-8 along side the barge and the LARC positioned astern of the LCM-8 while also moored with an upwind anchor. The launch vehicle was lowered by the crane, the firing circuit was checked at final time, and the embedment anchor fired into the seafloor after which the launch vehicle was recovered and prepared for the next placement. See Fig. 5.
- Each embedment anchor was tested for holding power by use of the barge and beach gear pulling wire attached to the embedment anchor cable. The required proof load was 100 kips measured by a load cell located near the fixed beach gear block. Divers connected the pulling wire to each anchor wire and also disconnected the wire after each test. Actual test loads were recorded as shown in Table 1, and ranged from 98 to 145 kips.

Installation Scenario. On-island lift equipment limitation (lack of suitable floating crane) have imposed special handling requirements and procedures. The need to transfer loads in excess of these limits is met by innovative use of the buoyancy effect of water. The need to transfer on-shore hardware to positions on seafloor is met by transferring the heavier components on pallets from the pier to the seafloor using cranes on the pier.
The barge then lifts the load off-bottom and transports it to the site while it is still suspended in the water. The lifting and lowering is accomplished with bow sheave on the barge, a deck-winch, and a beach gear. Figs. 6 and 7 show, respectively, the assembly of legs with spider plate and equalizer. These legs were then lowered to the seabottom for final connection to the ground ring.

The need to lift the mooring ground ring and chain legs for hook-up to the buoy is accomplished by flooding and sinking the buoy down a guide-line attached to the ground ring. The sink-refloat technique used on the buoy was another innovation to manipulate heavy weights greater than the lifting capacity of available equipment on the island. The keeper plate on the buoy is assembled to the riser chain; and the buoy is blown free of water to raise the buoy and suspended mooring chains to the surface.

These operations required palletizing of certain leg sub-assemblies and subsequent lowering to the seafloor. The sink-and-float capability requirement for the buoys required on-site modifications of the peg-top buoys. The flood-and-blow operations required air compressors, hoses and underwater hook-up by divers.

Mooring Inspection. A mooring inspection, as shown in Fig. 8, was made to document the final placement and as-built construction of the mooring using manual measurement and photographs and including the following:

- Survey of final buoy, sinker and anchor locations
- Electrical potential readings by use of underwater voltmeter of the cathodic protection system.
- Still photographs of each major mooring component
- Visual inspection of all cotter pins and hardware pins.

4. CONCLUSION REMARKS

The remote location and limited equipment assets of Diego Garcia created a unique construction environment which imposed demand on personnel, equipment and the construction scenario. The successful completion of this project is mainly attributed to the following factors:

- The involvement of the military construction forces in the early phase of project planning and design allowed direct input of detailed on-island equipment limitations, construction procedures, personnel capabilities, and the benefit of underwater construction expertise.
- Thorough inspection of every hardware component and/or total preassembly including component identification prior to deployment was the key factor for the control of construction and installation schedule, material logistics, and on-site personnel and equipment mobilization.

Table 1 Propellant Embedment Anchor Holding Power at Diego Garcia Lagoon

<table>
<thead>
<tr>
<th>Anchor Site</th>
<th>Test Loads (Pounds)</th>
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<tr>
<td>S1</td>
<td>115,000</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>3</td>
<td>100,000</td>
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<tr>
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<td>145,000</td>
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<td>4</td>
<td>105,000</td>
</tr>
<tr>
<td>5</td>
<td>105,000</td>
</tr>
</tbody>
</table>

REFERENCES


2. "Harbor and Coastal Facilities", NAVFAC DM-26, July 1968 (Revision in progress)
Figure 1  POL Pier Buoy-Mooring Systems
Diego Garcia, B.I.O.T.

Figure 2  Characteristics of Standard Navy
CLASS C Free-Swinging Riser-Type
Mooring (2 1/4" Chains without
Sinker)

Figure 3  Sinker Weight vs Chain Slack at
50 Feet Water Depth

Figure 4  Characteristics of Designed
Mooring Leg at 50 Feet Water
Depth
Figure 5 Barge-Lifting Launching Vehicle after Shot

Figure 6 Barge-Handling Spider Plate and Leg Nos. 4 & 5

Figure 7 Barge-Handling Equalizer and Leg Nos. 1 & 2

Figure 8 Diver Taking Voltmeter Readings