CONCEPT DEVELOPMENT
COST ESTIMATES FOR
DIEGO GARCIA POL MOORING
ISLAND INSTALLATION

26 MARCH 1979

Ocean Engineering

CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON NAVY YARD
WASHINGTON, DC 20374

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The Ocean Engineering and Construction Project Office (FPO-1) of Chesapeake Division Naval Facilities Engineering Command (CHESNAVFACENGCOM) was tasked by Pacific Division Naval Facilities Engineering Command (PACNAVFACENGCOM) to perform a study of viable concepts for the installation of mooring.
island dolphins at Diego Garcia, Chagos Archipelago, B.I.O.T. The six following concepts were analyzed for their relatively safe and economical constructability by Naval Construction Forces on the island:

- Crawler Crane with Additional Bents
- Direct Pile Driving from Work Barge
- Jack-up AMMI Pontoon
- Construction Jacket
- Semi-Submersible Templet
- Flexifloats

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The estimated construction jacket weighs 43 tons per jacket. The FPO-1 engineering efforts are estimated to be $70,800 which includes the concept development, engineering analysis and design, drawings and specifications and 3 weeks on-site consultation. The in-house design work will be complete in 8 (earliest) to 16 weeks (latest).
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C. CHERN

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CONCEPT DEVELOPMENT AND COST ESTIMATE
FOR
POL PIER MOORING ISLAND INSTALLATION
DIEGO GARCIA, CHAGOS ARCHIPELAGO
BY
C. CHERN
SEPTEMBER 1978
REVISED JANUARY 1979

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OCEAN ENGINEERING AND CONSTRUCTION PROJECT OFFICE
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WASHINGTON NAVY YARD
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EXECUTIVE SUMMARY

The Ocean Engineering and Construction Project Office (FPO-1) of Chesapeake Division Naval Facilities Engineering Command (CHESNAVFACENGCOM) was tasked by Pacific Division Naval Facilities Engineering Command (PACNAVFACENGCOM) to perform a study of viable concepts for the installation of mooring island dolphins at Diego Garcia, Chagos Archipelago, B.I.O.T. The six following concepts were analyzed for their relatively safe and economical constructability by Naval Construction Forces on the island:

- Crawler Crane with Additional Bents,
- Direct Pile Driving from Work Barge,
- Jack-up AMMI Pontoon,
- Construction Jacket,
- Semi-Submersible Templet,
- Fluxifloats.

The analysis concluded that the construction jacket would be the best one since it provided the highest constructability by SEABEE/Underwater Construction Team. PACDIV and OIC Pier Team, Diego Garcia, concurred with this conclusion and requested continuation of CHESDIV's effort into final design, plans, and specifications.

The estimated construction jacket weighs 43 tons per jacket. The FPO-1 engineering efforts are estimated to be $70,800 which includes the concept development, engineering analysis and design, drawings and specifications and 3 weeks on-site consultation. The in-house design work will be completed in 8 (earliest) to 16 weeks (latest).
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1. INTRODUCTION

1.1 Background

The U.S. Navy Construction Force is currently undertaking a Naval Support Facilities Project at Diego Garcia - one of the five islands in Chagos Archipelago. The Petroleum-Oil Lubricant (POL) Pier is one of the major facilities in this construction project. The pier mainly consists of a 1,150 feet approach trestle, a 560 feet by 40 feet main platform and two mooring islands. Figure 1.1 shows the key plan of the POL pier system. The mooring islands are located 175 feet away from the edge of the main platform and 60 feet setback from the docking face of the pier. The plan and the elevation of the mooring island are shown in figure 1.2.

The mooring island will be located at approximately 60 feet water depth and supported by a group of steel pilings. The group consists of 13 vertical and 16 batter piles at 1 to 3 slope. All pilings are 16 inches outside diameter and 0.344 inch wall thickness. The mooring islands are planned to be installed in May-July, 1979 period. One of the reasons is the favorable construction weather window. It appears that the sea states in this period are most favorable for the installation of pilings under open sea environment.

In August, 1978, CDR L. Donovan, Project Officer - Diego Garcia (Code 09DG), conferred with LCDR J. Stamm and the supporting staff of the Ocean Engineering and Construction Project Office (Code FPO-1), CHESNAVFACENGCOM, for developing concepts to install the mooring island in an efficient and economical way. In addition, the installation procedures have to be safe for the SEABEE operation. In early September, 1978, LT. J. Wong,
OIC, Pier Team of Diego Garcia met with the FPO-1 personnel for further study of the concept development. During meetings with LT Wond, FPO-1 presented the following 5 concepts for discussion. These concepts were constrained to utilize the existing SEABEE/UCT manpower and equipment available on the island and not change the A&E's design.

- Crawler Crane with Additional Bents
- Direct Pile Driving from Work Barge
- Jack-up AMMI Pontoon
- Construction Jacket
- Semi-Submersible Templet

After preliminary assessment of the above concepts, the construction jacket was recommended as the potential candidate. LT Wong, with concurrence of CDR Donovan, requested FPO-1 to pursue the cost estimate and design completion schedule for this candidate concept.

In November 1978, PACDIV requested an assessment of a commercially available FLEXIFLOAT ASSEMBLAGE for possible application. It was then found that the maximum length of the elevating spud columns with lift lugs is 50 feet which can only operate at about 33 feet water depth. The prescribed water depth at the mooring island site is 60 feet which is too deep to operate the flexifloat assemblage.

1.2 Objectives

The main objective of this report is to compile the FPO-1 efforts for the Diego Garcia POL Pier mooring island installation concept development. The documents and engineering drawings gathered during the course of concept study will provide needed information for future workload development in this area.
2. MOORING ISLAND INSTALLATION CONCEPTS

2.1 Concept No. 1 -- Crawler Crane with Additional Bents

This concept utilizes the existing pile-driving technique and procedures as those for the trestle and main pier. The advantages of this concept are:

- Seabees are familiar with the construction technique and procedures
- Proven success of pile-driving

The disadvantages are:

- Required more steel pipe piles for the additional bents
- Crawler cranes may be trapped in the mooring island during the construction period.
2.2 Concept No. 2 -- Direct Pile-Driving from Work Barge

The prerequisites for the application of this concept are:

- Extremely calm sea
- Rigidly moored work barge

Pictorial presentations of the pile driving procedures are shown in figures 2.1 to 2.3. A pile-driven supporting truss is installed on the barge deck as shown in figure 2.1. Vertical piles are then driven to grade.

A reclaimable seafloor mat shown in figure 2.2 is clamped to the vertical piles as the position keeping guide for the batter piles at the mud-line level. The pile-driver lead is then leaned on the slope of the supporting truss, as shown in figure 2.3, for driving batter piles.
Figure 2.1 Barge Driving Scheme -- Vertical Pile with Pile Driver Support
Figure 2.3  Barge Driving Scheme -- Batter Pile with Pile Driver Support
2.3 Concept No. 3 -- Jack-Up AMMI Pontoon

Figure 2.4 is the AMMI Pontoon in a jack-up mode (obtained from reference 1). The pontoon possesses the following characteristics:

- **Dimension:** 90 ft x 28 ft x 5 ft
- **Displacement:**
  - Nominal 50 Short Tons @ 8 inches draft
  - Nominal 290 Short Tons @ 50 inches draft
- **Structural Members:**
  - Shell and Bulkhead 1/4 inch plate
  - Framing Members 3/16 inch plate
    (Separated, bent and welded to shell and bulkhead)
- **Design Deck Load:** 600 psf
- **Supporting Piles:** 4 to 6 piles at 20 inches outside diameter

In order to evaluate the practical applicability of the jack-up AMMI pontoon at the mooring island sites, the weight items and the required supporting pile penetration are computed. It is noted that the following contributions are provided by Mr. David Raecke (FPO-1).

**Weight Item**

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMMI Pontoon</td>
<td>105,000</td>
</tr>
<tr>
<td>Crane, 50 ton mobile</td>
<td>72,000</td>
</tr>
<tr>
<td>Hammer, MKT DE 30</td>
<td>10,000</td>
</tr>
<tr>
<td>Lead</td>
<td>5,000</td>
</tr>
<tr>
<td>Batter Lead</td>
<td>18,500</td>
</tr>
<tr>
<td>Winches (2)</td>
<td>60,000</td>
</tr>
<tr>
<td>Pile Section (90 ft)</td>
<td>5,300</td>
</tr>
</tbody>
</table>

**SUBTOTAL** 275,800 lbs

5% for incidentals 13,790 lbs

**Total weight to be lifted** 289,590 lbs
Pile Penetration Requirement

Friction area of a 20" Ø pile

\[ \frac{20\pi}{12} = 5.24 \text{ sq. ft/ft of penetration} \]

Assuming that the average of 200 psf of skin friction between soil and pile steel surface is available, the pile penetration resistance is:

\[ = 5.24 \times 200 \]
\[ = 1,000 \text{ lbs/ft of penetration} \]

The penetration requirement, \( L \), is

\[ L = \frac{289,590}{6 \times 1,000} = 48.3 \text{ ft} \]

An alternative way of determining the pile penetration requirement can be obtained by the following expressions:

\[ f = \bar{\sigma}_v K \tan \delta \]  
\[ \bar{\sigma}_v = \gamma' D \]  

where \( f \) = skin friction between soil and pile steel surface

\( \bar{\sigma}_v \) = vertical effective stress in soil

\( k \) = earth pressure coefficient relating vertical to lateral stress, use 0.7 in this case

\( \delta \) = angle of friction between soil and pile steel surface, estimated 20° for silt and calcareous sand

\( \gamma' \) = submerged unit weight of soil, 30#/cu. ft

\( D \) = depth of soil above point where \( f \) is calculated

Combining Eqs (1) and (2), following expression is obtained:

\[ D = \frac{f}{\gamma' k \tan \delta} \]  

If the average skin friction, \( f \), is to be 200 psf, the pile penetration at mid-point (where the average \( f \) is computed) is
\[
\text{Dave} = \frac{200}{\left(30\right) \left(0.7\right) \tan 20^\circ} = 26.2 \text{ ft}
\]

The total pile penetration is then

\[D = 2 \times \text{Dave} = 52.4 \text{ ft}.
\]

**Findings**

- The total pile length required:
  
<table>
<thead>
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<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Penetration below mud-line</td>
<td>50 ft</td>
</tr>
<tr>
<td>Water Depth</td>
<td>50</td>
</tr>
<tr>
<td>Air Gap</td>
<td>10</td>
</tr>
<tr>
<td>AMMI Pontoon Hull Depth</td>
<td>5</td>
</tr>
<tr>
<td>Above Hull Section</td>
<td>10</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>125 ft</strong></td>
</tr>
</tbody>
</table>

- The normal AMMI elevating system does not permit easy welding of add-ons if the required pile length is greater than 40 feet.

- Penetrations may greatly exceed those estimated above depending on the depth of dredge spoil and other weak soils.
2.4 **Concept No. 4 -- Construction Jacket**

The construction jacket concept considers the following factors:

- The first section of the vertical pile and driving hammer will stand alone by itself under the working conditions of:
  - 3 feet wave
  - 10 knots wind
  - Maximum list angle of 10°
  - Minimum crane barge mooring operation
  - Safe operation

Figure 2.5 shows the elevation and the plans of the conceptual construction jacket.

**Installation Procedures**

The following steps are suggested in carrying out the mooring island pile driving:

1. Install construction jacket
2. Install welder's temporary work platform (for welding vertical piles only)
3. Drive vertical piles (a total of 13 piles)
4. Remove welder's temporary work platform
5. Remove construction jacket (optional)
6. Install work skid on top of vertical piles (design of work skid would not be included in this report)
7. Install batter-pile-driving-support
8. Drive batter piles (a total of 16 piles)
9. Remove batter-pile-driving-support
10. Remove work skid
11. Proceed with concrete deck work
Backup Data

Computations of the overturning moment and the resisting moment of the system are described briefly herein. The overturning moment consists of the moment components caused by the gravity load, crane boom imposed horizontal force and environmental forces. The force components are illustrated in Figure 2.6.

<table>
<thead>
<tr>
<th>Gravity Load</th>
<th>Hammer Weight</th>
<th>9,000#</th>
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<tbody>
<tr>
<td>Drive Cap</td>
<td>1,150</td>
<td></td>
</tr>
<tr>
<td>Flying Lead</td>
<td>4,550</td>
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</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>14,700#</strong></td>
<td></td>
</tr>
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</table>

- Pile weight (16" x .344" WT)
  
  95 ft x 57.52 lb/ft = 5,464#

  Moment $M_1 = (14,700 \times (95+7.5) + 5,464 \times 47.5) \sin 10^\circ$

  = 306,713 ft-lbs

- Horizontal Force: Assuming that the unexpected crane boom imposed horizontal force is 500 lbs.

  Moment $M_2 = 500 \times 110$

  = 55,000 ft-lbs

Environmental Forces:

Wind Velocity @ 10 knots = 11.5 MPH

Wind Area = 10 sq. ft (estimated)

Wind Force = $0.000256 C_v V^2 A$ (ref 2)

= $0.000256 \times 1.0 \times (11.5)^2 \times 10$

= 3.4 lbs

Moment $M_3 = 3.4 \times 80$

= 272 ft-lbs
Figure 2.6  Force Components on a Vertical Pile
Wave: Height \( H = 3 \) ft  
Period \( T = 5 \) sec.  
Water Depth \( h = 45 \) ft MLW*  
Pipe Diameter \( D = 16'' \)  
Drag Coefficient \( CD = 0.75 \)  
Inertia Coefficient \( CM = 1.5 \)

According to the method presented in reference 3, the following parameters are computed:

Wave length at deep sea, \( L_o = \frac{gT^2}{2\pi} \)

\[
= \frac{32.2 \times 5^2}{2\pi} 
= 128 \text{ ft}
\]

\( h/L_o = \frac{45}{128} = 0.351 \)

\( H/L_o = \frac{3}{128} = 0.0234 \)

\[
\frac{C_D D \left( \frac{H}{T} \right)^2 h^2}{2} = 0.75 \times 1.99 \times \frac{16}{12} \times \frac{3^2}{5} \times 45^2 
= 725 \text{ ft} - \# 
\text{(Drag Normalizing Moment)}
\]

\[
\frac{C_M \pi D^2 \left( \frac{H}{T^2} \right) h^2}{4} = 1.5 \times 1.99 \times \frac{12}{12} \times \frac{(3/5)^2}{4} \times 45^2 
= 1,013 \text{ ft} - \# 
\text{(Inertia Normalizing Moment)}
\]

According to Case 7A in reference 3, the moment at mud-line as a function of wave phase angle are tabulated below:

*Initial data and charts indicated 45 ft MLW. This figure used during concept study. November 1978 diver survey reported 60 foot water depths.
<table>
<thead>
<tr>
<th>Phase</th>
<th>0°</th>
<th>10°</th>
<th>20°</th>
<th>30°</th>
<th>50°</th>
<th>75°</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_D$</td>
<td>4.801</td>
<td>4.612</td>
<td>4.080</td>
<td>3.307</td>
<td>1.577</td>
<td>0.180</td>
</tr>
<tr>
<td>$M_D$ (ft-kips)</td>
<td>3.48</td>
<td>3.34</td>
<td>3.00</td>
<td>2.40</td>
<td>1.14</td>
<td>0.13</td>
</tr>
<tr>
<td>$M_I$</td>
<td>0</td>
<td>1.876</td>
<td>3.629</td>
<td>5.155</td>
<td>7.271</td>
<td>8.055</td>
</tr>
<tr>
<td>$M_I$ (ft-kips)</td>
<td>0</td>
<td>1.90</td>
<td>3.68</td>
<td>5.22</td>
<td>7.36</td>
<td>8.16</td>
</tr>
<tr>
<td>$M_T$ (ft-kips)</td>
<td>3.48</td>
<td>5.24</td>
<td>6.68</td>
<td>7.62</td>
<td>8.50</td>
<td>8.29</td>
</tr>
</tbody>
</table>

Where $M_D = M_D \times 725 \text{ ft-#}$ \hspace{1cm} (Drag Moment)

$M_I = M_I \times 1,013 \text{ ft-#}$ \hspace{1cm} (Inertia Moment)

and $M_D$ and $M_I$ are the dimensionless drag moment and inertia moment components, respectively.

The moment due to wave force contribution is:

$M_W = 8,500 \text{ ft-#}$

The total overturning moment is the sum of the above individual contributions, that is

$M_{Total} = M_I + M_2 + M_3 + M_4$

$= 306,713 + 55,000 + 272 + 8,500$

$= 370,485 \text{ ft-lbs}$

The resisting moment is contributed by the gravity weight of the construction jacket. Assuming that the jacket weight 25 tons (19.5 tons in water) and that the base is 44 ft by 44 ft, the resisting amount is:

$M_R = (19.5) \times 2,000 \times 22$

$= 858,000 \text{ ft-lbs}$
In order to develop the above resisting moment, the soil pressure at the jacket base shall be less than the allowable soil bearing pressure at the mooring island site. Due to the lack of available soil data, an estimate of 1 psi soil bearing capacity is assumed. The bearing area required at the jacket base is then:

\[
4A = \frac{19.5 \times 2,000}{1 \times 144}
\]

\[
= 270.8 \text{ sq. ft.}
\]

\[
A = 67.7 \text{ sq. ft at each corner}
\]

The factor of safety of the system is:

\[
\frac{858,000}{370,485} = 2.32
\]
2.5 **Concept No. 5 -- Semi-Submersible Templet**

The main function of the templet in this concept is to indicate the vertical pile location only. The templet does not possess any stabilizing effects to the positioning of the vertical pile prior to or during the pile-driving process. The procedures of installing the system are described briefly as follows:

1. Drive the first section of the first vertical pile by all means, as shown in figure 2-7.
2. Install welder's temporary work platform to the first pile section.
3. Weld the first add-on section
4. Remove welder's temporary work platform
5. Drive the pile
6. Repeat steps (2) to (5) for each add-on section
7. Anchor the semi-submersible templet to the first vertical pile at EL.(-) 10'-0" level and also tie to the seafloor, shown in figures 2.8 and 2.9.
8. Drive all other vertical piles
9. Remove semi-submersible templet (optional)
10. Set-up work skid on top of vertical piles
11. Install batter-pile-driving-support
12. Drive batter piles (a total of 16 piles)
13. Remove batter-pile-driving-support
14. Remove work skid
15. Proceed with concrete deck work

It is noted that steps (10) to (15) are similar to those required in the previous concept.
Figure 2.7  Barge Driving Scheme -- Vertical Pile without Pile Driver Support
Figure 2.8 Plan -- Semi-Submersible Templet
Backup Data

The computation herein is based on the following assumptions:

- The center pile is driven by any practical technique.
- The semi-submersible templet is pinned to the center pile at EL (-) 10'-0'' (35 feet above the seafloor).
- The templet is anchored to the seafloor by at least 4 cables similar to the configuration shown in figures 2.8 and 2.9.

CASE 1: Slack Cables -- Center Pile as Cantilever Beam

If the cables are slack, the overturning moment induced by the second pile at the initial state (see figure 2.6 and its force computations) will be resisted by the bending strength of the center pile at mud-line level.

The force components are shown in figure 2.10a.

According to the computation in the previous section, the overturning moment of a vertical pile at the initial state is:

\[ M_{\text{total}} = 365,985 \text{ ft-lbs} \]

The resisting moment of a 16''Ø x 344'' wt steel pipe pile is

\[ M_R = S \sigma_b \]

where \( S = 64.85 \text{ in}^3 \)

\( \sigma_b = 16 \text{ ksi (estimated allowable bending stress for 16''Ø pipe at S.F. = 1.65)} \)

\[ M_R = 64.85 \times 16 = 1,038 \text{ in-kips} \]

The factor of safety is:

\[ \frac{(1,038 \times 1,000) \times 1.65}{365,985 \times 12} = 0.39 \]
(a) Slack Cable Configuration

(b) Taut Cable Condition

Figure 2.10 Force Components on Semi-Submersible Template
If the factor of safety of 2.0 is required in the system, the number of piles required is:

\[
2.0 \\
N = 0.39 = 5.12 \quad \text{Say 5 piles}
\]

CASE 2: Taut Cables -- Center Pile as Compression Post

If the cables are taut by pretensioning, the center pile will behave as a compression post. When a horizontal force is applied at the templet level, the force will produce a uniform bending moment to the center pile. Figure 2.10b shows the force components of the system. In the figure, pre-tensioning force components are omitted because symmetrical cable forces produce only compressive reaction in the center pile.

The overturning moment of the second pile at the initial state is:

\[ M_r = 365,935 \text{ ft-lbs} \]

The resisting force at the templet level is:

\[
F_r = \frac{365,985}{35} = 10,467 \text{ lbs}
\]

The induced moment on the center pile is:

\[ M_{ind} = 10,467 \times 12 = 125,604 \text{ ft-lbs} \]

The factor of safety of the system is:

\[
\text{S.F.} = \frac{(1033 \times 1,000) \times 1.65}{125,604 \times 12} = 1.14
\]

The number of piles required to obtain a factor of safety of 2.0 is:

\[
N = \frac{2.0}{1.14} = 1.75 \quad \text{Say 2 piles}
\]
2.6 Concept No. 6 -- Flexifloats

Flexifloats are commercially available, standardized watertight, welded steel buoyant units. The floating work platform is constructed by interconnecting adjacent units into usable shapes having adequate buoyancy, strength and stability characteristics for supporting weights of material and mobile equipment imposed on the platform. In the open water environment, the assemblies of flexifloats with multipurpose attachments can be elevated above the tide and wave action for workover operations. Figure 2.11 illustrates the elevated mode of the flexifloat assemblage.

In November 1978, PACDIV requested an assessment of the applicability of the flexifloats for this project. Mr. Bodey (FP0-1) discussed the potential use of the flexifloats with Mr. Robishaw of Robishaw Engineering, Inc. The following information was the summary of this discussion:

- Flexifloat pontoons are available in two series:
  - Series 70  10'x40'x7'
  - Series 60  10'x20'x7'
- 36-inch diameter spud legs at 120 feet long are available from the Company base in the U.S. 48-inch diameter spuds are available from Holland.
- 16 feet length of the spuds are used up within jacks. With 10 feet air gap and 60 feet water depth on site, the maximum available column penetration is 34 feet.
- Shear carrying capacity per column is estimated at 140 tons.
- Estimated cost of the above flexifloat system will be $1,244/day for the first 30 days after which the rate will drop to $622/day.
Bearing Pads for spud legs are about 8 to 10 feet in diameter. At present, bearing pads are not available for 36-inch diameter spuds.

Pontoons have only 2 flood valves on the upper deck and not possible to use pontoons as a jack-up mat.

Basing upon the above information and engineering judgement, CDR Donovan was advised that:

- Four 36-inch diameter legs are not sufficient to support work platform reliably on coral seafloor.
- 8 to 10 foot diameter spread pads are not available for 36-inch diameter legs and these are still not big enough for 350 psf foundation bearing capacity.
- Using two extra pontoons for jack-up mats is not feasible with present pontoons valving system.

In conclusion, the flexifloats is not a viable substitute for a real multi-leg jack-up platform. Finally, Mr. Bodey suggested to CDR Donovan to check at Singapore for cost and availability of a suitable offshore rig.
3. SCHEDULE AND COST ESTIMATE

3.1 Schedule

A tentative project schedule is shown in Chart 3.1. The schedule is planned for the design of construction jackets. The fabrication, transportation and installation timetables are not included.

3.2 Cost Estimate

3.2.1 Engineering and Construction Support

3.2.1.1 Pile-Jacket Concept/Plan/Proposal

- Requirements Acquisition (60 hours) $1,290
- Develop/Select concept from 3-5 schemes with report (180 hours) 3,810
- Preliminary Plan and Cost Estimates (40 hours) 845
- Fonecon Proposal (4 hours) (Include Lt. Jerry Wong meetings) 86

$6,031

3.2.1.2 Resource/Capabilities/Environmental Data Acquisition *

- Trip to Diego Garcia: labor, travel and per diem for 14 total days

  Travel (via San Francisco) $2,700
  Labor 12 days (96 hours) 2,064
  Per diem 90
  D.G. @ $17/day 204

$5,058

* LCDR Pete Marshall of UCT 2 performed this task in November 1978.
**Probable Earliest/Latest Completion Date**

Mooring Dolphin Installation, Diego Garcia

<table>
<thead>
<tr>
<th>ITEM</th>
<th>WORK 1</th>
<th>WORK 2</th>
<th>WORK 3</th>
<th>WORK 4</th>
<th>WORK 5</th>
<th>WORK 6</th>
<th>WORK 7</th>
<th>WORK 8</th>
<th>WORK 9</th>
<th>WORK 10</th>
<th>WORK 11</th>
<th>WORK 12</th>
<th>WORK 13</th>
<th>WORK 14</th>
<th>WORK 15</th>
<th>WORK 16</th>
<th>WORK 17</th>
<th>WORK 18</th>
<th>WORK 19</th>
<th>WORK 20</th>
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<tbody>
<tr>
<td>1. Analysis &amp; Design</td>
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<tr>
<td>2. Bill of Material</td>
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<td>11</td>
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<td>4. Drawings</td>
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</tbody>
</table>

**Chart 3.1 Construction Jacket Design Completion Schedule**
3.2.1.3 Engineering Analyses and Design

- System Analysis: loads, stresses, design interface definition (with A&E falsework, environment, equipment), erection and handling loads, etc: 80 hours $1,720
- Jacket design (load-out, dwgs, spec call-outs, Bill of Materials: 480 hours 10,320
- Vert. pile add on splice sleeve and assy dwg(s): 40 hours 860
- Rail and Falsework System Modifications (Jacket interface mods, vertical pile guide mods, jacket and pile grouting call-outs: A&E Sapias with corrections, addition and notes) 150 hours 3,440

$16,340

3.2.1.4 Mooring Plan and Installation (Based on assumed support by CEL)

- Mooring design analyses for crane barge (one mooring per dolphin). Plan with recommended rigging hardware: 160 hours 3,440
- Install embedment anchors - 2 sites Travel/labor/per diem (see 2.0 above) 5,058
- Anchors & explosives - 12 20K anchors @ $1500 18,000

$26,498

3.2.1.5 Construction Supports

- Jacket fab & erection plan
- Jacket Floatation, upending, orientation and leveling plan
- Falsework installation plan
- Vertical pile stabbing, driving and add-on welding plan (scenarios, safety precautions, instructions, etc) 480 hours 10,320
- Field support: one man on site (4 weeks travel and field work)

Travel 2,700
Labor hours (40+6x10x3 = 720 hrs) 3,870

$16,390

3.2.1.6 Total engineering/construction supports $70,317
3.2.2 Materials

The materials listed below are obtained from the preliminary design drawings as of January 1979. These drawings are:

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<thead>
<tr>
<th>NAVFAC DWG. NO.</th>
<th>TITLE</th>
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<tr>
<td>3017671</td>
<td>Title Sheet</td>
</tr>
<tr>
<td>3017672</td>
<td>General Assembly</td>
</tr>
<tr>
<td>3017673</td>
<td>Details, Deck Module</td>
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<td>3017674</td>
<td>Details, Center Module</td>
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<tr>
<td>3017675</td>
<td>Details, Base Module</td>
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<td>3017676</td>
<td>Details, Construction</td>
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<td>3017677</td>
<td>Details, Construction</td>
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<td>3017678</td>
<td>Details, Construction</td>
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<tr>
<td>3017622</td>
<td>Pile Splice Detail</td>
</tr>
<tr>
<td>3017623</td>
<td>Supporting False Work</td>
</tr>
</tbody>
</table>

The estimated material costs per jacket are tabulated below. The cost item does not include planned falsework, shipping, fabrication, weld rod, labor, fuel, etc.
<table>
<thead>
<tr>
<th>ITEM</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Conventional Rolled Shapes and Pipes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C8 x 11.5</td>
<td>15.18 tons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20&quot;Ø Sch. 20 STD</td>
<td>17.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2x2x½</td>
<td>.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&quot; plates</td>
<td>1.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>½&quot; plates</td>
<td>0.89</td>
<td></td>
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<tr>
<td>3/8&quot; plates</td>
<td>2.13</td>
<td></td>
<td></td>
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<tr>
<td>Subtotal</td>
<td>37.11</td>
<td>$500/ton*</td>
<td>$18,555</td>
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<tr>
<td>(b) Special Rolled Pipes</td>
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<td></td>
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<tr>
<td>Pile Splice</td>
<td>8.35</td>
<td>$1,00/ton**</td>
<td>8,350</td>
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<tr>
<td>(c) Rough Timber</td>
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<tr>
<td>12x12 timber</td>
<td>310 L.F.</td>
<td>$10/L.F.</td>
<td>3,100</td>
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<tr>
<td>(d) Miscellaneous spikes, bolts, etc.</td>
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<tr>
<td></td>
<td></td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>Total Material Cost per Jacket</td>
<td></td>
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<td>$31,005</td>
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* Average mill price at Bethlehem Steel Corporation (Sep 1978)

** Estimated market price at west coast
3.2.3 Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Jacket Materials</td>
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<tr>
<td>2 @ $31,000 ea.</td>
<td>$62,000</td>
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<tr>
<td>Engineering/construction supports</td>
<td>$70,800</td>
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<td><strong>TOTAL</strong></td>
<td>$132,800</td>
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4. SUMMARY AND RECOMMENDATIONS

4.1 Summary

Summaries of the concept development for the installation of POL Pier mooring island at Diego Garcia, Chagos Archipelago, may be drawn as follows:

- The use of crawler crane with additional bents to reach the mooring island site may result in trapping the crane in the last construction bent. In addition, the amount of steel pipes needed as the construction bents may be uneconomical.

- Direct driving of all pilings from the barge will require a rigidly moored barge which appears to be an extremely difficult task at the construction site.

- Jack-up AMMI pontoon concept is site dependent. Without extensive modification of the current jacking system, the jack-up operation can not be applied to this approach.

- Construction jacket concept presents a safe operational procedure. The operating environment is designed for a 3 feet wave and 10 knots wind condition which is a common sea state at the construction site during May-July period. Under the design sea state, the system will have a factor
of safety of 2.5 at the initial stage of driving the first pile. However, the jacket weight (dead weight) of approximately 28 tons may cause some difficulties in weight handling process.

- Semi-submersible templet concept has the light weight advantage. However, the concept requires driving of at least 3 to 5 vertical piles to grade at high risk which is not commonly carried out in engineering practice.
4.2 Recommendations

The recommendations based on the results of this concept study are:

- the construction jacket concept possesses safe operational procedure for SEABEE to perform offshore pile driving. This concept shall serve as the base for further engineering development in conjunction with the mooring island installation assistance.

- an installation plan shall be proceeded to investigate practical methods of overcoming the weight handling difficulties of the construction jacket.
REFERENCES


5. Reliability, Availability, and Maintainability (RAM) for the Elevated Causeway Facility of the Container Off-loading Transfer System (COTS), CEL TH 55-78-06, 1978


10. FLEXIFLOAT, Robishaw Engineering Inc., Houston, Texas (Catalog No. 8595).
APPENDICES

A.1 Documents and Drawings

The following documents and drawings are used in this report:

Documents


Drawings

<table>
<thead>
<tr>
<th>NAVFAC Dwg. No.</th>
<th>TITLE</th>
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<tr>
<td>7,013,333</td>
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<td>7,013,395</td>
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<td>7,013,398</td>
<td>Piping</td>
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<td>Electrical</td>
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<tr>
<td>7,013,417</td>
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</table>
CONSTRUCTION SUPPORT

7,013,431  Isometric and Construction Sequence
           Structural-Mooring Island and Catwalk
           Pier Isometric

7,013,432  Isometric and Construction Sequence
           Structural-Mooring Island and Catwalk
           Pier Construction Sequence

7,013,440  Main Pier Structural-Construction Sequence
           at Main Pier

1,109,804  AMMI Pontoon Hoisting Arrangement
A.2 Correspondence

The following messages were compiled during the period of this concept study:
OIC SPECIAL PIER DET, DIEGO GARCIA

1. FOR 31ST NCR: LT J. WONG, OIC SPECIAL PIER DET, WILL ARRIVE LOS ANGELES 4 SEP 73 ON WA 582, ETA 1355. REQUEST 31ST NCR BE PREPARED TO DISCUSS FCL TOPICS WITH LT WONG ON 5 SEP.
   A. HOMEPORT TANG FOR RETURNING PIER DET MEMBERS.
   B. ADMIN PROCEDURES RE PIER DET.
   C. MAIL SUPPORT STATUS FOR PIER PROJ.

2. FOR 20TH NCR: LT WONG WILL ARRIVE GULFPORT ON SO 341, ETA 2223 ON 5 SEP 73. FCL TOPICS WILL BE DISCUSSED 7 SEP 73.
   A. HOMEPORT TANG FOR RETURNING PIER DET MEMBERS.

3. FOR CHESDIV: LT WONG WILL BE PREPARED TO DISCUSS FOLLOWING TOPICS ON 11 SEP 73:
   A. DESIGN CONCEPTS FOR MOORING DOLPHIN TEMPLATE.
   B. EQUIP AND MAIL AVAILABILITY.
   C. DRIVING BARGE MOORING REGTS.
   D. MOORING DOLPHIN CONSTRUCTION SEQUENCE.

PAGE 62 RHMSGC2415 UNCLAS

B. ADMIN PROCEDURES RE PIER DET.
C. PERSONNEL REPLACEMENT PROCEDURES.

260417Z AUG 78/JB
NAVAL MESSAGE

FROM: CRESNAVFEACOM WASHINGTON DC
TO: 30 NCR BAY DIEGO GARCIA
INFO: PACNAVFEACOM KALAPAPA HI 31 NCR PT EVANS CA
CONCERNT KALAPAPA HI 89 NCR PT EVANS CA

UNCLASS /311000/1

PASS TO PIER TEAM

EC-831 PERMANENT PIER

1. IN SUPPORT OF DESIGN OF CONSTRUCTION SUPPORT EQUIPMENT FOR WORKING ISLANDS, conduct bottom survey of working island sites. Survey area within 100 ft radius from center of working island. Identify and locate, to 1/2 ft, locations bearing and distance from center of working island, all obstructions. Measure bottom composition, eg. soft, loose sand or coral debris. Measure width of each piece of debris or similar hard solid tool to check depth of water at debris.

2. Information requested is required in order to proceed with design of hull construction platform for working islands and support structures. Inform platform construction plans. Required specifications on area, power, loading and

3. Include a sketch showing the layout of the working island and the extent and conditions of the working island. Include next item: Availability/Waist 700" 6.7. 70-100.

4. Include the following:

UNCLASSIFIED
UNCLAS //NOOOOC/

PIER TEAM SENDS FOR LT WONG, OIC
DG-5-851 PERMANENT PIER
A. YOUR 131903CZ SEP 75

1. SEA BOTTOM SURVEY WILL BE CONDUCTED IAW REF A. NOORING ISLAND
LOCATIONS "SHOT-IN" EARLY THIS WEEK. ACTUAL SURVEY TO BEGIN THURSDAY/
FRIDAY. SURVEY RESULTS WILL BE FORWARDED EARLIEST.

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141302Z SEP 75
FM THREE ZER NCR DET DİEGO GARCIA
TO RUEBJHA/CHESENAVFACECON WASHINGTON DC
INFO RHH ERA/PACNAVFACECON PEARL HARBOR HI
RHH ERA/COMCSPAC PEARL HARBOR HI
RUDPAA/COM THREE ONE NCR PORT HUENEME CA
RUDPAA/UCI TWO

ET

CHES-A
UNCLASSIFIED

D3-51, PERMANENT PIER
A. YOUR 131930Z SEP 78
1. SURVEY REQUESTED REF (A) CONDUCTED BY DIVERS FROM UCT TWO.
AVERAGE DEPTH AT SITE OF MOORING ISLANDS WAS SIXTY FEET. VISIBILITY AT BOTTOM WAS FIVE TO TEN FEET. BOTTOM SURVEY WAS MADE USING A PROBE AND 200 FT. SEARCHING LINE WHICH HAD BEEN MARKED OFF AT SIX FT. INTERVALS. NO MAJOR OBSTRUCTIONS WERE NOTED WITH THE EXCEPTION OF THE NORTH SITE. AT 100 FT. NORTH OF THIS SITE THERE IS A BANK WHICH APPARENTLY WAS CAUSED BY THE PASSAGE OF A DREDGE. THE DEPTH AT THIS AREA IS 40 FT. WITH A GRADUAL SLOPE. SILT WITH A DEPTH OF ONE FOOT UNDERLAIN BY A

PAGE 02 RUGG861483 UNCLASSIFIED

Coral layer is evident at both sites. Both north and south sites are strewn with large chunks of coral. Coral boulders which average 4 ft. in dia are randomly spread over each site.
DIEGO GARCIA M O O R I N G DOLPHINS

A. DG SITE VISIT BY LCO MARSHALL FO 21-27 OCT 78
B. FUTURE MG LCO STUMM AND LCO MARSHALL 12-15 NOV 78

1. AS A RESULT OF REF A, FOLLOWING DATA PROVIDED:

A. NORTH AND SOUTH DOLPHIN SITES HAVE CIRCULAR AREAS APPROX 100 FT RADIUS WHICH ARE RELATIVELY LEVEL AT DEPTH 52 FT BELOW MLW. TIDE RANGE APPROX EIGHT FT.


C. ANTICIPATE LEVELING OF TEMPLATE TO BE MAJOR DIFFICULTY OF DOLPHIN INSTALLATION. REQUEST DESIGN EFFORT AND INSTALLATION SEQUENCE CONSIDER ADAPTING UP TO TWO FOOT VARIANCE ACROSS TEMPLATE FOOTING.

2. ADDL MINOR INFO AND PICTURES TO BE PROVIDED DURING REF B.

3. ALL FIELD COAST PERSONNEL ARE MOST ANXIOUS TO VIEW AND ANALYZE DOLPHIN DESIGN AT THE EARLIEST OPPORTUNITY. REQUEST CONTINUE TO KEEP US WORKERS INFORMED ON PROGRESS AND DESIGN.

BT

#2231

0 4 0 2 1 1 ZNOV 78/JR
END FILMED

6-86

D Tic