Progress Report 1
PP-2318 Alternate Block Materials

01 May 2023
Rev A

Prepared for:

National Shipbuilding Research Program

Prepared by:

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1. Executive Summary

This document summarizes the activities since the start of the project to date. This document is a preliminary / rough draft of the final report, with portions or sections written as the engineering related to those section is performed. The intent is to continue to add, revise, and expand this report until the final report is completed.

As of the date on this report, the neoprene pads and HDPE soft caps have been designed, ordered, paid for, and are expected to be delivered before the next dry docking for the GC-9500 at the Gulf Copper shipyard in Port Arthur. The fiber reinforced concrete blocks have been designed and are out for bid.

2. Introduction

Although material science has undergone significant changes in the past 120 years, the construction of dry dock blocks has remained relatively unchanged. The advent of new materials such as polymers, composite materials, and rubber compounds has brought about a revolution in many industries. These materials possess distinct characteristics that provide several benefits for block construction. Using modern materials in dry dock block construction has several advantages such as reducing labor and material costs, increasing overall safety, and being more environmentally friendly. Despite some exploration of these ideas, the industry has not seen significant testing of these new materials to date. Further independent research is needed to outline the advantages and promote the progression of the industry.

The objective of this project is to develop and evaluate three different materials that could potentially replace the structural components of dry dock blocks. Two of the materials selected for testing are HDPE and Neoprene, which are aimed at replacing both soft and hard wood caps. The third material to be evaluated is fiber reinforced concrete, intended to replace the conventional steel reinforced concrete portion of the block. The main aim of investigating alternative blocking materials is to decrease the wood material costs incurred during each dry docking and prolong the service life of the concrete blocks, thereby reducing the overall operating cost of the shipyard and mitigating the local environmental impact.

Polymers are available in a diverse range of materials and stiffness levels. For example, UV stabilized polyethylene, polypropylene copolymer, and other similar thermoplastics have been used successfully in small boat construction around the world for the past two decades and are starting to be introduced to the American market. These polymers offer mechanical properties similar to those of soft woods. Rubber compounds and neoprene have been successfully employed in various industries to provide flexibility and dampening in connections between large structural elements like offshore platforms, bridge design, and tall high-rise buildings. Additionally, fiber reinforced concrete has been utilized in a variety of industries and has been tested in limited use as dry dock blocks in shipyards.

The HDPE cap will be constructed using commercially available sheets of HDPE of varying thicknesses, which will be cut to match the length and width of the concrete block. The sheets will then be fastened together to form thicker layers, allowing for more local deflection. Similarly, the neoprene pad will be constructed using commercially available materials similar to bridge bearing pads, arranged to cover the entirety of the concrete block and at least one layer expected to be approximately 2” thick. The fiber reinforced concrete will be constructed using either synthetic (nylon) macro fibers for reinforcement. The dimensions of the block will vary by shipyard, so that it can match the existing blocks or be used in conjunction with them.

Each of these blocks will be constructed at two different shipyards to be placed into service as keel blocks. The blocks will be rotated to different positions in the keel block string between dockings, and each test block will be separated from the other test block by at least two standard blocks. Furthermore, the blocks will be designed with additional capacity so that failure of the test blocks will not result in damage to the dry dock or the vessel being lifted.

Several shipyards have requested DMC to conduct research on alternate block materials. However, due to the lack of available data, none of the suggested solutions were implemented. DMC is aware of a Northern California shipyard utilizing fiber reinforced concrete blocks and a Gulf Coast shipyard using polymer block caps. Unfortunately, there is insufficient documentation and publicly available technical information to adequately evaluate the materials' performance. This study aims to directly test these materials to verify their benefits in block construction and stimulate their implementation in the drydocking industry.

If successful, the project will lead to the development of more cost-effective, stronger, more flexible, and safer blocks with a longer service life than traditional materials. These materials can be constructed using either recycled or virgin materials and can be recycled at the end of their useful service life. Additionally, these proposed materials are not subject to corrosion or degradation, except for UV exposure or mechanical ripping/tearing, which can lead to an expected extremely long service life. (Previous rubber cap designs implemented internationally have advertised a 20-year service life.) The long service life and the ability to recycle these materials have the potential to significantly reduce the amount of hardwood, softwood, and concrete consumed by dry docking activities, which in turn can reduce the carbon footprint of the shipyard.

3. Progress Report

Since award, DM Consulting has accomplished the following tasks / activities since the project award:

Accomplished to Date:

- Wrote project execution plan
- Further researched fiber reinforced block design
- Designed a fiber reinforced block for use with dry dock GC-9500 at Gulf Copper Port Arthur
- Confirmed supply, pricing, and delivery schedule of the neoprene bridge pads
- Purchased neoprene bridge pads
- Confirmed supply, pricing, and delivery schedule of the HDPE materials
- Purchased HDPE materials
- Issued the fiber reinforced block design for a fabrication and delivery quote
- Prepared project timesheet and invoice templates for the project
- Prepared this document

Planned Activities for Next Month

- Receive and inspect neoprene bridge pads
- Receive and inspect HDPE materials
- Install HDPE materials onto a dry dock at Gulf Copper Galveston
- Finalize procurement of the fiber reinforced concrete blocks
- Send sample HDPE materials for material testing
- Send sample neoprene materials for material testing

- Update this document

Major and Noteworthy Changes to Project

- Gulf Copper has offered for DM Consulting to use the two dry docks located at their Galveston facility as well. They have a dry docking planned for mid-May for their GC-4500 dry dock.

The remainder of this document represents the current revision of the final deliverable that will be issued at the end of this panel project.

4. Which types of blocks and why

To test alternate materials for dry dock blocking, specifically fiber-reinforced concrete instead of traditionally reinforced concrete and HDPE and neoprene bridge pads in place of softwood.

<u>HDPE</u>

Pipe grade weldable virgin HDPE typically possesses a yield stress of around 3,000 psi and an ultimate stress of approximately 4,000 psi. These values mean that the HDPE material is approximately equal to most species of soft wood, but still well below most species of hardwood.

In addition to strength considerations, HDPE also has excellent flexibility and resistance to abrasion. HDPE typically has an elongation at break of at least 700%, giving plenty of deformation and warning prior to failure much greater than to wood. These properties mean that this material can withstand significant amounts of bending and flexing without cracking, thanks to its high degree of elasticity. Flexibility is a crucial property for soft caps of dry dock blocks.

The failure modes of HDPE can include elastic deformation, yielding, and finally, brittle failure, similar to failure modes of wood construction.

DM Consulting does not have any direct knowledge of any uses or tests of HDPE materials as a soft cap for dry dock block applications.

<u>Neoprene</u>

The neoprene pads selected are 100% virgin Neoprene Elastomer pads, rated for AASHTO and commercial applications (60 Duro). This material has a tensile strength of 2,250 psi, slightly less than soft wood that is typically used for dry dock applications. However, this is still significantly higher than the maximum allowable dry dock block pressure loads of 300 psi for service loads and 800 psi for ultimate load cases.

This material has a minimum ultimate elongation of 350% before brittle failure, giving plenty of deformation and warning prior to failure similar to wood.

Various different rubbers and similar polymers have been used and tested over the last several years. Most of these tests have performed successfully in regards to technical considerations. However, none of the materials tested to date have been as readily available as AASHTO neoprene bridge pads. DM Consulting does not have any direct knowledge of any uses or tests of AASHTO neoprene bridge pads materials as a soft cap for dry dock block applications.

<u>Fiber-reinforced Concrete</u>

Concrete can be mixed in many different strengths and many different additives. Additionally, fibers for reinforcement can be made from a variety of materials and in a variety of lengths. Based on discussions with other shipyards, the following parameters were selected for testing.

Mix Strength: F'c = 5,000 psi at 30 days

Aggregate: ¾"

Fibers: 2" (macro) synthetic (buckeye) fibers

Of the shipyards that have used fiber reinforced blocks, the blocks have been loaded several times to 240 psi. This stress level is commensurate with the higher end of the typical dry dock block design of a maximum allowable design load of 300 psi. One shipyard reported that they have been using fiber reinforced concrete blocks for 10 years without any cracking or damage to the blocks.

5. Installation

HDPE

The HDPE soft cap materials were designed to be the same area as the concrete block on to which they were being placed. HDPE materials were ordered in 1", ½", and ¾" thicknesses so that the final block height can be shimmed to the correct block height.

Neoprene

The Neoprene soft cap materials were designed to be the same area as the concrete block on to which they were being placed. Traditional wood shims were used so that the final block height can be shimmed to the correct block height.

Fiber-reinforced Concrete

Hold for development.

6. Procurement Information

HDPE

The HDPE soft cap materials were designed to be the same area as the concrete block on to which they were being placed. HDPE materials were ordered in 2" and 1" thicknesses so that the final block height can be shimmed to the correct block height.

HDPE Materials				
Line No.	**Description**	**Unit Cost**	**Qty**	**Cost**
1	48" x 120" x 1/2"	$ 259	3	$ 776
2	48" x 120" x 3/4"	$ 387	3	$ 1,161
3	48" x 120" x 1"	$ 517	3	$ 1,551
3	**Total Cost**			**$ 3,489**

Neoprene

The Neoprene soft cap materials were designed to be the same area as the concrete block on to which they were being placed. Traditional wood shims were used so that the final block height can be shimmed to the correct block height.

Neoprene Materials				
Line No.	**Description**	**Unit Cost**	**Qty**	**Cost**
1	42" x 48" x 2"	$ 2,613	2	$ 5,226
2	42" x 48" x 1"	$ 804	2	$ 1,608
3	**Total Cost**			**$ 6,834**

Fiber-reinforced Concrete

Hold for development.

7. Risk Management

Technical difficulties during testing and analysis

Delays in procurement due to material availability

Budget overruns due to unexpected costs

8. Dockings

HDPE

Hold for development.

Neoprene

Hold for development.

Fiber-reinforced Concrete

Hold for development.

9. Results of testing

HDPE

Types of testing

Before Testing

After Testing

Comparison

Neoprene

Types of testing

Before Testing

After Testing

Comparison

Fiber-reinforced Concrete

Types of testing

Before Testing

After Testing

Comparison

10. Adjusting the design and re-testing

Hold for development.

11. Carbon Footprint

Hold for development.

12. Future work to continue

Hold for development.

Other materials

Adding shaped blocks

Appendix A. References

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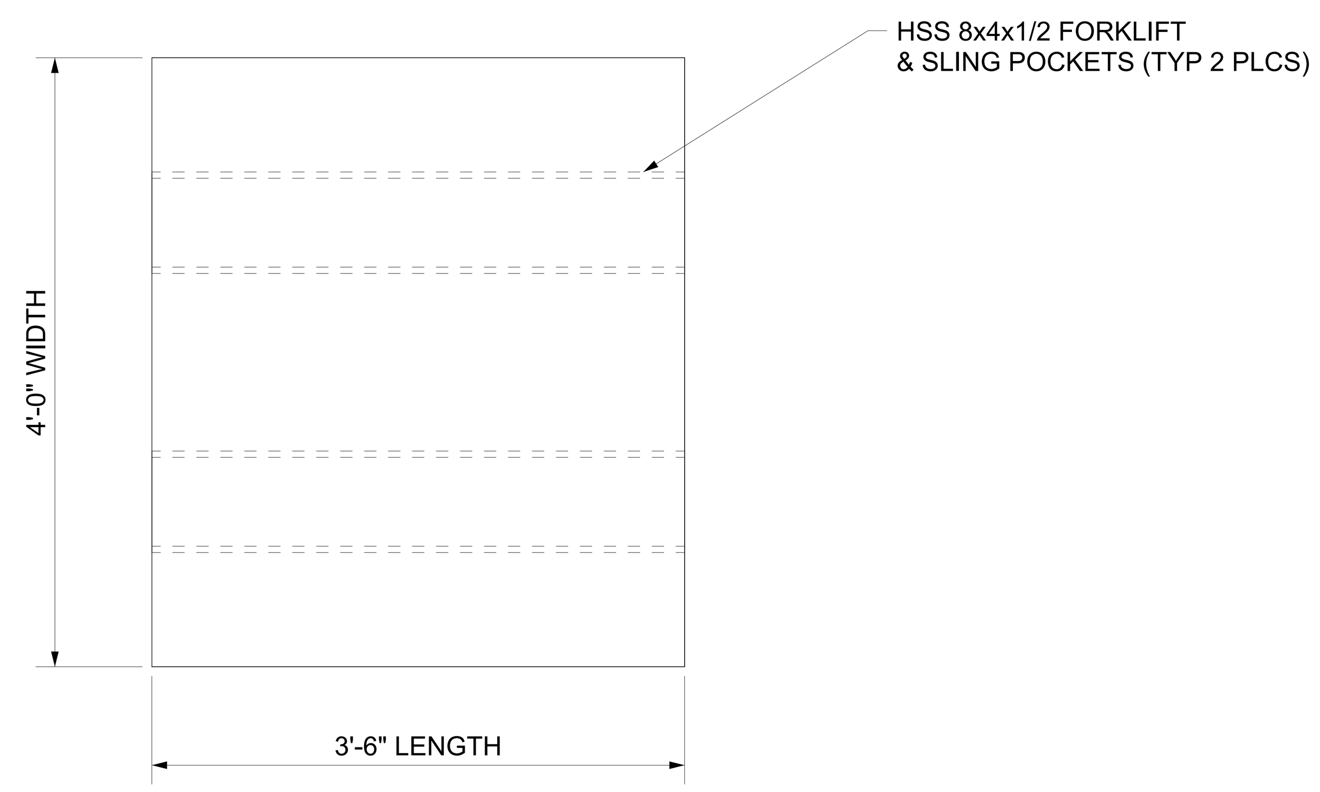
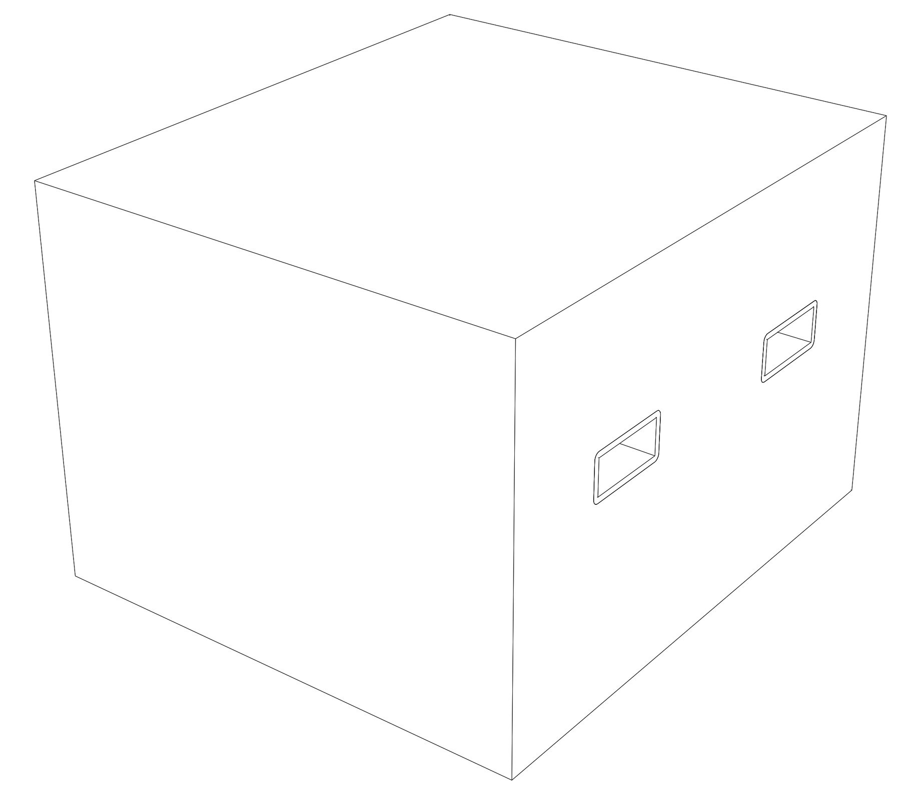
Appendix B. Neoprene Pad & HDPE Soft Cap Design

Appendix C. Fiber Reinforced Block Design



PLAN VIEW



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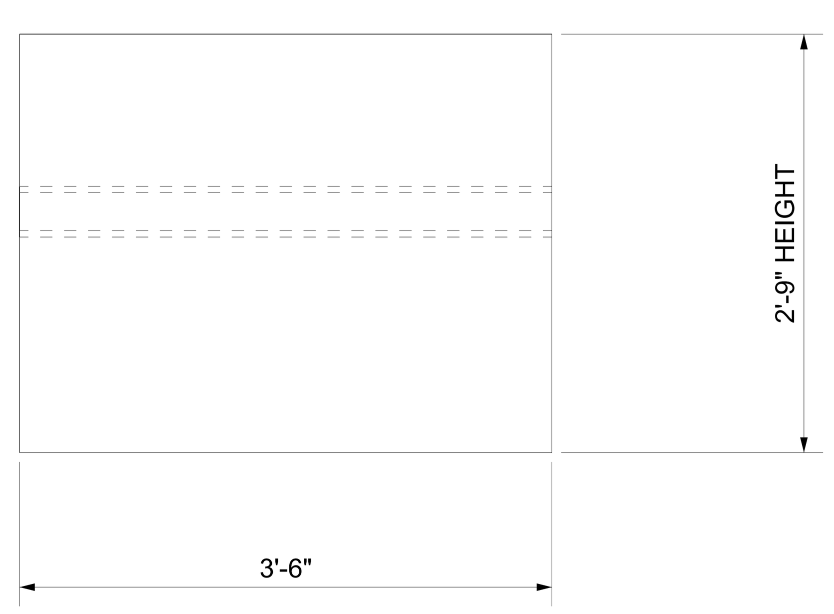
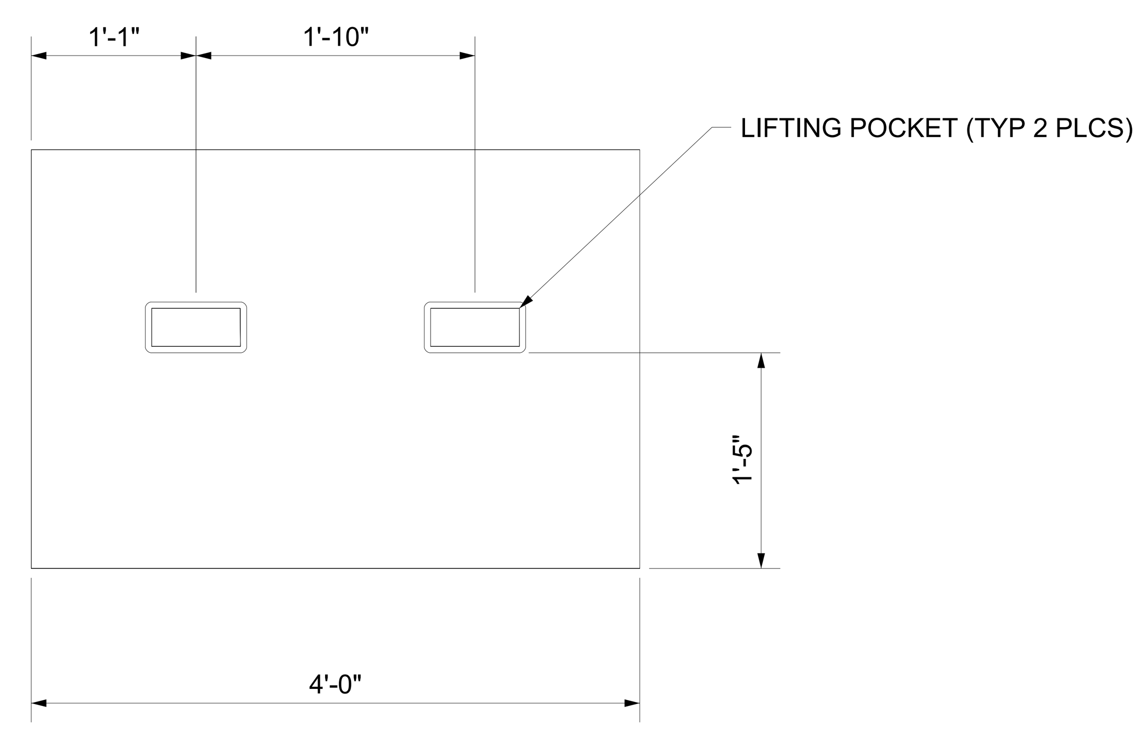


SIDE VIEW



FRONT VIEW

NOTES:
1. ALL CONCRETE TO BE fc' 5,000 psi OR BETTER.
2. REINFORCEMENT TO BE 2" (MACRO) LEGNTH SYNTHETIC (NYLON) BUCKEYE FIBERS
3. HSS POCKETS TO BE ASTM A500 Gr B (46 ksi) OR BETTER
4. THIS BLOCK DESIGNED FOR USE ON GULF COPPER GC-9500 FOR TESTING.

CLIENT: NSRP
HULL/PROJECT: PANEL PROJECT
ALTERNATE BLOCK MATERIALS
TITLE.: PLANS, SECTIONS, & DTLS
FIBER REINF. CONCRETE BLOCKS
SCALE: 1" = 1'-0"
DATE: 18 APR 2023
DWG NO.: 2318-ST-100
REV. A
SHT: 1 OF 1

CAD FILE: 2318-ST Block Details rev A.3dm