Final Report
PP-2318 Alternate Block Materials

18 Mar 2024

Rev A

Prepared for:

National Shipbuilding Research Program

Prepared by:

DM Consulting, Inc.
www.DryDockTraining.com
12316 Dormouse Rd.
San Diego, CA 92129

Category B Funding: Data developed partially with funding from project participants that was not charged to a government contract, and partially with government funding.

Distribution: Distribution unlimited.

Contents

1. Executive Summary

This project is a Research and Development Panel Project sponsored by the National Shipbuilding Research Program (NSRP). Panel Projects are funded project opportunities that are important to the shipbuilding and ship repair industry chosen by the NSRP Executive Control Board.

This project will explore the use of alternative materials in drydocking blocks through engineering analysis, material testing, and full-scale practical trials.

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 soft 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 drydocking 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 caps were constructed using commercially available sheets of HDPE of varying thicknesses, which were cut to match the length and width of the concrete block. The sheets were then fastened together to form thicker layers, allowing for more local deflection, in the normal way soft caps are intended. 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 blocks were constructed using synthetic (nylon) macro fibers for reinforcement. The dimensions of the block match the existing blocks and be used in conjunction with them.

The fiber reinforced blocks were placed into service as keel blocks. The blocks were designed with additional capacity so that the failure of the blocks will not result in damage to the dry dock or the vessel being lifted.

If successful, the project will lead to the development of more cost-effective, materially superior, 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 softwood and concrete consumed by drydocking activities. This in turn can reduce the carbon footprint of the shipyard.

3. Which Types of Blocks and Why

Alternate materials for dry dock blocking were tested, 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 prior 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 370 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 prior uses or tests of AASHTO neoprene bridge pads materials as a soft cap for dry dock block applications.

Fiber-reinforced Concrete

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: 1/16" x 2" nylon (macro) synthetic (buckeye) fibers

At the shipyard that 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 safe working load of 370 psi.

4. 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

Mare Island Dry Dock was able to build their fiber reinforced concrete blocks for $750/block.

5. Cost Analysis

Cost Analysis Parameters

- Example Case of Using HDPE or Neoprene instead of soft wood for the soft cap.
- 60 Concrete blocks, topped with hard wood and a soft wood cap.
- Block length = 3.5’
- Block Width = 4’
- Soft Cap = 2”
- Soft Cap Vol = 210 cu ft
- Assume 6 dockings per year.
- Assume 1 hour for a crew of 3 at $40 / hour labor.

Cost Analysis Table

Description	Wood 2x4x8 Yellow Pine	HDPE 54x48x1/2 Marine Grade	Neoprene Pads
Volume per Piece (cu ft)	1.5” x 7.5” x 8’ = 0.292 cu ft	54” x 48” x ½” = 0.75 cu ft	1 per block
Quantity	720	280	60
Unit Cost	$3.35	$256	$2,538
Extended Cost (Initial Cost)	$2,412	$71,680	$152,280
Labor Cost	$7,200	$7,200	$7,200
Install Cost	$9,612	$78,880	$159,480
% Replacement per Docking	100%	5%	2%
Annual Maintenance Cost	$57,672	$23,664	$19,138
10 Year Cost	$586,332	$315,520	$350,856

Fiber Reinforced blocks will cost approximately the same as traditional blocks. Expected life span 33% more than traditional reinforced blocks (15 yrs vs 20 yrs).

All the materials presented have the ability to reduce material waste and reduce cost through increased service life and decreased labor costs to replace those materials. The addition effect of decreased labor for replacing materials could mean less downtime for a dry dock.

6. Practical Testing

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.

For testing at the Gulf Copper Shipyard in Galveston, TX, the HDPE materials were intermingled with plywood and treated as the same. For testing at the Gulf Copper Shipyard in Port Arthur, TX, the HDPE materials were placed on top of the blocks as the soft cap.

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

The fiber reinforced blocks are in use under US Coast Guard and MSC vessels at Mare Island Dry Dock. Mare Island has utilized these blocks for upwards of 10 years. This is an unusually progressive step for a shipyard that Mare Island has undertaken, and speaks to their ingenuity. The industry has rarely considered this option. It is not in use at any shipyards drydocking US Navy ships to our knowledge.

See the below tests where the materials were utilized:

Docking 1: Tug onto dry dock GC-4500 in Galveston, TX

- Materials: HDPE
- Block Info:
    - Type: Keel block
    - Calculated Block Pressure: 8.7 LT / sq ft
- Results: Successfully supported the vessel, no noticeable changes to the materials post-docking.

Figure 1: Docking 1 Keel Block

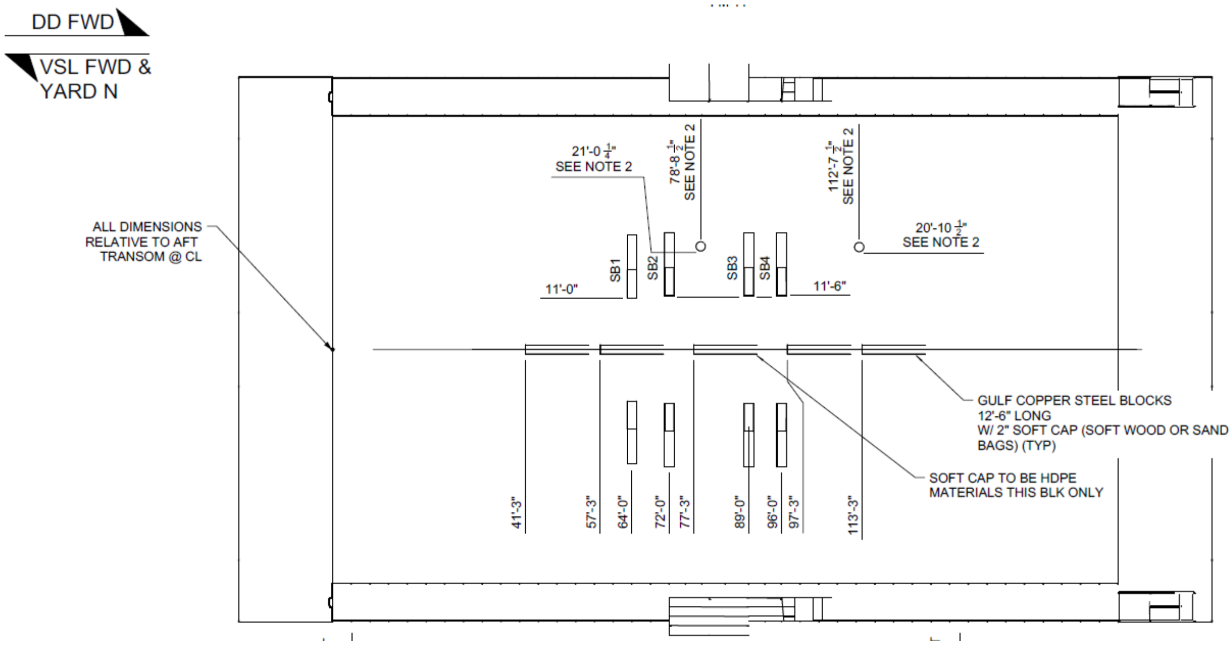


Figure 2: Docking 1 Blocking Plan

Docking 2: Offshore Work Vessel onto dry dock GC-9500 in Port Arthur, TX

- Materials: HDPE & Neoprene
- Block Info:
  - Type: Keel blocks & Side Blocks
  - Calculated Keel Block Pressure: 14.6 LT / sq ft
  - Calculated Side Block Pressure: 6.8 LT / sq ft
- Results: Successfully supported the vessel, no noticeable changes to the materials post-docking.

Figure 3: Docking 2 HDPE Side Block

Figure 4: Docking 2 HDPE Keel Block 1

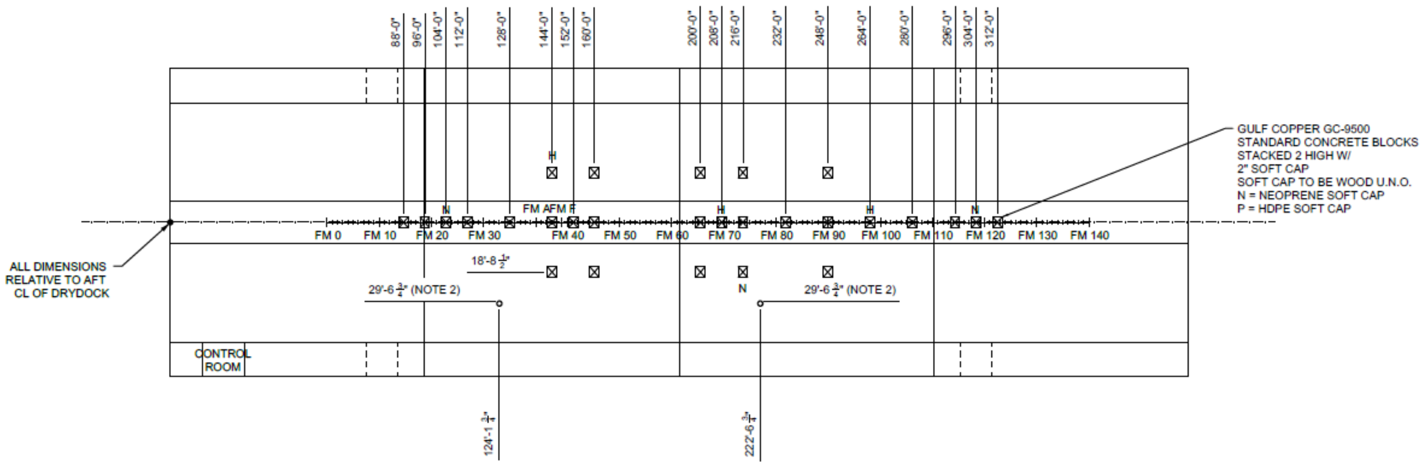
Figure 5: Docking 2 HDPE Keel Block 2

Figure 6: Docking 2 HDPE Loaded

Figure 7: Docking 2 Neoprene Side Block

Figure 8: Docking 2 Neoprene Side Block Loaded Showing ½" Compression

Figure 9: Docking 2 Neoprene Side Block Loaded Showing ¼" Compression

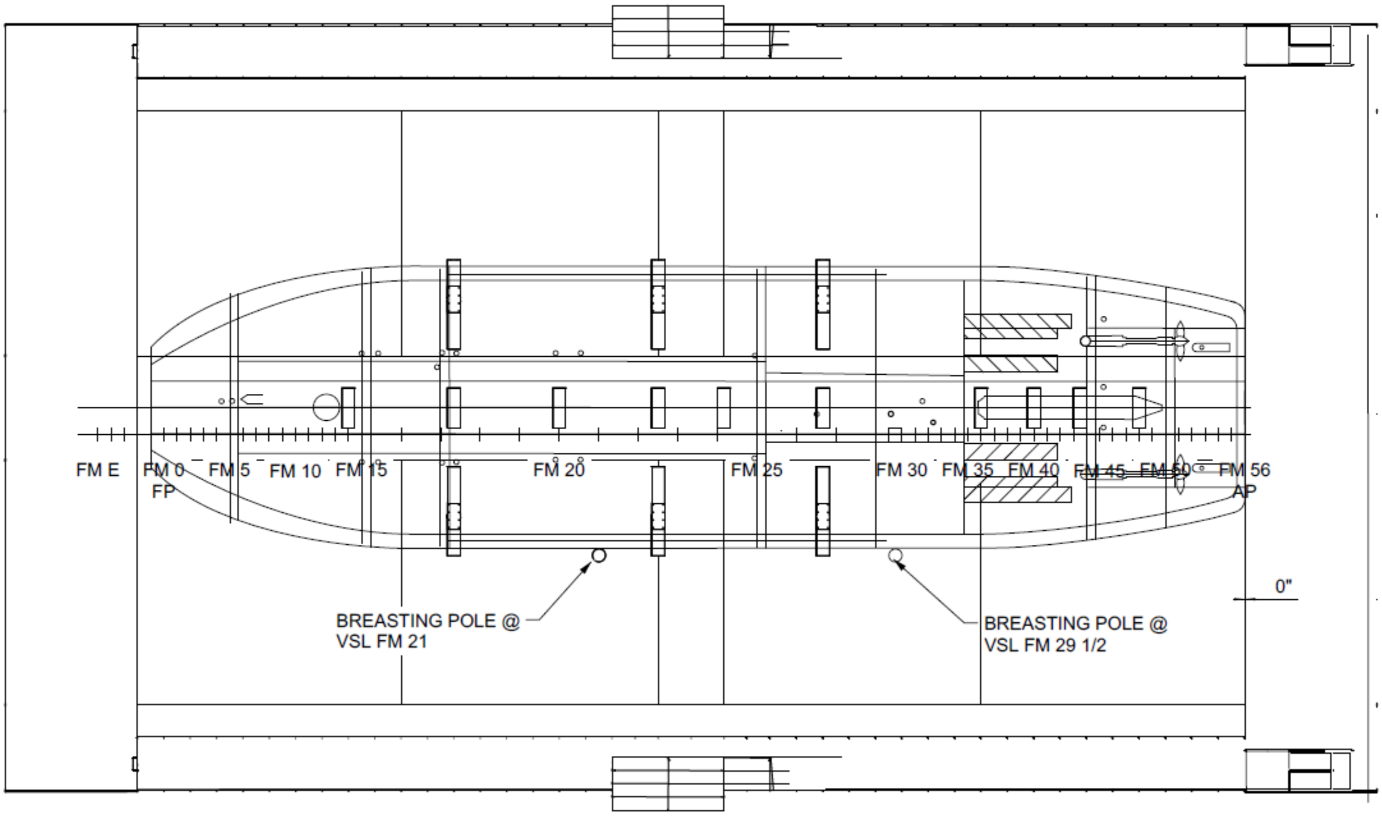


PLAN VIEW - BLOCKS

Figure 10: Docking 2 Blocking Plan

Docking 3: USACE Utility Vessel Brandy Station onto dry dock GC-4500 in Galveston, TX

- Materials: HDPE
- Block Info:
  - Type: (Rotating) Side Blocks
  - Calculated Side Block Pressure: 14.7 LT / sq ft
- Results: Successfully supported the vessel, no noticeable changes to the materials post-docking.



PLAN VIEW

Figure 11: Docking 3 HDPE Side Block

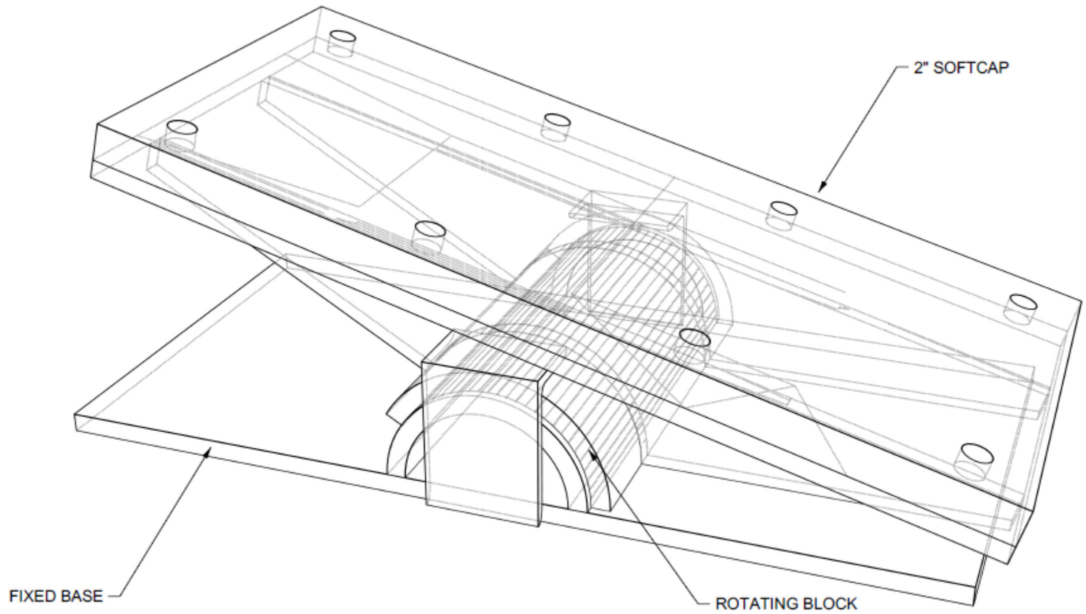


Figure 12: Isometric of Rotating Side Block

Figure 13: Docking 3 HDPE Side Block Before Docking

Figure 14: Docking 3 HDPE Side Block After Docking

Docking 4: US Coast Guard Cutter at Mare Island Dry Dock, Graving Dock #3 in Mare Island, CA

- Materials: Fiber reinforced blocks
- Used on 100% of the blocks.
- Results: Successfully supported the vessel, no noticeable changes to the materials post-docking.

Figure 15: The block Fiber-reinforced block under USCG Cutter

Figure 16: (old) Fiber-reinforced block under USCG Cutter

7. Laboratory Testing

<u>HDPE</u>

Tensile testing was performed samples of the HDPE materials before and after docking. The results of material testing are given below:

HDPE Material Testing Results		
Nominal Material Thickness	Yield Strength (Control)	Yield Strength (Post Dockings)
1/2 inch	870 psi	1,100 psi
3/4 inch	780 psi	1,080 psi
1 inch	960 psi	1,120 psi

The above table indicates that the material has a higher yield strength after being used as soft cap material. The tests conducted were selected as the best available in a timely manner that would suit the project, however, the tests performed are primarily for metallic materials. However, it can be reasonably concluded that the HDPE material did not degrade as a result of being used in dry docking.

Neoprene

Since the neoprene was quickly determined after the first docking to not be a viable solution, no material testing was performed.

Fiber-reinforced Concrete

3 blocks were tested:

Old Navy Concrete Docking Block This block originally belonged to the US Navy when they were still operating the Mare Island Facility. Naval operations ceased and the facility was decommissioned in 1996. These blocks are conventionally made of steel reinforced concrete.

Figure 17: Old concrete block

New Fiber-Reinforced Concrete The blocks are newly constructed within the last few years. They are blocks made of Concrete with Fiber-Reinforcement, with no internal steel reinforcement. These blocks were designed by Mare Island Dry Dock. They have been used in drydockings.

Figure 18: New fiber reinforced concrete block

Old Fiber-Reinforced Concrete This block, is an older generation of the same make of Fiber-Reinforced Concrete >5 years old.

Figure 19: Old Fiber-Reinforced Concrete block under a USCG Cutter.

Figure 20: Equipment Used for Compression Tests

Figure 21: Equipment Used for Splitting Tensile *Tests*

Testing Results:

	Compressive Strength [PSI]	Splitting Tensile Strength [PSI]
Old Navy	7500	548
New Fiber	8970	902
Old Fiber	7850	662

Results discussion: The fiber blocks outperformed the old Navy block. This is expected. Fiber reinforced concrete has more internal tensile resistance, which should do better in both listed tests. There seems to be a large discrepancy between the Old Fiber blocks and New Fiber blocks. This is unexpected. However, the results still show a viability for Fiber Reinforcement as a replacement for Steel-Reinforced Concrete.

8. Materials Friction Testing

Friction testing was added as expanded scope to this project. The friction between the blocks and the ship is not addressed in dry dock standards, including US Navy, US Coast Guard, or ASCE. However, there have been some dry dock accidents that have occurred due to slip. Notably however, these accidents occur primarily on marine railways, where there is an extreme incline.

For this test DM Consulting conducted friction testing using a slip meter (typically used to test the slipperiness of floors). The results of friction testing indicate that HDPE can be treated just as plywood for shimming blocks to their final height.

Materials that had been scored by use exhibited better friction coefficients.

The results of the friction testing are given below. While the averages below seem fairly consistent, the minimum values measured for the gritty HDPE were much lower than other values. It is expected that this grit would actually increase the coefficient of friction when enough compression load is applied to drive the grit into the polymer surface. However, this hypothesis was not tested during this project.

Friction Testing Summary			
Material	**Avg.**	**Max**	**Min**
HDPE (clean)	0.72	0.78	0.66
HDPE (gritty)	0.45	0.58	0.28
HDPE (extra gritty)	0.51	0.81	0.20
Neoprene	0.59	0.72	0.47
Plywood (clean)	0.72	0.78	0.64
Plywood (rough)	0.46	0.52	0.40

It is important to note that the friction coefficient presented in the table above is the friction between the tester and the material. **The above static coefficient of friction does not represent a true coefficient between a ship and the materials.** The information is useful to gauge the materials against each other.

Published data for friction coefficients between polyethylene and steel lists the static coefficient of friction (μ) to be 0.20. The manufacturer stated that μ=0.20 is what they utilize for their own internal use as well. Considering the testing limitations, μ=0.2 is the best value DM consulting available.

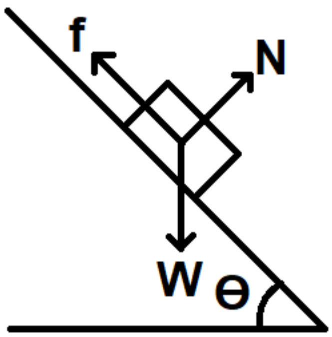
Lastly, an additional concern that we considered was that certain types of marine growth may reduce the coefficient of friction by lubricating the HDPE surface (such as a layer of slick algae). However, in discussions with the HDPE manufacturer, the manufacturer indicated that applying lubricant to the surface did not significantly decrease the static coefficient of friction. With other materials, the static coefficient of friction is reduced with lubricant by filling and smoothing bumps and holes on the surface of the material. However, with HDPE, the material is very homogeneous and smooth, not allowing any place for the lubricant to help smooth out the surface.

Figure 22: Alex Stiglich, DMC performing a friction test on a wooden cap.

Figure 23: Slip meter utilized for friction testing, reading a coefficient of 0.38

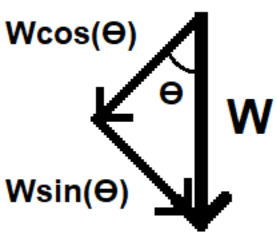
Below is derived slip analysis for a ship on the blocks. As previously suggested, there isn't a standardized calculation for drydocking, so this analysis was created from basic physics principals. The free body diagrams depict the ship as a rectangle and the blocks as a smooth surface. This analysis can represent any direction of slip; longitudinal, transverse, or anything in between. The curved surfaces of the blocks are conservatively negated for this analysis. The effects of block curvature would be difficult to quantify and would likely change for each vessel/blocking plan.

Slip Analysis at Angle:
Free Body Diagram



W = Weight
N = Normal Force
f = Friction
Θ = Angle of Slope

Dividing W into Components



Solving

Equal and opposite
N = Wcos(Θ)

Equal and opposite
f = Wsin(Θ)

Equation for Friction
f = μN
μ = Coefficient of friction

Solving f = f
μN = Wsin(Θ)

Substitute for N
μ(Wcos(Θ)) = Wsin(Θ)
Solving for μ
μ = ~~W~~sin(Θ)/~~W~~cos(Θ)

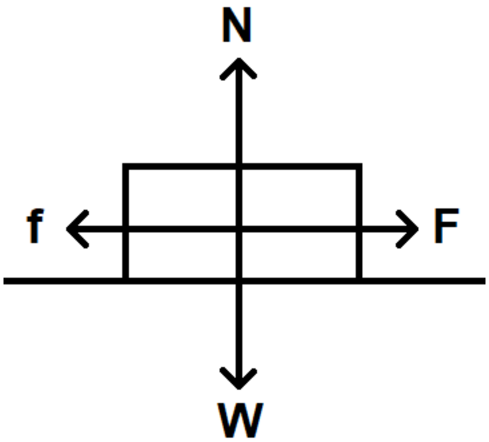
μ = tan(Θ) or Θ = atan(μ)

Results	
μ	Θ [deg]
0.05	2.9
0.10	5.7
0.15	8.5
0.20	11.3
0.25	14.0
0.30	16.7

This analysis suggests that with a static coefficient of friction of 0.2, the ship/block system should not slip up to an angle of 11.3 degrees. This calculation has no margin of safety included.

Slip analysis for Siesmic Force:

Free Body Diagram



W = Weight
N = Normal Force
f = Friction
F = Siesmic Force

Solving

Siesmic Force

Reference: US Standard Drydocking Claculations from NSTM 997

$F = 0.2W$

Equal and Opposite

$N = W$

Equal and Opposite

$F = f$

Equation for Friction

$f = \mu N$

Solving F = F

$f = 0.2W$

Substitute for f

$\mu N = 0.2W$

Substitute for N

$\mu \cancel{W} = 0.2\cancel{W}$

$\mu = 0.2$

This analysis shows that based o the US Navy standards, and the minimum earth quake acceleration factor of 0.2 g, the minimum coefficient of friction required is proportional; μ=0.2. This has no margin of safety included.

9. Carbon Footprint

When researching the carbon footprint of wood materials, wood materials are considered a negative carbon footprint. This is because those materials are typically used in construction, which sequesters the organic carbon contained within the wood materials rather than letting them rot or burn.

However, in dry docking, the wood materials are consumed and then disposed of. While come of the wood is used for multiple dockings when possible, the wood materials are still consumed rather than sequestered.

Implementing reusable soft caps greatly reduces the wood consumed for each docking, resulting in a smaller carbon footprint dry dock operation. Combining the reusable soft caps with some sort of universal block (shape or rotating), the carbon footprint of dry docking is further reduced.

In addition to the direct reduction of carbon footprint, the reduced labor time in soft wood shaping also reduces the carbon footprint of dry docking.

Lastly, polymer materials are biproducts of oil refining. If not used, the polymer materials would simply be waste materials from gasoline production. Rather than disposing of the carbon in these materials, the carbon is sequestered in the HDPE sheets used in dry docking.

Once HDPE has reached the end of its useful life, the material can be recycled and reconstituted into any number of uses.

The carbon footprint of the neoprene materials is similar to HDPE in that it reduces the amount of wood consumed during dry docking. While neoprene materials can be recycled, there are not nearly as many various uses for recycled neoprene materials as with HDPE.

10. Project Challenges

The following are some of the challenges and unforeseen issues encountered during this project:

- Marine growth prevented the team from measuring the deflection of the soft caps immediately after docking. The deflections could only be measured after the marine growth had been removed.

- The material testing conducted on the HDPE materials was conducted using tests intended for metallic materials. Given a longer duration project, the proper tests could be conducted to confirm actual material properties.

- Friction testing was performed using a slip meter intended to testing walking surfaces. This slip meter is not a true indication of the coefficient of friction between the materials that were tested and steel.

- A navy dry docking was scheduled to place that was canceled. However, the project was able to incorporate two government-owned vessels, one USCG cutter and one USACE utility vessel.

11. Summary of Results and Recommendations

Results of Dockings

The results of the docking 1 indicate that HDPE can be treated just as plywood for shimming blocks to their final height.

The results of docking 2 indicate that the HDPE performed well as soft cap. The material showed very little stress. The neoprene also performed very well; however, the material is much softer and showed stress by bulging on perimeter of the material.

The results of docking 3 indicate that the HDPE performed well as soft cap. The material showed very little stress. This docking indicates that cutting wood can be eliminated altogether in most dockings when combining HDPE materials with a universal shaped cap, such as the swiveling blocks used.

The results of docking 4 indicate that fiber reinforced concrete performs as well as traditional steel reinforced concrete.

Material & Friction Testing

The results of the material testing indicate that the HDPE materials do not degrade as quickly as softwood when used as a soft cap for docking.

The results of the fiber reinforced concrete blocks indicate that the fiber reinforced concrete may be used in place of traditional steel reinforcement.

Recommendations

NAVSEA approval is required before alternate material use on drydocking US Navy Vessels. Use any of the below recommendations at your own risk, see disclaimer section below.

- HDPE – HDPE materials performed very well and are a direct replacement for soft wood. The material can be easily cut / shaped using the same tools used for cutting wood. Based on testing conducted within this project, HDPE materials may be used in locations where earthquake loading is not expected. HDPE materials should be further evaluated for friction testing before implementing in earthquake prone locations. Since friction increases once the material is scored from use, it is recommended to limit the amount of new (unscored) HDPE materials to a maximum of 25% of the blocks for any particular docking. Also, consider additional recommended testing before use.

- Neoprene – The neoprene materials performed satisfactorily in compression. However, they did not exhibit resilience to local deformation, neoprene cannot be easily shaped with common wood tools, and the cost of neoprene is much higher than HDPE or wood. Based on the testing performed within this project, we do not recommend the use of neoprene sheets as tested. A tougher rubber compound may be used to alleviate the local abrasion issues.

- Fiber Reinforced Concrete – Fiber reinforced concrete performed well, and the older blocks tests appeared to have less spalling than steel reinforced blocks of similar ages. Based on the testing performed within this project, we recommend that fiber reinforced blocks be used instead of steel reinforced blocks.

12. Additional Recommended Testing

The following additional studies are recommended to pursue and progress the design of alternate block materials:

- Friction Testing between HDPE and vessels of different material makes/levels marine growth to determine if HDPE can be fully implemented in earthquake zones.
- Testing of HDPE materials in extreme cold weather conditions
- Testing of HDPE materials in proximity to hot work such as grinding or welding
- Testing of HDPE materials in long-term use of the material replacement should be considered.
- Testing of HDPE materials failure mechanisms in contrast to wood.
- The neoprene materials performed well under compression loads but were damaged by marine growth and contact with jagged edges. It is recommended to test a harder rubber compound that may provide similar compression strength to softwood which may be less prone to local damage.

13. Disclaimer

The findings, recommendations, and conclusions presented in this project paper are provided for informational purposes only. While every effort has been made to ensure the accuracy and reliability of the information presented, it is important to note that all experimentation and implementation of alternative materials in dry dock block construction should be undertaken at the user's own risk.

DM Consulting, Inc. and the National Shipbuilding Research Program (NSRP) do not assume any responsibility or liability for any loss, damage, injury, or inconvenience sustained by individuals or entities as a result of the use or reliance upon any information, methods, or materials presented in this project paper. Users are advised to conduct their own thorough assessment and testing to determine the suitability and safety of employing alternative materials in drydock block construction within their specific applications and environments.

Furthermore, DM Consulting, Inc. and NSRP expressly disclaim any warranties, expressed or implied, including but not limited to the implied warranties of merchantability and fitness for a particular purpose. In no event shall DM Consulting, Inc. or NSRP be liable for any direct, indirect, incidental, special, exemplary, or consequential damages (including, but not limited to, procurement of substitute goods or services; loss of use, data, or profits; or business interruption) arising in any way out of the use of this information, even if advised of the possibility of such damage.

14. Distribution

DM Consulting is dedicated to supporting the distribution of this project's information. Below are the efforts of distribution.

March 28-30, 2023	NSRP All Panels Meeting
April 1, 2023	Dry Dock Quarterly Newsletter
April 24-28, 2023	Dry Dock Training - Asia/Australia/Oceania - Live Online
May 8-11, 2023	Dry Dock Training - Pascagoula, MS, USA
June 6-9, 2023	Dry Dock Training - London, United Kingdom
June 13-16, 2023	Dry Dock Training - London, United Kingdom
July 1, 2023	Dry Dock Quarterly Newsletter
July 20, 2023	NSRP Sustainment Panel Meeting
September 6, 2023	NSRP Sustainment Panel Meeting at FMMS – San Diego, CA
October 1, 2023	Dry Dock Quarterly Newsletter
October 23-26, 2023	Dry Dock Training - North America/South America - Live Online
Nov 29-Dec 1, 2023	WorkBoat Show - New Orleans, LA. USA
December 5-8, 2023	Dry Dock Training - Virginia Beach, VA, USA
January 1, 2024	Dry Dock Quarterly Newsletter
February 5-9, 2024	Dry Dock Training - San Diego, CA, USA
March 5-8, 2024	Dry Dock Training - London, UK - Live Online
March 13, 2024	Final Presentation – NSRP Sustainment Panel – San Antonio, TX
April 1, 2024 (upcoming)	Dry Dock Quarterly Newsletter

Home Page Updates on our website: www.DryDockTraining.com
Dedicated Project Page on our website:www.DryDockTraining.com/Alternate-Blocking-Materials.html

Appendix A. References

1. "Polyethylene & HDPE PE100 Pipe: Properties and Types". PE100+. Retrieved from https://www.pe100plus.com/PE-Pipes/Technical-guidance/Trenchless/Methods/PE-Pipe-i1341.html

2. "HIGH DENSITY POLYETHYLENE (HDPE) PIPES". Gulf Eternit Trading. Retrieved from https://gulf-eternit.com/wp-content/uploads/2019/03/HDPE-Product-Information-GET-2019.pdf

3. PPI Handbook of Polyethylene Pipe, 2nd ed. (n.d.). Retrieved April 27, 2023, from https://plasticpipe.org/pdf/chapter09.pdf

4. Wood Handbook–Wood as an Engineering Material. (n.d.). Retrieved April 27, 2023, from https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr190/chapter_04.pdf

5. Pine Wood – Density – Strength – Melting Point - Material Properties. (n.d.). Retrieved April 27, 2023, from https://material-properties.org/pine-wood-density-strength-melting-point-thermal-conductivity/

6. Design Values - Southern Pine. (n.d.). Retrieved April 27, 2023, from https://www.southernpine.com/using-southern-pine/design-values/

7. Coefficient of Friction Reference Chart Retrieved December 18, 2023, from https://www.schneider-company.com/coefficient-of-friction-reference-chart/

Appendix B. Related Works

1. Docking Block Revolution Presentation, by: the Docking Office at JRMC Yokosuka, JP
2. Fiber-Reinforced Rubber Blocks Presentation, by: Shibata, JP
3. Engineering and Economic Feasibility of Using Rubber Soft Caps For Drydocking of Naval Vessels, by: LCDR Vincent C. Watson, FL, USA

Appendix C. Control HDPE Material Testing Results

ANDERSON& ASSOCIATES
CONSULTING METALLURGICAL ENGINEERS AND TESTING LABORATORY

July 28, 2023

DM Consulting

Attn: Tim Greeson, P.E.

By email

Re: DM Consulting - Tensile Testing of HDPE

Dear Mr. Greeson:

Pursuant to your request, we have completed testing on the submitted samples. This report details the results.

SPECIMEN

Three samples were submitted for tensile testing Samples identified as SwRI #was submitted for testing as shown below.

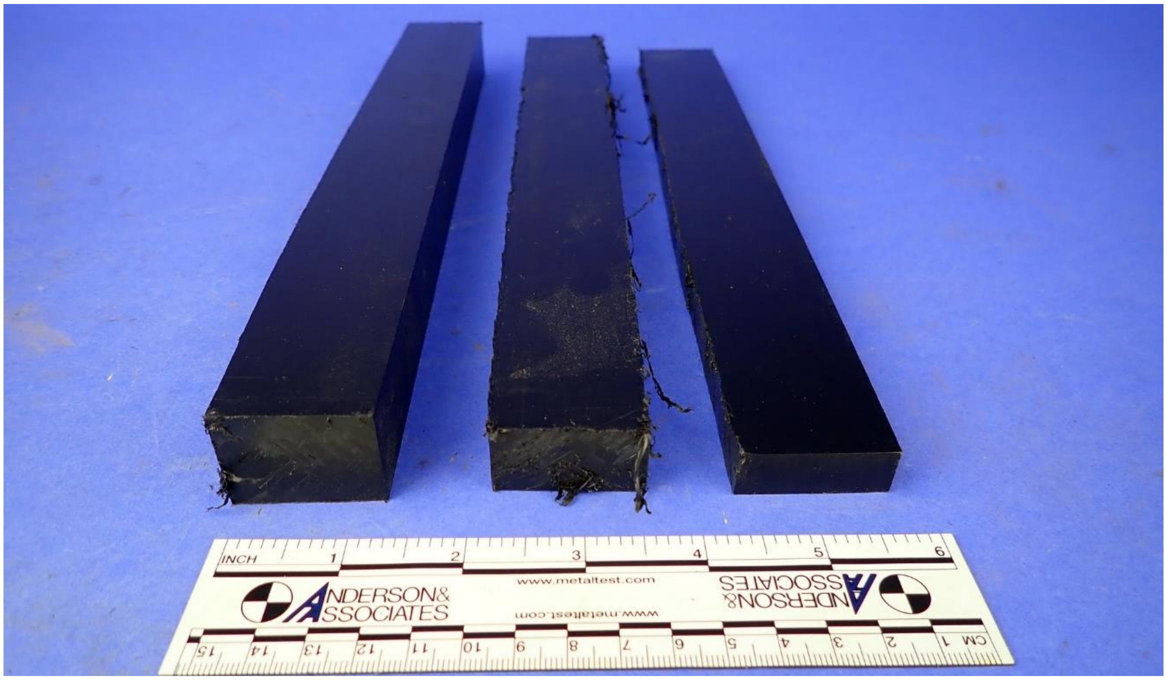


Figure 1
The submitted samples are shown above.

Sample	Identification
A	0.492" thick
B	0.724" thick
C	1.022" thick

TENSILE TESTING

1. One full thickness, reduced section tensile was removed each sample. The specimens were pulled in tension to failure while monitoring the strain over the first part of the load curve. The results are as follows.

Specimen	0.2% Offset Yield Strength [Ksi]	Ultimate Tensile Strength [Ksi]	Elongation [%]
262-A	0.87	1.42	173
262-B	0.78	1.43	170
262-C	0.96	1.40	76

2. The datasheets are attached.

Respectfully submitted July 28, 2023.

ANDERSON & ASSOCIATES, INC.
Engineering Firm Registration # F-816

J. Edgar Zapata, P.E., Lic # 72859
President

Samples will be discarded after 30 days unless other arrangements are made.

ANDERSON& ASSOCIATES

CONSULTING METALLURGICAL ENGINEERS AND TESTING LABORATORY

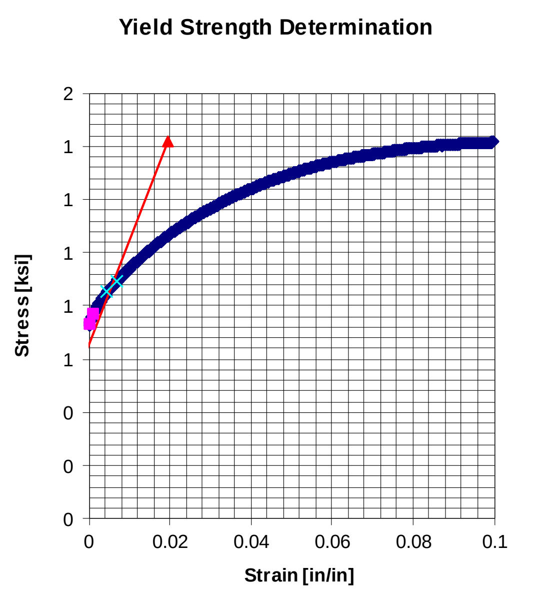
Specimen: 262-A

Job #: 230262

Other ID:

Other ID:

Other ID:



Tensile Strength Determination per ASTM E8

0.2% Offset Yield Strength [Ksi]	Ultimate Tensile Strength [Ksi]	Elongation [%]
0.871	1.419	172.6

Strain Hardening Exponent per ASTM E646

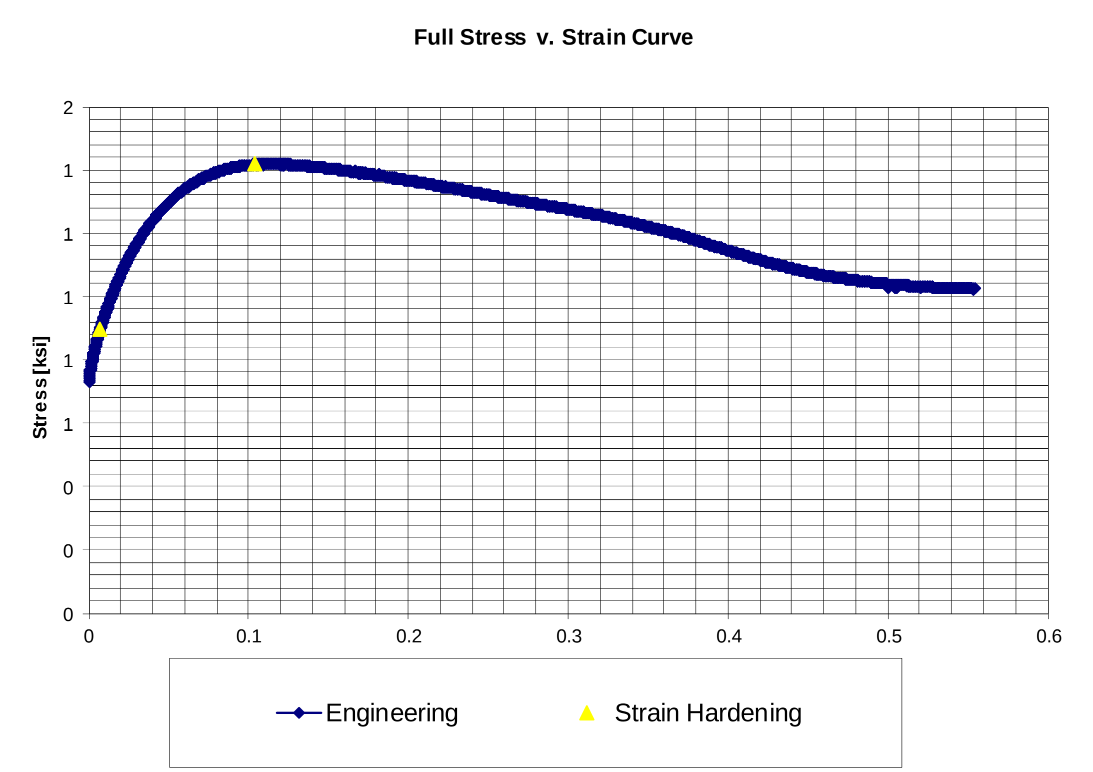
Strain Hardening Exponent n	Strength Coefficient K	Standard Deviation of the n value
0.2268254	2.68409951	0.000206566

Ramberg-Osgood Constants

K:	1.7438E+15
n:	10.84643296
α:	0.090172272

Estimated Modulus of Elasticity

E [Mpsi]	0.039



ANDERSON& ASSOCIATES

CONSULTING METALLURGICAL ENGINEERS AND TESTING LABORATORY

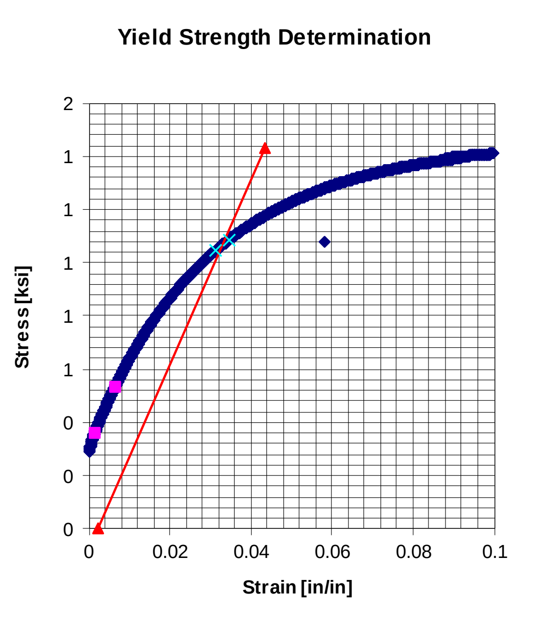
Specimen: 262-B

Job #: 230262

Other ID:

Other ID:

Other ID:



Tensile Strength Determination per ASTM E8

0.2% Offset Yield Strength [Ksi]	Ultimate Tensile Strength [Ksi]	Elongation [%]
0.777	1.429	170.2

Strain Hardening Exponent per ASTM E646

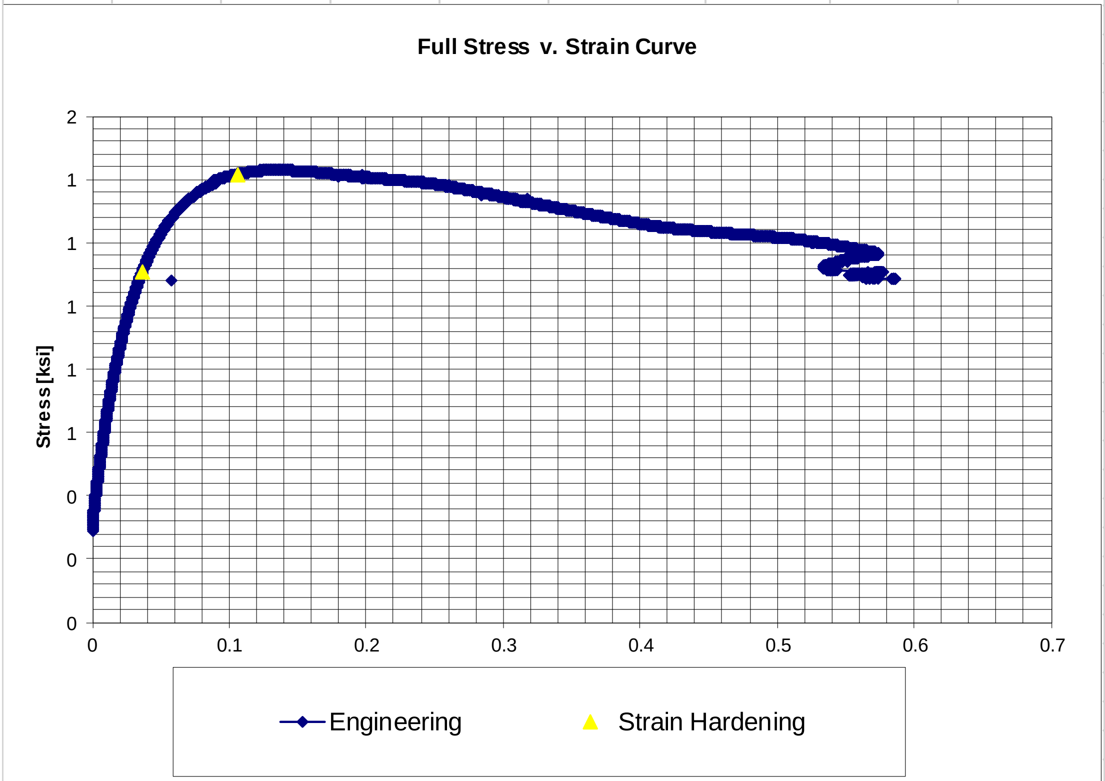
Strain Hardening Exponent n	Strength Coefficient K	Standard Deviation of the n value
0.2970992	3.15137025	0.000494207

Ramberg-Osgood Constants

K:	67.52197529
n:	2.104719981
α:	0.283519091

Estimated Modulus of Elasticity

E [Mpsi]	0.110



ANDERSON& ASSOCIATES

CONSULTING METALLURGICAL ENGINEERS AND TESTING LABORATORY

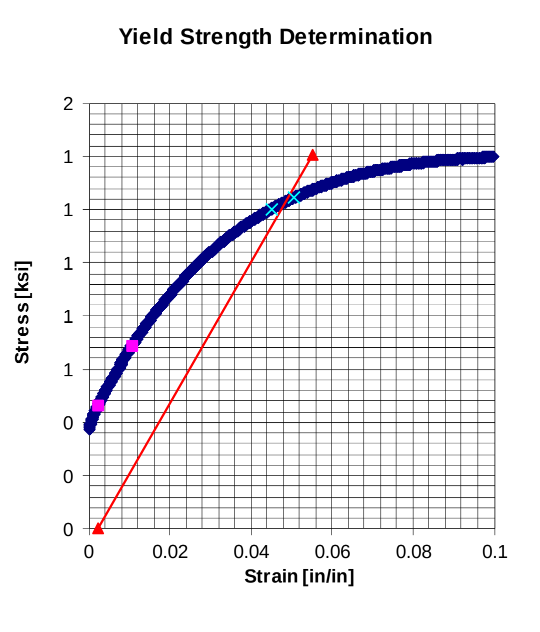
Specimen: 262-C

Job #: 230262

Other ID:

Other ID:

Other ID:



Tensile Strength Determination per ASTM E8

0.2% Offset Yield Strength [Ksi]	Ultimate Tensile Strength [Ksi]	Elongation [%]
0.962	1.403	75.7

Strain Hardening Exponent per ASTM E646

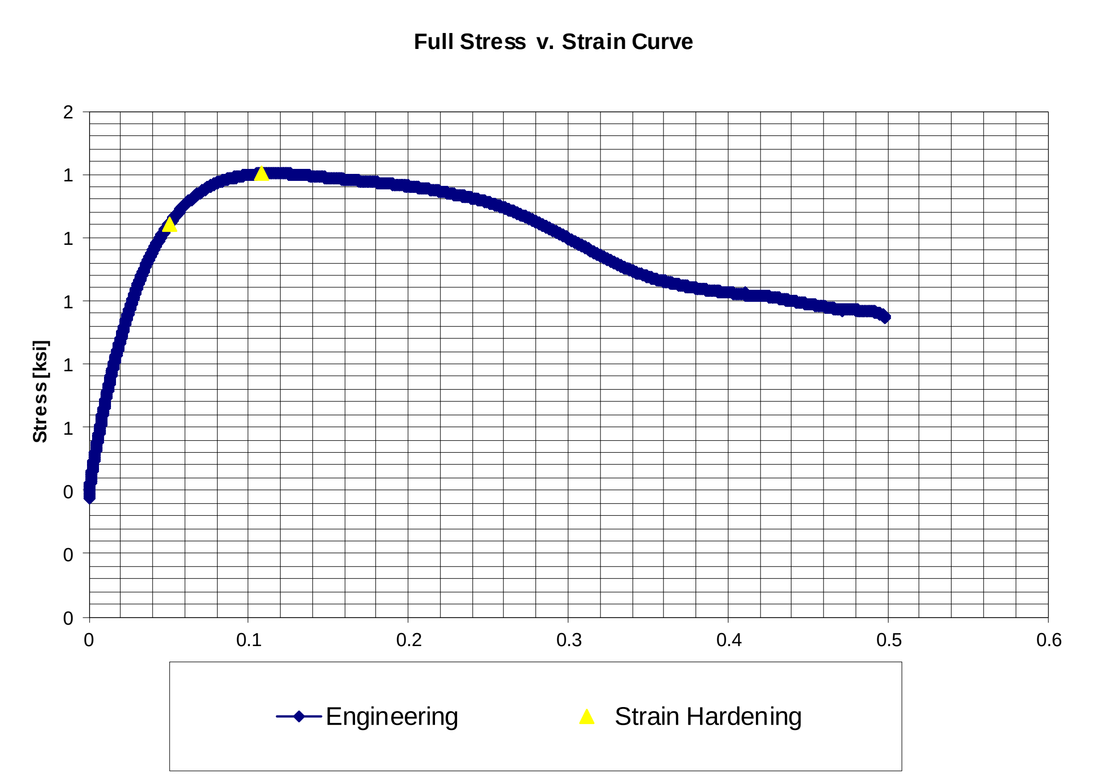
Strain Hardening Exponent n	Strength Coefficient K	Standard Deviation of the n value
0.2332591	2.67663891	0.000721435

Ramberg-Osgood Constants

K:	0.156994824
n:	0.974867314
α:	0.175685487

Estimated Modulus of Elasticity

E [Mpsi]	0.085



Appendix D. Post-Docking HDPE Material Testing Results

ANDERSON& ASSOCIATES
CONSULTING METALLURGICAL ENGINEERS AND TESTING LABORATORY

March 8, 2024

DM Consulting
Attn: Tim Greeson, P.E.

By email

Re: 230262 DM Consulting - Tensile Testing of HDPE

Dear Mr. Greeson:

Pursuant to your request, we have completed testing on the submitted samples. This report details the results.

SPECIMEN

Three samples were submitted for tensile testing. Samples identified as shown below.

Figure 1
The submitted samples are shown above.

Sample	Identification
A	0.497" thick
B	0.729" thick
C	1.015" thick

TENSILE TESTING

1. One full thickness, reduced section tensile was removed each sample. The specimens were pulled in tension to failure while monitoring the strain over the first part of the load curve. The results are as follows.

Specimen	0.2% Offset Yield Strength [Ksi]	Ultimate Tensile Strength [Ksi]	Elongation [%]
104-A	1.10	2.72	173
104-B	1.08	2.83	78.2
104-C	1.12	3.05	163

2. The datasheets are attached.

Respectfully submitted March 8, 2024.

STATE OF TEXAS
J EDGAR ZAPATA
72859
REGISTERED
PROFESSIONAL ENGINEER

ANDERSON & ASSOCIATES, INC.
Engineering Firm Registration # F-816

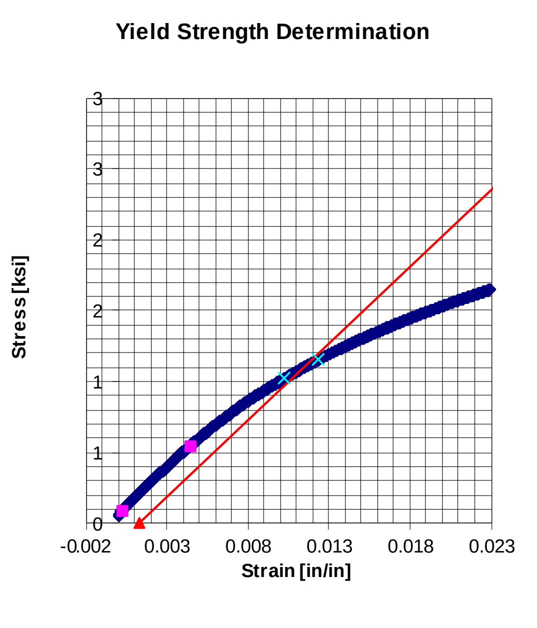
J. Edgar Zapata, P.E., Lic # 72859
President

Samples will be discarded after 30 days unless other arrangements are made.

ANDERSON& ASSOCIATES
CONSULTING METALLURGICAL ENGINEERS AND TESTING LABORATORY

Specimen: 104-A
Job #: 240104

Other ID:
Other ID:
Other ID:



Tensile Strength Determination per ASTM E8

0.2% Offset Yield Strength [Ksi]	Ultimate Tensile Strength [Ksi]	Elongation [%]
1.098	2.720	173.3

Strain Hardening Exponent per ASTM E646

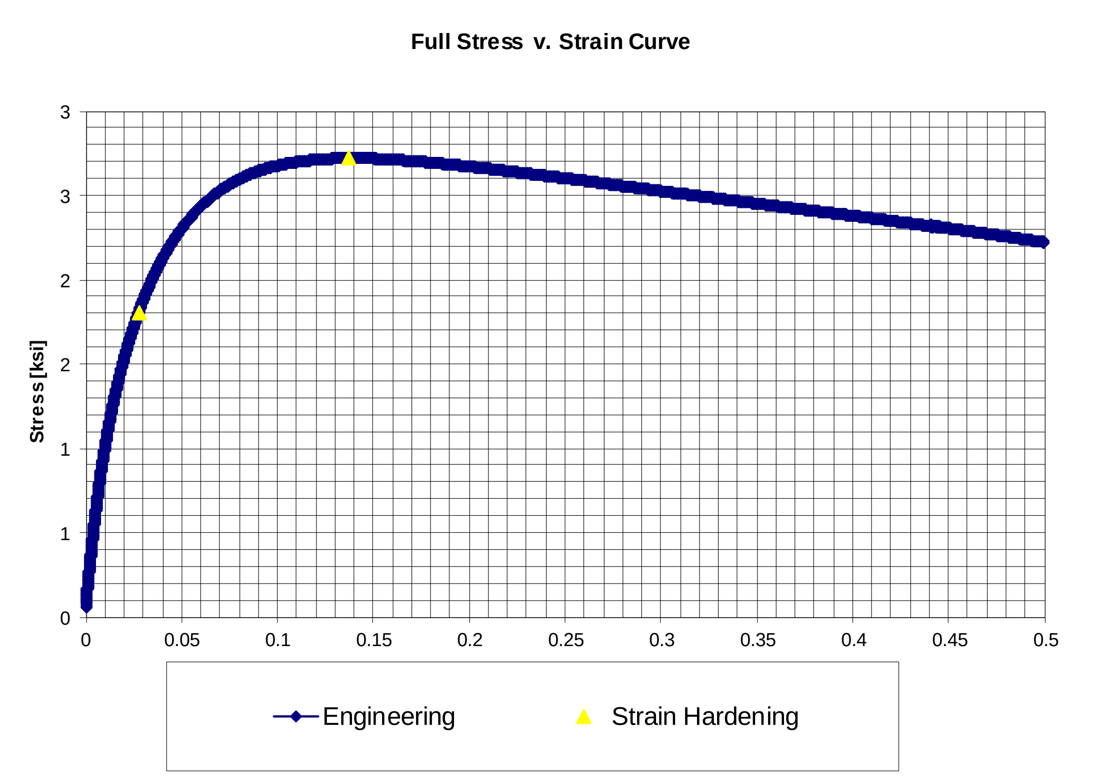
Strain Hardening Exponent n	Strength Coefficient K	Standard Deviation of the n value
0.3175858	6.1970489	0.000902243

Ramberg-Osgood Constants

K:	81257.3903
n:	3.813050822
α:	0.19792522

Estimated Modulus of Elasticity

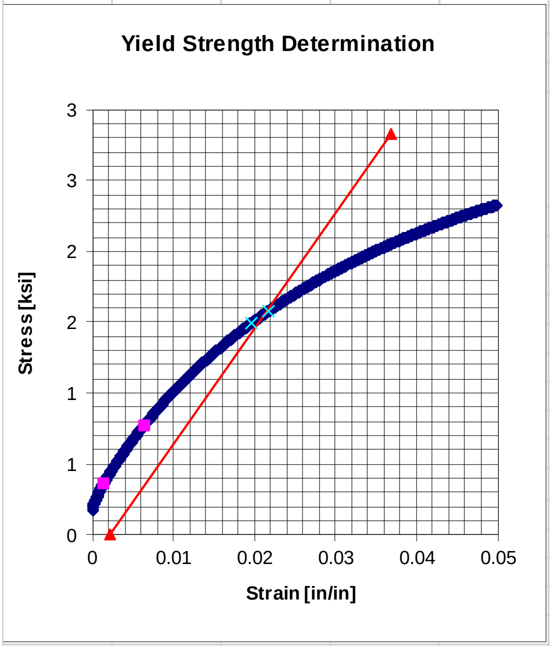
E [Mpsi]	0.109



ANDERSON& ASSOCIATES
CONSULTING METALLURGICAL ENGINEERS AND TESTING LABORATORY

Specimen: 104-B
Job #: 240104

Other ID:
Other ID:
Other ID:



Tensile Strength Determination per ASTM E8

0.2% Offset Yield Strength [Ksi]	Ultimate Tensile Strength [Ksi]	Elongation [%]
1.083	2.833	78.2

Strain Hardening Exponent per ASTM E646

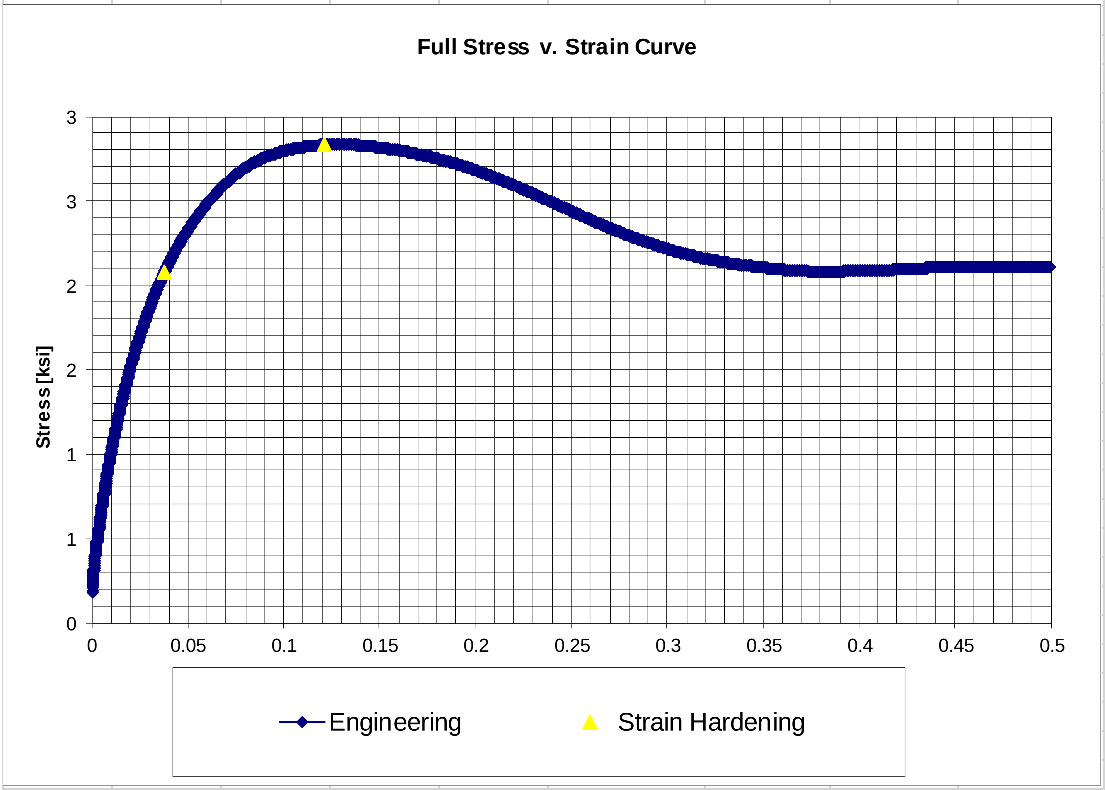
Strain Hardening Exponent n	Strength Coefficient K	Standard Deviation of the n value
0.3449705	6.93604962	0.000998442

Ramberg-Osgood Constants

K:	101.2718641
n:	2.2120084
α:	0.267800643

Estimated Modulus of Elasticity

E [Mpsi]	0.145



ANDERSON& ASSOCIATES

CONSULTING METALLURGICAL ENGINEERS AND TESTING LABORATORY

Specimen: 104-C

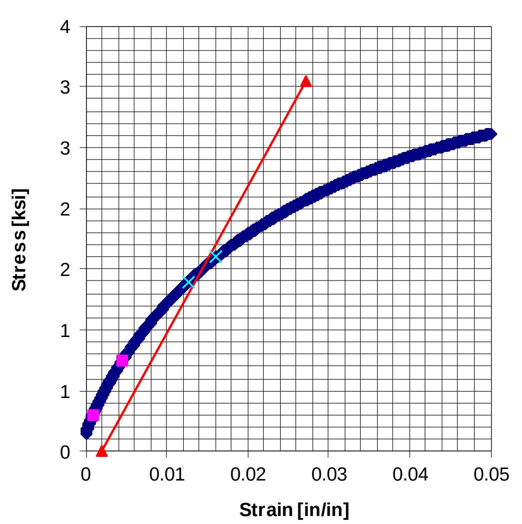
Job #: 240104

Other ID:

Other ID:

Other ID:

Yield Strength Determination



Tensile Strength Determination per ASTM E8

0.2% Offset Yield Strength [Ksi]	Ultimate Tensile Strength [Ksi]	Elongation [%]
1.119	3.048	163.1

Strain Hardening Exponent per ASTM E646

Strain Hardening Exponent n	Strength Coefficient K	Standard Deviation of the n value
0.3034718	6.78875187	0.000862357

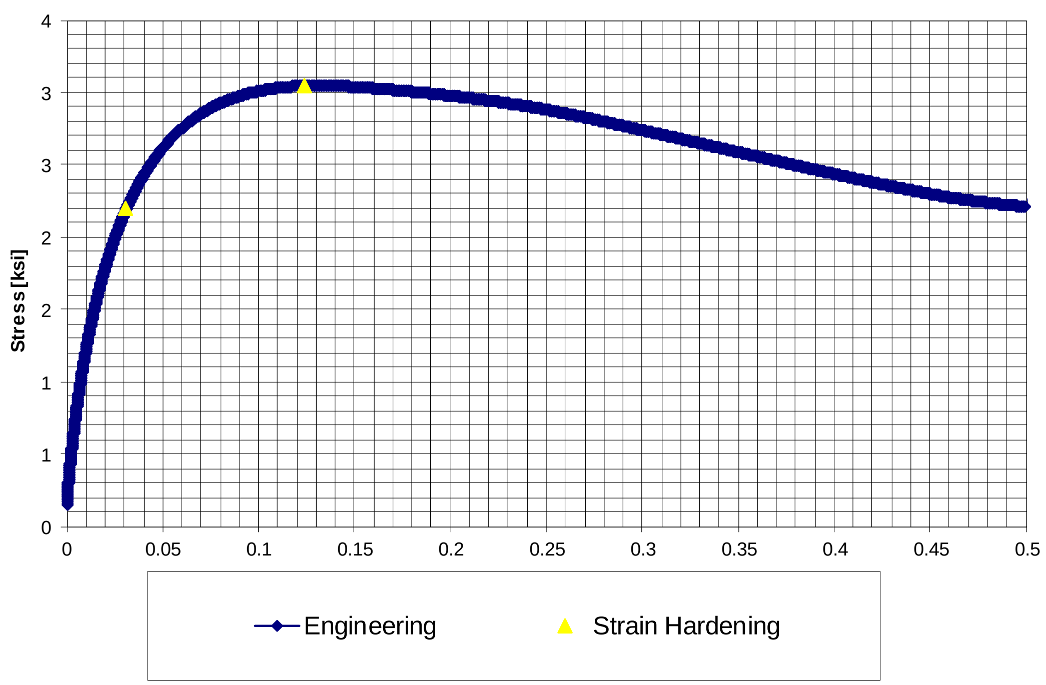
Ramberg-Osgood Constants

K:	3000.364639
n:	2.755978665
α:	0.348360168

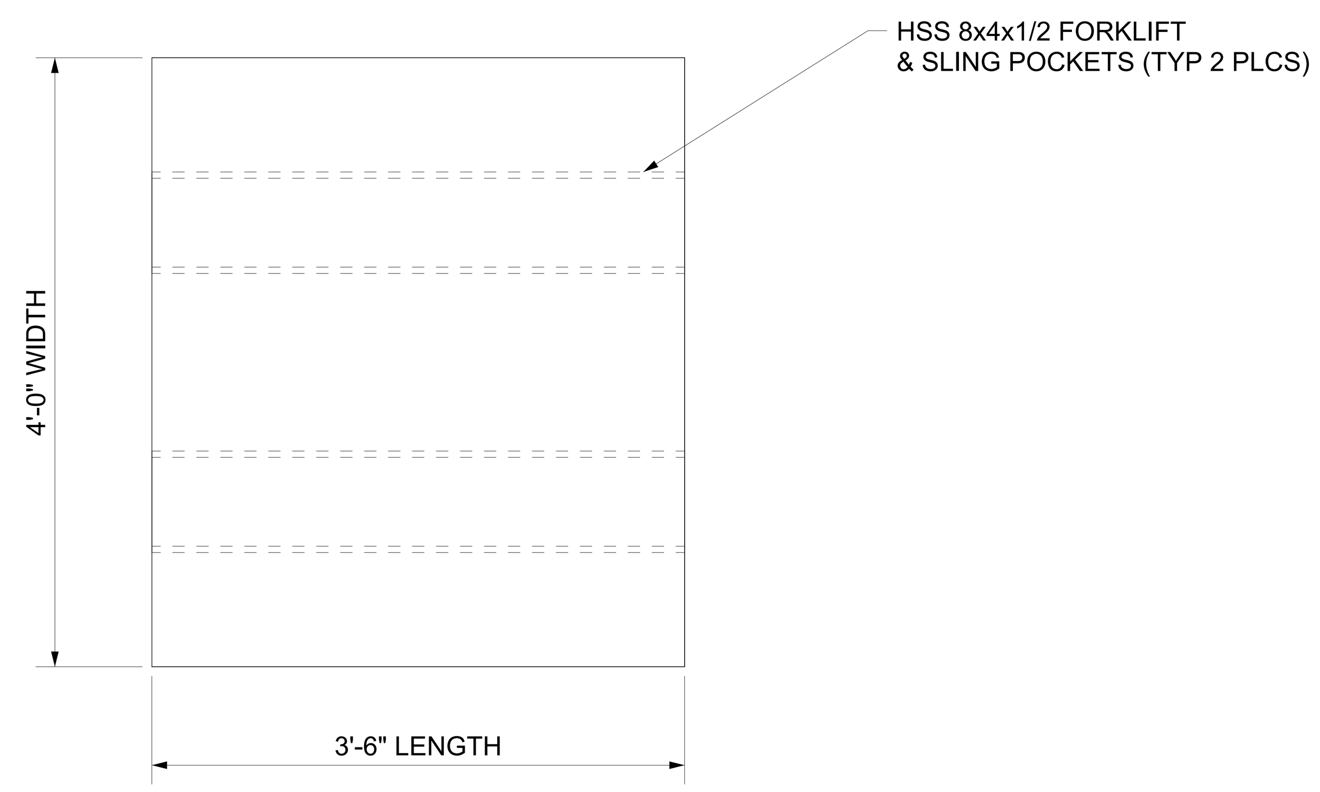
Estimated Modulus of Elasticity

E [Mpsi]	0.195

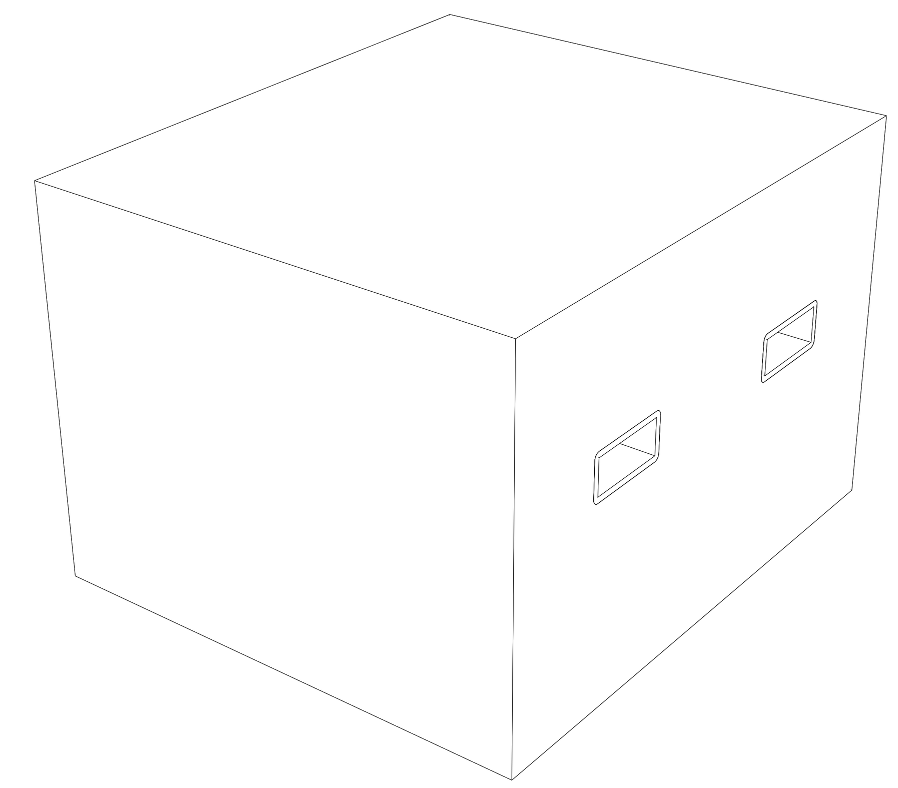
Full Stress v. Strain Curve



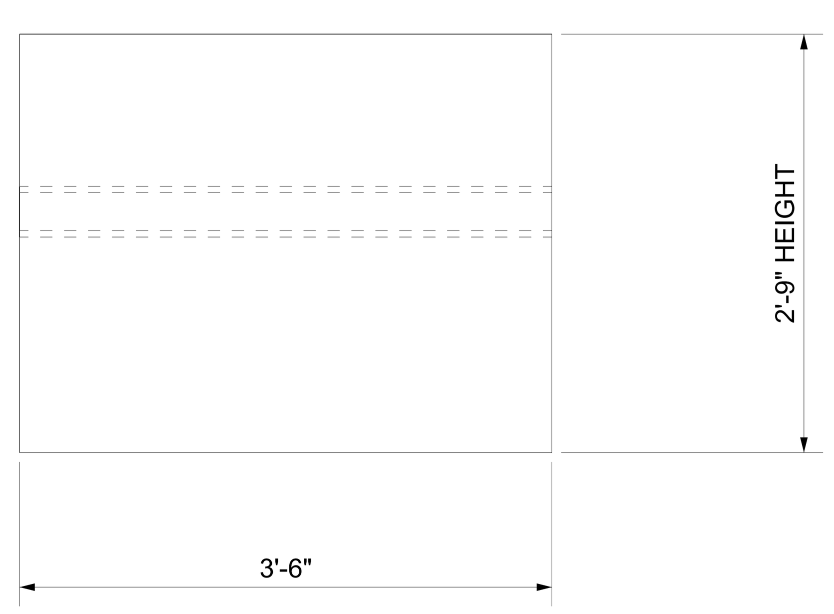
Appendix E. Fiber Reinforced Block Design



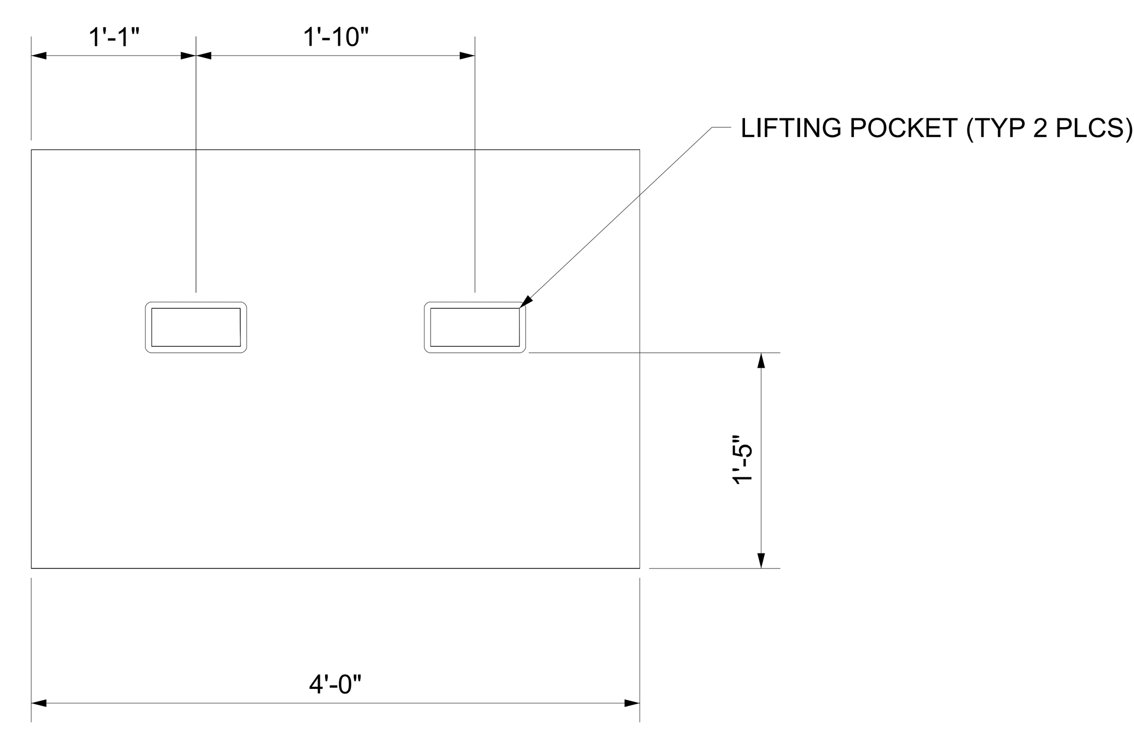
PLAN VIEW



ISO VIEW



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

Appendix F. Fiber Reinforced Blocks Testing Full Report

TESTING ENGINEERS, INC.

Quality Assurance Services
Materials Consulting
Since 1954

September 13th , 2023 *TEI Project No. R105*
Revised September 20, 2023

DM Consulting
12316 Dormouse Road
San Diego, California 92129
Attn: Alex Stiglich
P: 858-774-1270
E: alex@drydocktraining.com

SUBJECT: ***Investigation of Concrete Blocking***
1180 Nimitz Avenue, Vallejo, California

Dear Mr. Stiglich,

At your request, Testing Engineers, Inc. (TEI), conducted an investigation of the concrete blocking located at the subject address above. Testing was performed on August 25th, 2023 in order to determine concrete compressive strengths and splitting tensile strengths of blocks.

PROCEDURE & RESULTS

A total of (3) blocks were presented for testing and were identified by your team as Old Navy Standard, New Fiber & Old Fiber. Four core samples were taken from a face from each block, a total or (12) cores samples. From each sample set (3) of the cores were tested in compression and (1) was tested in splitting tensile. Compressive strength samples were approximately 3.75-inches diameter and splitting tensile samples were approximately 2.75" in diameter. Coring was performed using a water-cooled diamond tip bit core bit. Samples were tested in general conformance with ASTM C42- *Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*. Results of the individual samples can be found in the table on the following pages. Splitting Tensile testing was performed in general conformance with ASTM C496 and results can be found in the associated table on the following pages. A summary of our findings is as follows:

- The average compressive strength of the **Old Navy** block cores was **7,500 psi** and the splitting tensile strength was **548 psi.**
- The average compressive strength of the **New Fiber** block cores was **8,970 psi** and the splitting tensile strength was **902 psi.**
- The average compressive strength of the **Old Fiber** block cores was **7,850 psi** and the splitting tensile strength was **662 psi.**

.

If you have any questions, or if we may be of further service, please contact me at (510) 835-3142 extension 142 or by email at hughestei@gmail.com

TESTING ENGINEERS, INC.

Sean P. Hughes
Engineering Technician

CONCRETE CORE COMPRESSION TEST

LAB. NUMBER:	K0991	CLIENT NUMBER:		SAMPLE NUMBER	303870

PROJECT NUMBER: **L183**

PROJECT NAME: Coast Guard Island
1180 Nimitz, Mare Island, CA

Permit #: N/A

ISSUE DATE: 8-25-23

LOCATION: See report for core locations

Sampling Method:- Systematic

Deviated from Standard: No
Reasons Deviated from Standard:

Old Navy Standard

Date of placement, if known:	Not known
Cored By:	S. Hughes
Date & Time Cored:	8-24-23 3pm
Time placed in sealed bag or non-absorbent container:	4:00 pm
Received By:	B. Green, TEI
Date Received:	8-25-23
Date & Time Trimmed & returned to container:	8-25-23@1:30pm

DATE TESTED		8-28-23	8-28-23	8-28-23
CORE ID		A	B	C
DIAMETER	In.	3.75	3.75	3.75
CROSS-SECTIONAL AREA	In.	11.04	11.04	11.04
LENGTH RECEIVED	In.	6.01	6.04	4.83
LENGTH TRIMMED	In	4.82	5.39	4.29
LENGTH TESTED	In.	5.84	5.63	4.54
LENGTH/DIAMETER RATIO		1.34	1.50	1.21
CORRECTION FACTOR		.941	.960	.920
ULTIMATE LOAD	Lbs.	86950	86950	90410
ULTIMATE STRENGTH	Psi	7880	7880	8190
CORRECTED ULTIMATE STRENGTH	Psi	**7420**	**7560**	**7560**
AGE TESTED (after cored)	Days	4	4	4
AVERAGE STRENGTH (At Date Tested)	Psi	-	-	7500
SPECIFIED STRENGTH	Psi	-	-	-
MAXIMUM AGGREGATE. SIZE	In.	¾	¾	¾
TYPE OF FRACTURE		3	3	4
TIME TESTED		2:19pm	2:19pm	2:19pm
WEIGHT after trimming	Lbs.	4.525	5.025	4.015
DENSITY	pcf	146	146	146
EMBEDDED METAL		none	none	none
CALIPER SERIAL No.		(12" #2)	(12" #2)	(12" #2)
SERIAL No. COMPRESSION MACHINE		85028	85028	85028

*Cores were tested under wet conditions, parallel the cast plane and in general accordance with ASTM C42.
*Compressive strength testing and density was performed for investigative purposes

Reviewed By: ______________________FOR:
Robert Green
Concrete Lab Supervisor

CONCRETE CORE COMPRESSION TEST

LAB. NUMBER: K0991	CLIENT NUMBER:	SAMPLE NUMBER 303870

PROJECT NUMBER: **R105**

ISSUE DATE: 8-25-23

PROJECT NAME: Coast Guard Island
1180 Nimitz, Mare Island, CA

Permit #: N/A

LOCATION: See report for core locations

Sampling Method:- Systematic

Deviated from Standard: No
Reasons Deviated from Standard:

Old Fiber

Date of placement, if known:	Not known
Cored By:	S. Hughes
Date & Time Cored:	8-24-23 3pm
Time placed in sealed bag or non-absorbent container:	4:00 pm
Received By:	B. Green, TEI
Date Received:	8-25-23
Date & Time Trimmed & returned to container:	8-25-23@1:30pm

DATE TESTED		8-28-23	8-28-23	8-28-23
CORE ID		A	B	C
DIAMETER	In.	3.75	3.75	3.75
CROSS-SECTIONAL AREA	In.	11.04	11.04	11.04
LENGTH RECEIVED	In.	6.95	8.13	7.17
LENGTH TRIMMED	In	5.99	7.15	6.80
LENGTH TESTED	In.	6.24	7.40	7.05
LENGTH/DIAMETER RATIO		1.66	1.97	1.88
CORRECTION FACTOR		.973	-	-
ULTIMATE LOAD	Lbs.	93370	95500	73710
ULTIMATE STRENGTH	Psi	8460	8650	6680
CORRECTED ULTIMATE STRENGTH	Psi	**8230**	**8650**	**6680**
AGE TESTED (after cored)	Days	4	4	4
AVERAGE STRENGTH (At Date Tested)	Psi	-	-	7850
SPECIFIED STRENGTH	Psi	-	-	-
MAXIMUM AGGREGATE. SIZE	In.	¾	¾	¾
TYPE OF FRACTURE		4	3	4
TIME TESTED		2:19pm	2:19pm	2:19pm
WEIGHT after trimming	Lbs.	5.620	6.710	6.395
DENSITY	pcf	156	147	156
EMBEDDED METAL		none	none	none
CALIPER SERIAL No.		(12" #2)	(12" #2)	(12" #2)
SERIAL No. COMPRESSION MACHINE		85028	85028	85028

*Cores were tested under wet conditions, parallel the cast plane and in general accordance with ASTM C42.
*Compressive strength testing and density was performed for investigative purposes

Reviewed By: ______________________FOR:
Robert Green
Concrete Lab Supervisor

CONCRETE CORE COMPRESSION TEST

LAB. NUMBER: K0991 CLIENT NUMBER: SAMPLE NUMBER 303870

PROJECT NUMBER: **R105**

ISSUE DATE: 8-25-23

PROJECT NAME: Coast Guard Island
1180 Nimitz, Mare Island, CA

Permit #: N/A

LOCATION: See report for core locations

Sampling Method:- Systematic

Deviated from Standard: No
Reasons Deviated from Standard:

New Fiber

Date of placement, if known: Not known
Cored By: S. Hughes
Date & Time Cored: 8-24-23 3pm
Time placed in sealed bag or non-absorbent container: 4:00 pm

Received By: B. Green, TEI
Date Received: 8-25-23
Date & Time Trimmed & returned to container: 8-25-23@1:30pm

DATE TESTED		8-28-23	8-28-23	8-28-23
CORE ID		A	B	C
DIAMETER	In.	3.75	3.75	3.75
CROSS-SECTIONAL AREA	In.	11.04	11.04	11.04
LENGTH RECEIVED	In.	7.95	7.25	7.28
LENGTH TRIMMED	In	7.13	6.66	6.84
LENGTH TESTED	In.	7.35	6.89	7.04
LENGTH/DIAMETER RATIO		1.96	1.83	1.87
CORRECTION FACTOR		-	-	-
ULTIMATE LOAD	Lbs.	99510	99680	97970
ULTIMATE STRENGTH	Psi	9010	9030	8870
CORRECTED ULTIMATE STRENGTH	Psi	9010	9030	8870
AGE TESTED (after cored)	Days	4	4	4
AVERAGE STRENGTH (At Date Tested)	Psi	-	-	8,970
SPECIFIED STRENGTH	Psi	-	-	-
MAXIMUM AGGREGATE. SIZE	In.	1	1	1
TYPE OF FRACTURE		3	3	4
TIME TESTED		2:19pm	2:19pm	2:19pm
WEIGHT after trimming	Lbs.	6.640	6.115	6.350
DENSITY	pcf	146	144	145
EMBEDDED METAL		none	none	none
CALIPER SERIAL No.		(12" #2)	(12" #2)	(12" #2)
SERIAL No. COMPRESSION MACHINE		85028	85028	85028

*Cores were tested under wet conditions, parallel the cast plane and in general accordance with ASTM C42.
*Compressive strength testing and density was performed for investigative purposes

Reviewed By: ______________________FOR:
Robert Green
Concrete Lab Supervisor

Splitting Tensile Strength Results & Photographs

SPLITTING TENSILE TESTING (ASTM C496)							
Specimen	**Test Diameter [in]**	**Test Length [in]**	**Maximum Force [lbf]**	**Splitting Tensile Strength [psi]**	**Max Aggregate Size [in]**	**Percent Aggregate Fractured [%]**	**Failure**
Old Fiber	3.2	6.4	21,282	662	0.8	99	Crack at midsection through specimen followed by split.
Old Navy Std.	3.2	6.3	17,369	548	1.4	60	Split down center with aggregate pull out, with crack on single side 0.8" from center line on top to 1" deep of center line.
New Fiber	3.2	6.5	29,469	902	0.7	90	Split through center. Random cracks around both halves.

Test Equipment: Instron 5985 S/N B17048, Fowler 12” Digital Calipers S/N 200406768, DFS-9010A S/N 011211000608

Old Fiber

Old Navy STD

New Fiber