ERDC/CERL TR-17-10

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Investigation of Hydrophobic Concrete Additive for Seawall Replacement at Pililaau Army Recreation Center, Hawaii

Final Report on Project F09-AR05A

Michael K. McInerney, Steven C. Sweeney,
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Construction Engineering Research Laboratory

DoD Corrosion Prevention
and Control Program

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Final report

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Washington, DC 20301-3090

Under Project F09-AR05, “Seawall Replacement at Pililaau Army Recreation Center, Hawaii”

Abstract

This Office of the Under Secretary of Defense Corrosion Prevention and Control Program project was to demonstrate the long-term performance of an ultrahydrophobic concrete additive that blocks water intrusion and chloride penetration into concrete. The proprietary additive was to be used to repair the seawall in a highly corrosive environment at Pililaau Army Recreation Center (PARC) in Waianae, Hawaii. The deteriorating stone seawall at PARC was to be covered in a concrete veneer with a new stair access to the beach, both using the waterproofing additive. Chloride, humidity, and corrosion rate sensors were placed in the concrete veneer panels and were to be monitored for two years.

Unfortunately, while the seawall veneer panels were completed, the government was unable to obtain necessary permits to allow excavation of the beach at the base of the seawall for construction of the footing. Even after it became clear that the work could not be completed under the contract for this project, the Corps of Engineers Honolulu District in Hawaii initiated their own project to complete the work by using the prepared veneer panels, but they also were unable to do so because of the permitting and environmental study requirements.

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Preface

This demonstration was performed for the Office of the Secretary of Defense (OSD) under Department of Defense (DoD) Corrosion Prevention and Control Program Project F09-AR05, "Seawall Replacement at Pililaau Army Recreation Center, Hawaii." The proponent was the U.S. Army Office of the Assistant Chief of Staff for Installation Management (OACSIM), and the stakeholder was the U.S. Army Installation Management Command (IMCOM). The technical monitors were Daniel J. Dunmire (OUSD(AT&L)), Bernie Rodriguez (IMPW-E), and Valerie D. Hines (DAIM-ODF).

The work was performed by the Engineering and Materials Branch (CEERD-CFM), Facilities Division (CF) of the U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL. Significant portions of this work were performed by MEC Development LLC, Warner Robins, GA. At the time of publication, Vicki L. Van Blaricum was Chief, CEERD-CFM; Donald K. Hicks was Chief, CEERD-CF; and Kurt Kinnevan was the Technical Director for Adaptive and Resilient Installations, CEERD-CZT. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Dr. Ilker Adiguzel.

The following individuals are gratefully acknowledged for their contributions to this project:

- Nelson Lee – Project Manager, Honolulu District (CEPOH)
- Eugene Arter – Engineering Technician, US Army Garrison Hawaii (USAP-PTA/DPW)

The Commander of ERDC was COL Bryan S. Green, and the Director was Dr. David W. Pittman.

Unit Conversion Factors

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
square feet	0.09290304	square meters

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1 Introduction

1.1 Problem statement

Approximately $7 million is spent annually for maintenance of Department of Defense (DoD) facilities constructed for the prevention of shore erosion. Of that amount, 23% ($2 million) is attributed to corrosion (Herzberg, O'Meara, and Stroh 2014). Concrete is porous and absorbs water through capillary action. Additionally, in a seawater environment, dissolved salts (chlorides) readily migrate into the concrete and accelerate corrosion of the steel reinforcement materials. Progressive corrosion of the steel rebar greatly increases internal stresses in a concrete structure. Ultimately, the concrete fractures and spalls at a highly accelerated rate that will destroy the structure many years short of its intended service life.

Pililaau Army Recreation Center (PARC; formally Waianae Army Recreation Center) at Pokai Bay in Waianae, Hawaii, is a high-quality military recreational beach facility located on the island of Oahu. It includes a 2,000-foot seawall that was erected between the beach and the buildings at PARC. The seawall dates to about 1950, and major rehabilitations of seawall sections were executed in 1983 and 1993. The existing 700-foot reach of seawall north of the 1993 repair was part of the 1983 rehabilitation. This section has areas that are cracked and undermined, and in general, this section needs to be repaired or replaced. This section is stone-faced with rubble fill and capped with reinforced concrete.

El Niño and La Niña currents interact along this section of coastline. During the winter of 2007–2008, storms washed out a portion of the seawall. The location and depth of this washout threatens the wall integrity and lodging facilities near the beach. In addition, the concrete cap has deterioration over a large portion of the seawall, and large cracks have developed in the wall at other locations. During the winter of 2008–2009, storms breached the seawall in the area where it had failed the previous winter. The wall was repaired by the Schofield Barracks Directorate of Public Works (DPW), which has the overall responsibility for the facilities at PARC. To reduce maintenance costs, PARC needs a concrete seawall that resists saltwater penetration. Due to the current condition of the structure and the extreme and ongoing corrosivity at the site, the repair of a section of PARC seawall was selected as a demonstration/validation project under the DoD Corrosion Prevention and Control (CPC) Program.

The technology selected for demonstration during this project is a patented concrete-waterproofing admixture called Hycrete,* which is claimed by its manufacturer to prevent water and chloride intrusion into reinforced concrete and thereby to protect the embedded reinforcement steel from corrosion. Two related Hycrete projects were funded under the CPC Program. One was Project F09-AR05B, which consisted of a series of laboratory tests comparing the corrosion-prevention performance of concrete specimens made with and without Hycrete (Sweeney and McInerney 2017). The other was Project F09-AR05A, which is the seawall rehabilitation work documented by this report.

1.2 Objective

This project was to demonstrate and validate the ability of a new concrete admixture to prevent severe corrosion of embedded reinforcement steel by waterproofing the structure to inhibit the intrusion of seawater and chlorides.

1.3 Approach

The project team coordinated with the Schofield Barracks DPW to select a portion of the seawall to be repaired or replaced.

Based on the nature of seawall deterioration—severe degradation from tidal and wind erosion—it was decided that a concrete veneer would be the most economical way to restore integrity to the existing structure. The project required the design of 180 feet of concrete veneer with a concrete cap to adjoin the section that had been repaired in 1993. Environmental precautions related to water contamination and excavation were addressed in the work plan. A cofferdam was to be used to isolate the worksite from the ocean waters during excavation and prevent construction materials from entering the water.

* Hycrete is a trademark of Hycrete, Inc., http://www.hycrete.com/.

Concrete precast panels were fabricated to include Hycrete. These panels were produced with a rocklike relief pattern and stained color scheme similar in appearance to the seawall adjacent to the repair site. Corrosion sensors to monitor performance were installed in two of the panels. The precast panels were to be installed on the wall and backfilled with the same concrete and admixture used in the panels.

At the time the panels were fabricated, smaller test specimens were also prepared using concrete with and without the hydrophobic additive. Corrosion sensors were installed inside these specimens. The specimens were to serve as exposure coupons at the demonstration site.

1.4 Metrics

The metrics for assessing the success of the proposed Hycrete application demonstration were to be based on data collected from sensors embedded in the precast seawall panels and the exposure specimens. This data would then compare the performance of Hycrete-treated specimens with standard reinforced concrete specimens. The metrics of interest for the precast panels was the corrosion potential of the rebar, as derived from the following parameters:

- moisture content,
- chloride penetration depth, and
- rebar corrosion rate.

The performance metric for the Hycrete product was to be made up of the differences between the Hycrete-treated concrete and the untreated reinforced concrete specimens in terms of moisture intrusion, chloride penetration, and rebar corrosion rate.

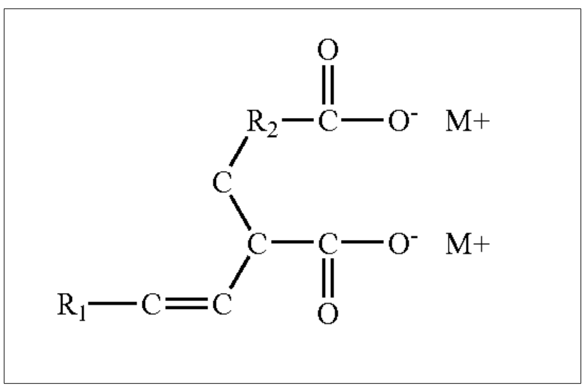
2 Technical Investigation

2.1 Technology overview

As stated in Chapter 1, Hycrete is marketed as an ultrahydrophobic admixture that makes concrete waterproof and protects the embedded steel reinforcement components. In an oceanfront environment, effective waterproofing should prevent seawater and the dissolved salts (chlorides) it contains from penetrating into the concrete and corroding the reinforcing steel.

The composition of Hycrete includes a proprietary aqueous solution of an alkali salt of a dioic acid, as shown in Figure 1. The M^+ is selected from the group that consists of Na^+ and K^+. R_1 and R_2 represent the linear aliphatic hydrocarbons in Hycrete. In an attempt to prevent the active ingredient in Hycrete from precipitating, the molecules include each of the alkali metal constituents Na^+ (90%–95%) and K^+ (5%–10%) (Rhodes 2007).

Figure 1. Chemical composition of Hycrete.



As an additive, Hycrete uses water in the concrete to migrate to the anodic surface of the reinforcing steel. One of the molecular ends uses its polarity to protect the positively charged anode of the reinforcement steel during the corrosion process. The reinforcement in concrete attracts the hydrophilic end of the additive. Once the additive reaches the surface of the reinforcement, it adheres to the iron of the reinforcement to form a slightly soluble hydrophobic layer. This layer helps to protect the anodic potential of steel from chlorides, sulfates, carbon dioxide, oxygen, and moisture.

In an aqueous solution, Hycrete reacts with metallic or other ions it encounters in the concrete or the reinforcement. These reactions form molecules that have long, hydrophobic, hydrocarbon chains with limited water solubility. These long hydrocarbon chains fill the capillaries, cracks, and fissures of the post-construction structure, and they help to repel water and prevent or reduce the capillary absorption of moisture (Rhodes 2007).

2.2 Field work and repair

As noted in Chapter 1, the PARC seawall dates from about 1950 and includes major rehabilitations performed in 1983 and 1993. The existing reach of seawall that is north of the 1993 repair was part of the 1983 rehabilitation project. This reach has sections that are cracked and undermined, and are in need repair or replacement (Figure 2).

Figure 2. Section of deteriorated seawall.

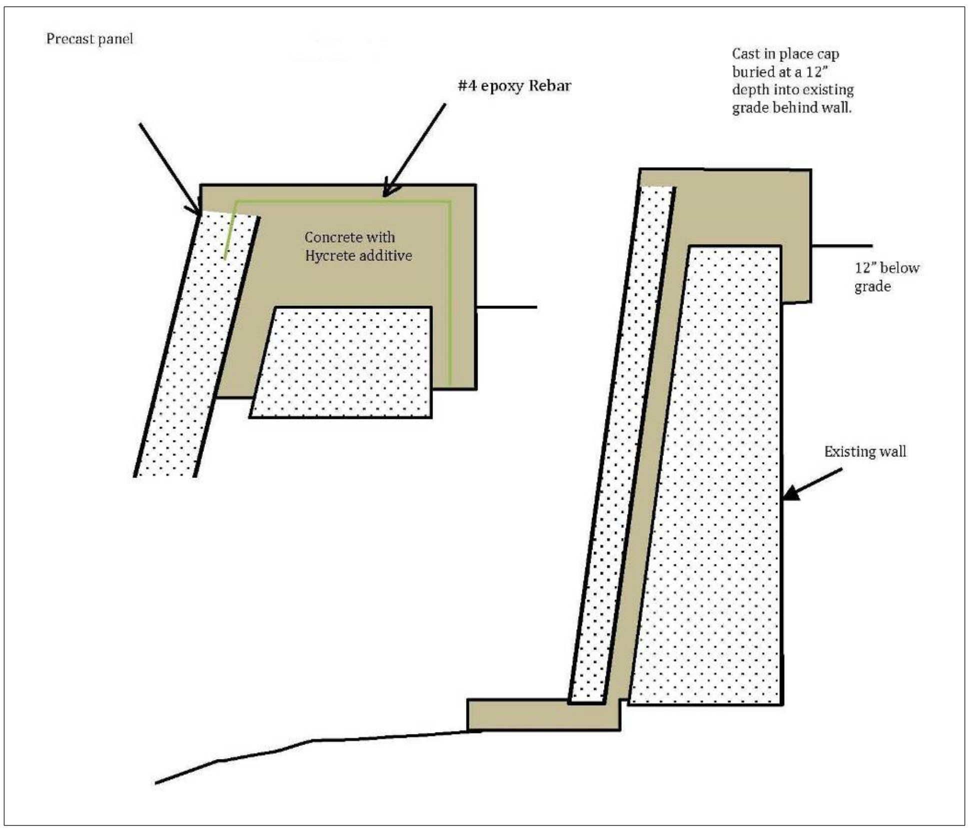
2.2.1 Seawall inspection

An onsite inspection was performed by the Engineer Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL), the Hawaii Garrison DPW, and contractors. The team surveyed the seawall to plan and program the execution of the project. Given the amount of funds available for the project, it was determined that the seawall would have to be repaired rather than replaced.

2.2.2 Design of repair

The design selected and approved by ERDC-CERL and the garrison's DPW was a concrete veneer structure to repair an existing section of seawall. The veneer was designed to include precast panels with the front molded to resemble the rock pattern of the adjacent wall. The panels would be secured to the existing seawall and placed on a concrete footer at the base of the seawall. Treated concrete then would be poured between the precast panels and the seawall and over the top of the existing seawall to create a reinforced concrete cap (Figure 3).

Figure 3. Repair concept.



The full design for repair of the seawall section, based on the concept shown above, included a set of stairs that would give PARC visitors easy access to the beach. The original repair design is shown in Appendix A, and later modifications are shown in Appendix B.

2.2.3 Preparation of the seawall

Initially, the work began by drilling the seawall (Figure 4) to facilitate using epoxy to secure rebar that would be interlaced with rebar that would project from the back of the panels and become the face of the seawall. To support this work, a cofferdam was constructed using “super sack” bags to provide a temporary barrier between the seawall and the ocean. The bags were lined up approximately 20 feet from the seawall. However, the cofferdam was unable to withstand the surf from a large storm of more than 2 days, and it had to be removed. Initially the project team had determined that the work would require no permit, but after the cofferdam collapsed, local officials advised the team that, in fact, a permit was required. During the request for the temporary permit, all work on the seawall was suspended.

Figure 4. Holes bored in the existing seawall, to be fitted with rebar and epoxy.

2.2.4 Production of precast panels

At an offsite location, production of the panels for the seawall repair was started. Each precast panel measured 72" x 144" x 8" and included a 3-inch lap joint. The panels were reinforced with #4 epoxy-coated rebar arranged in a grid pattern on 8-inch centers and suspended a minimum of 3 inches from all surfaces, as shown in Figure 5. The panels were poured with concrete mixed with the ultrahydrophobic admixture. A representative from the manufacturer of the admixture was on site during the concrete pouring of the precast panels to provide technical assistance with mixing. The concrete mixture was ordered with 2 gallons of water per cubic yard of concrete, which is short of normal, to provide room for the admixture to be mixed in onsite. The admixture was pumped from a 275-gallon tote into the concrete truck and then mixed for a minimum of 5 minutes, as shown in Figure 6. After mixing, a sample was taken and measured for air entrainment, and the mix was adjusted as needed.

Once the concrete was poured, vibrated, and leveled, #4 epoxy-coated rebar dowels were inserted every 12 inches on center (Figure 7); the rebar would later be used to anchor to the front of the existing seawall, as shown in Figure 3. The panels were allowed to cure for a minimum of 24 hours before the forms were removed, and an additional 3 days were allowed before they were relocated for staining. Each panel was given a faux finish by using an acid to produce colors similar to those of the adjacent seawall (Figure 8).

Figure 5. Formed 144" x 72" x 8" panels with #4 epoxy-coated rebar reinforcement.

Figure 6. Hycrete X1000 being pumped from a 275-gallon tote into concrete trucks.

Figure 7. Rebar dowels inserted in the precast panels.

Figure 8. Stained panel.

2.2.5 Corrosion sensors

To assess the performance of the ultrahydrophobic admixture, three types of sensors were employed: a chloride ladder sensor, a humidity sensor, and a corrosion sensor. These sensors were placed into two panels during their construction. The sensors would measure moisture content in the concrete, chloride depth penetration, and the corrosion rate relative to the rebar. The Omega HX 71 relative humidity sensor was inserted into a PVC tube and capped with a known volume, providing a method to measure the amount of moisture entering the concrete. Two moisture sensors were installed at each sensor location at 1 and 2 inches from the surface. The Cosasco 900 chloride ladder sensor contains four stainless steel and four standard steel electrodes that measure impedance and correlate to chloride penetration. The chloride ladder sensors were arranged 30 degrees from the surface, to provide 1-inch increments in relation to the surface. The Cosasco 800 Corrater is a linear polarization resistance (LPR) sensor that is fitted with two standard steel electrodes. The probes measure and calculate a corrosion current that can be related to the corrosion rate. Typical installation of a set of sensors can be seen in Figure 9. A set of these sensors were installed above the splash-zone area of the panel when placed on the seawall, in the average splash-zone area, and below the splash-zone area in one precast panel. A second panel was similarly constructed but without the Cosasco 800 Corrater sensors. The sensor sets' locations in each of the precast panels are shown in Figure 10 and Figure 11.

Additional sensors were to be installed in the seawall; however unresolved permitting did not allow for this phase of the project to be completed. An additional Cosasco 900 sensor was to be placed in a 5-inch core hole in the existing adjacent seawall. This sensor would measure chlorides at 2-inch increments beginning 1 inch from the core hole surface. Two additional Omega moisture sensors were to be placed in the same core hole in the existing adjacent seawall and arranged to begin measuring moisture 1 inch and 2 inches from the face of the core hole. Upon installation of the sensors, the core was to be filled with fresh concrete. Two separate locations throughout the first 30 feet of the south end of the veneer were to contain a set of 2 moisture sensors and 1 chloride ladder sensor in the cast-in-place cap. The wires from all the sensors were to terminate into a junction box recessed into the back of the seawall.

Figure 9. Sensor layout.

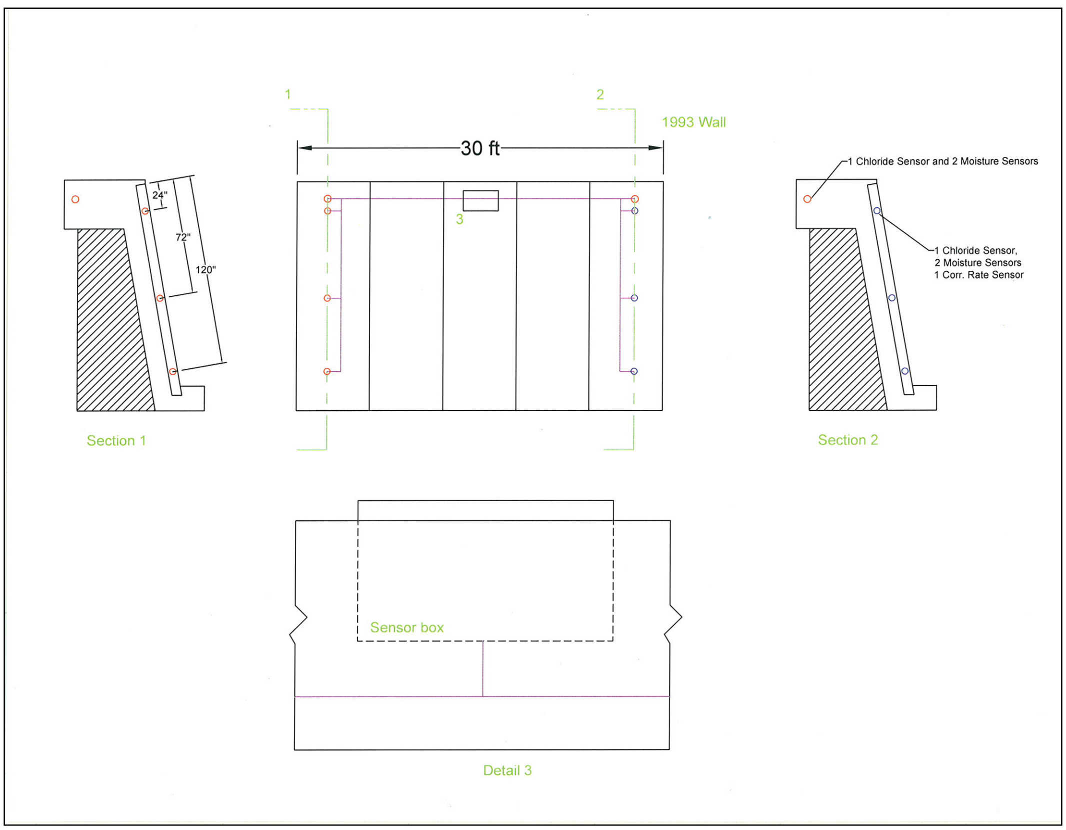


Figure 10. Sensor sets located in three areas of the precast panels.

Figure 11. Installation of one set of sensors in a precast panel.

2.2.6 Test panels

Three 18 x 48 x 8 in. test panels were fabricated with each containing a set of corrosion sensors including 1 chloride sensor, 2 moisture sensors, and 1 corrosion rate sensor. One panel contained concrete with the ultrahydrophobic admixture and epoxy coated rebar, one panel with ultrahydrophobic admixture and standard rebar, and one panel without ultrahydrophobic admixture and standard rebar. The test panels were to be mounted vertically approximately halfway up the south end of the sea-wall veneer. PVC conduit was to be used to route the sensor wires to the control box. Typical sensor installation is depicted in Figure 12 and Figure 13.

Figure 12. Installation of sensors in one precast test panel.

Figure 13. Installation of the Cosasco 900 chloride ladder sensor at 1-inch increments from the surface.

2.3 Initial operation and monitoring

It was planned to have a National Association of Corrosion Engineers (NACE) certified engineer visually survey the new seawall section and collect the measurements from the corrosion sensors at 6 months, 12 months, and 18 months following construction. At 18 months, four concrete core samples measuring 3 inches in diameter were to be taken from each of the three test panels in the splash zone and above the splash zone, and then sent to a laboratory for chloride analysis to alternately assess the depth of chloride penetration. Further laboratory analysis was to be conducted by EDRC-CERL after the chloride analysis. The data collected and evaluations would have provided a method to conduct a return on investment analysis and estimate life cycle; however this phase of the project could not be completed without approved permits for construction.

ERDC-CERL and the Hawaii Garrison DPW worked with the Honolulu Engineer District (POH) to obtain required permits needed to proceed with the repair of the seawall. Initial attempts were to obtain a temporary permit, but complications developed that prohibited the temporary permit. It was then determined that the repair could not be completed under the scope of the existing contract. POH decided to initiate its own project to repair the seawall at PARC and work with ERDC-CERL to use the existing precast panels. ERDC-CERL revised the project plan to provide support for obtaining the environmental permit and provide a draft Request for Proposal (RFP) to POH for their consideration in completing their project. Unfortunately, the requirements for environmental assessment to obtain the permits became too onerous, so the project could not be completed.

3 Discussion

3.1 Results

The seawall rehabilitation design was completed, incorporating the Hycrete admixture. Prototype panels were fabricated according to the design, and exposure specimens were fabricated, both with and without Hycrete.

Unforeseen permitting related to protected Hawaii oceanfront waters was required to construct the project. Ultimately, the necessary permit was not issued, so the seawall repair project was terminated. Consequently, the efficacy of the concrete admixture and rehabilitation design could not be evaluated.

After the termination of this project, the Hawaii Garrison DPW initiated a new repair project for the site, and the constructed panels may be used in that work.

3.2 Lessons learned

3.2.1 Planning

The sand on the beach at Pokai Bay moves with the currents and tides of the ocean. Approximately 20 feet of the beach, at depths of up to 12 feet, washes away and returns twice a year. It is advantageous to schedule beachfront construction during times when beach sand is migrating out of the bay; when sand is returning to the beach, the tides prevent construction work. Therefore, there is only a small scheduling window during which rehabilitation or reconstruction of the seawall would have been practical from a logistical perspective.

3.2.2 Permitting

For demonstration/validation projects planned at similar sites, the project team should fully investigate permitting requirements involving any natural or cultural resources that could be affected. In the case of the project reported here, environmental permitting costs were not foreseen and, therefore, were not programmed into the project budget. Work within Hawaiian tidal datum planes requires specific permits, and obtaining them can involve a lengthy and time-consuming approval process. Administrative research on environmental regulations is required when developing a preliminary project plan so that project schedules can account for all required reviews as well as tidal or other natural constraints on work execution.

4 Economic Analysis

4.1 Costs and assumptions

Total actual costs for the execution of this demonstration project are shown in Table 1.

Table 1. Project field demonstration costs.

Item	Description	Amount
1	Labor for project management and execution	$188,122
2	Travel for project management and installation work	$61,360
3	Labor for installation of monitoring system	$49,934
4	Cost of environmental engineering, design changes, and RFP	$103,170
5	Cost of Hycrete ($54,500 for materials plus labor for technical support)	$78,160
6	Cost of sensors and materials	$43,601
7	Cost of panel fabrication and all work on seawall	$528,774
	Total	$1,053,121

Because the technology was not installed, an actual return on investment (ROI) cannot be completed. What follows are the cost assumptions used when the project was developed.

It is assumed that the seawall completely fails during a storm, resulting in 4 guest cabins destroyed due to loss of foundation. With these cabins destroyed, there is 150 feet of water, electrical, and sewer lines lost. In addition, 500 feet of seawall and sidewalk is washed away. A cost breakdown for replacement of these losses is shown in Table 2. Identical losses are assumed to occur again at year 26.

Between the major losses outlined above, it is assumed that every 5 years a storm occurs that damages 20–25 feet of seawall, requiring repairs. A DPW cost estimate to repair a 21-foot section of seawall and landings and replace all unserviceable concrete stairways, sidewalks, and seawall caps is $500,000.

Table 2. Costs of complete seawall failure.

Infrastructure	Quantity	Cost per Unit	Replacement Cost
Guest cabins	4 cabins, 4,800 total sq ft	$105/sq ft	$504,000
Water lines	150 ft	$50/ft	$7,500
Electrical lines	150 ft	$363/ft	$54,500
Sewer lines	150 ft	$31.40/ft	$4,700
Seawall	500 ft	$15,000/ft	$11,904,000
Total repair costs			$12,474,700

As Table 3 and Table 4 show, using the Hycrete additive instead of using traditional calcium nitrite and waterproofing would result in a cost savings of $32, 500 for the planned 687-foot seawall replacement.

Table 3. Costs of construction to replace 687 feet of seawall using Hycrete additive, with estimated lifespan of 50 years; lifetime maintenance costs noted.

Material	Quantity	Cost per Unit	Total Cost
Concrete	720 yd^3	$200/$yd^3$	$144,000
Hycrete additive*	1,440 gal	$35/gal	$50,400
Stones#	n/a	n/a	0
Materials and labor for cofferdam, formwork, and landscape rehabilitation	n/a	n/a	$460,600
Total cost of materials and labor			$655,000
Expected lifespan			50 years
Maintenance costs - $5,000 every 10 yr for crack repair			$50,000

* At rate of 2 gal/yd^3 of concrete.

Stones will be reused. Value of stones is $15,000.

Table 4. Cost of construction to replace 687 feet of seawall using standard methods, with estimated lifespan of 20 years; lifetime maintenance costs noted.

Material	Quantity	Cost per Unit	Total Cost
Concrete	720 yd^3	$200/$yd^3$	$144,000
Calcium nitrate additive		$55/$yd^3$	$39,600
Waterproofing - backside		$4.50/sq ft	$31,300
Waterproofing - base		$4.50/sq ft	$12,000
Stones#	n/a	n/a	0
Labor and materials for cofferdam, formwork, and landscape rehabilitation	n/a	n/a	$460,600
Total cost of materials			$687,500
Expected lifespan			20 years
Maintenance costs - $5,000 every 2 yr for crack repair			$50,000

Stones will be reused. Value of stones is $15,000.

4.2 Projected return on investment (ROI)

Because the technology could not be implemented as planned, the actual ROI for this demonstration is zero (0).

When this project was proposed, a projected ROI of 22.8 was calculated based on the assumptions above and the guidelines prescribed by Office of Management and Budget (OMB) Circular A-94 (OMB 1992). Table 5 reproduces the original calculations to illustrate the project team's conception of how costs and benefits would accrue over the 30-year analysis period.

Table 5. Reproduction of ROI calculation from original project management plan.

Return on Investment Calculation

Investment Required			800
Return on Investment Ratio	22.81	Percent	2281%
Net Present Value of Costs and Benefits/Savings	612	18,862	18,250

A Future Year	B Baseline Costs	C Baseline Benefits/Saving	D New System Costs	E New System Benefits/Saving	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1	12,471		655	2,791	612	14,264	13,651
2							
3							
4							
5							
6	500					333	333
7							
8							
9							
10							
11	500					238	238
12							
13							
14							
15							
16	500					169	169
17							
18							
19							
20	12,471					3,223	3,223
21							
22							
23							
24							
25	500					92	92
26				2,776		478	478
27							
28							
29							
30	500					66	66

5 Conclusions and Recommendations

5.1 Conclusions

The seawall panels were designed and fabricated, but seawall repair could not be completed due to permitting issues encountered after the project began. No difficulties were encountered when using the Hycrete additive during panel fabrication or when coloring the panels to match the rock of the existing seawall. With reference to the difficulties executing seawall reconstruction, it is important to identify all potential permitting requirements during the project development stage so that similar work stoppages will not be encountered in future projects. This lesson learned is especially important in locales that may host natural or cultural resources that could be affected by construction activities.

5.2 Recommendations

5.2.1 Applicability

Much DoD infrastructure is constructed with reinforced concrete. The life cycle of those concrete structures is significantly reduced by the corrosive effects of water and chemical intrusion. Upon successful demonstration and validation, the project team expected that Hycrete could mitigate corrosion caused by the migration of water and chlorides into coastal concrete and masonry infrastructure. However, because the demonstrated technology could not be implemented or validated, the research team can offer no specific recommendations of its applicability.

5.2.2 Implementation

Because the project could not be completed, the authors can make no specific recommendations for implementing this technology. A separate controlled study would be needed to fully demonstrate and validate the technology.

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Appendix A: Design for PARC Seawall Repair

Figure A1. Engineering drawings for PARC seawall repair.

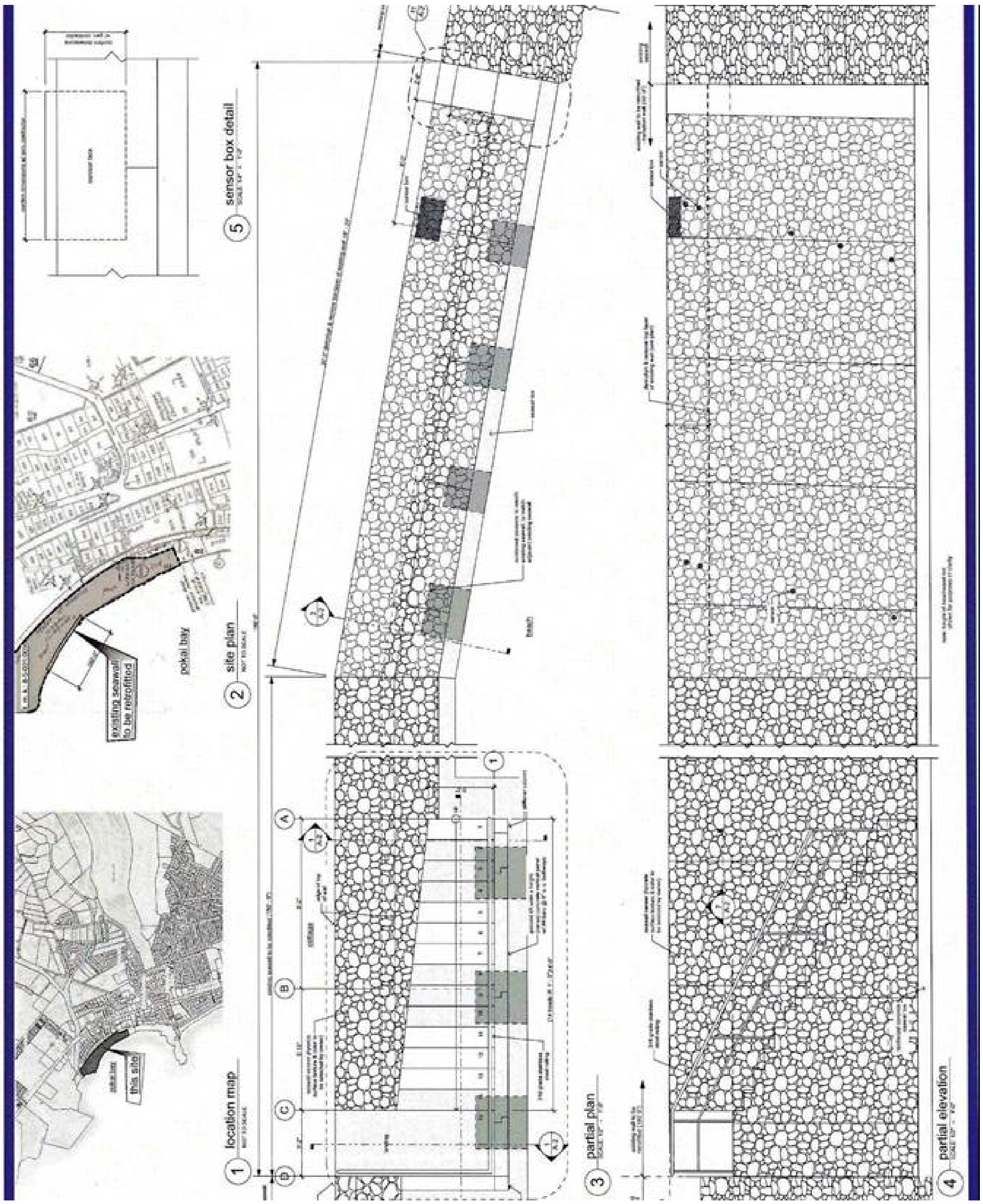
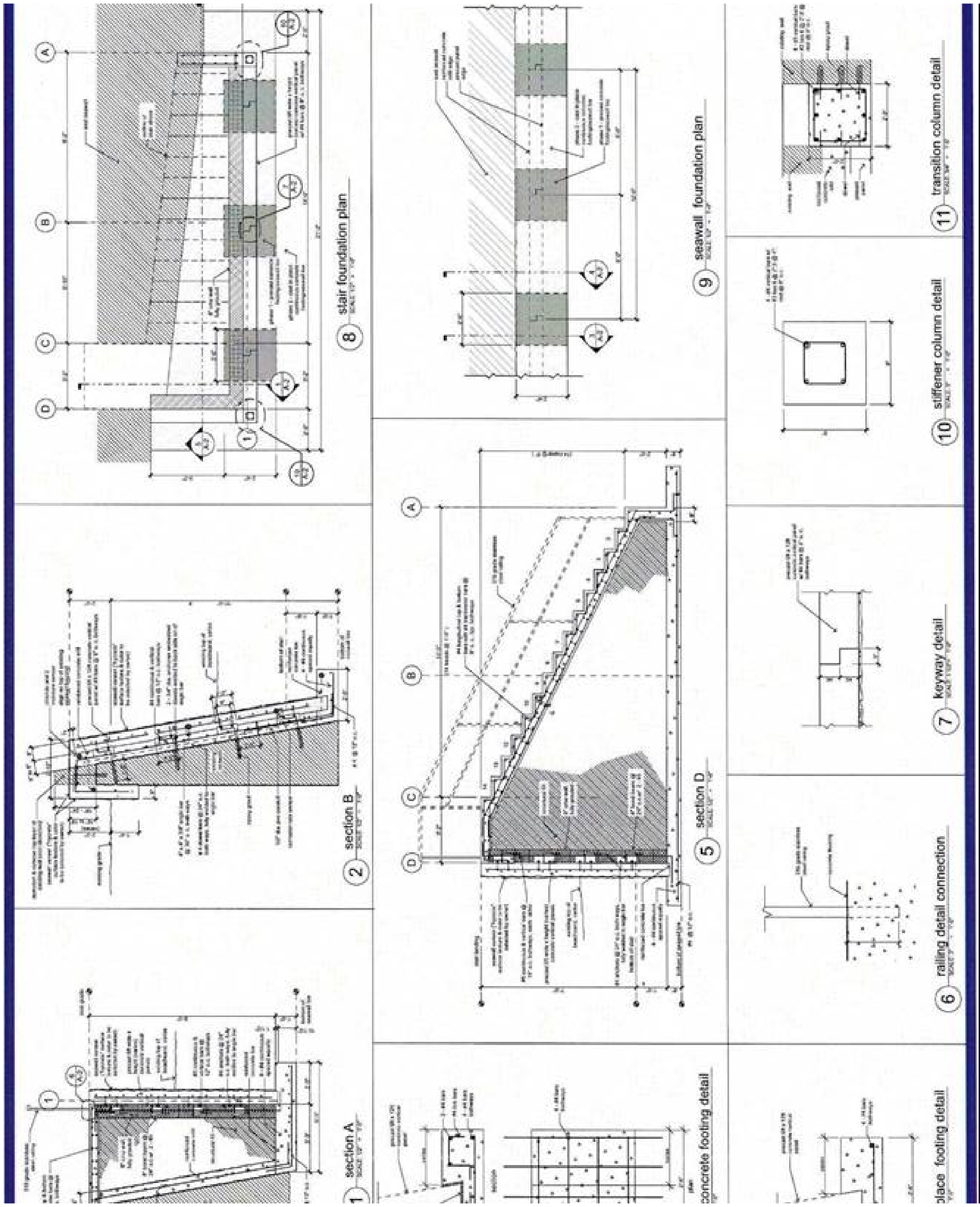


Figure A2. Continued engineering drawings for PARC seawall repair.



Appendix B: Revision of Seawall Design

Figure B1. Engineer drawing for seawall veneer anchoring.

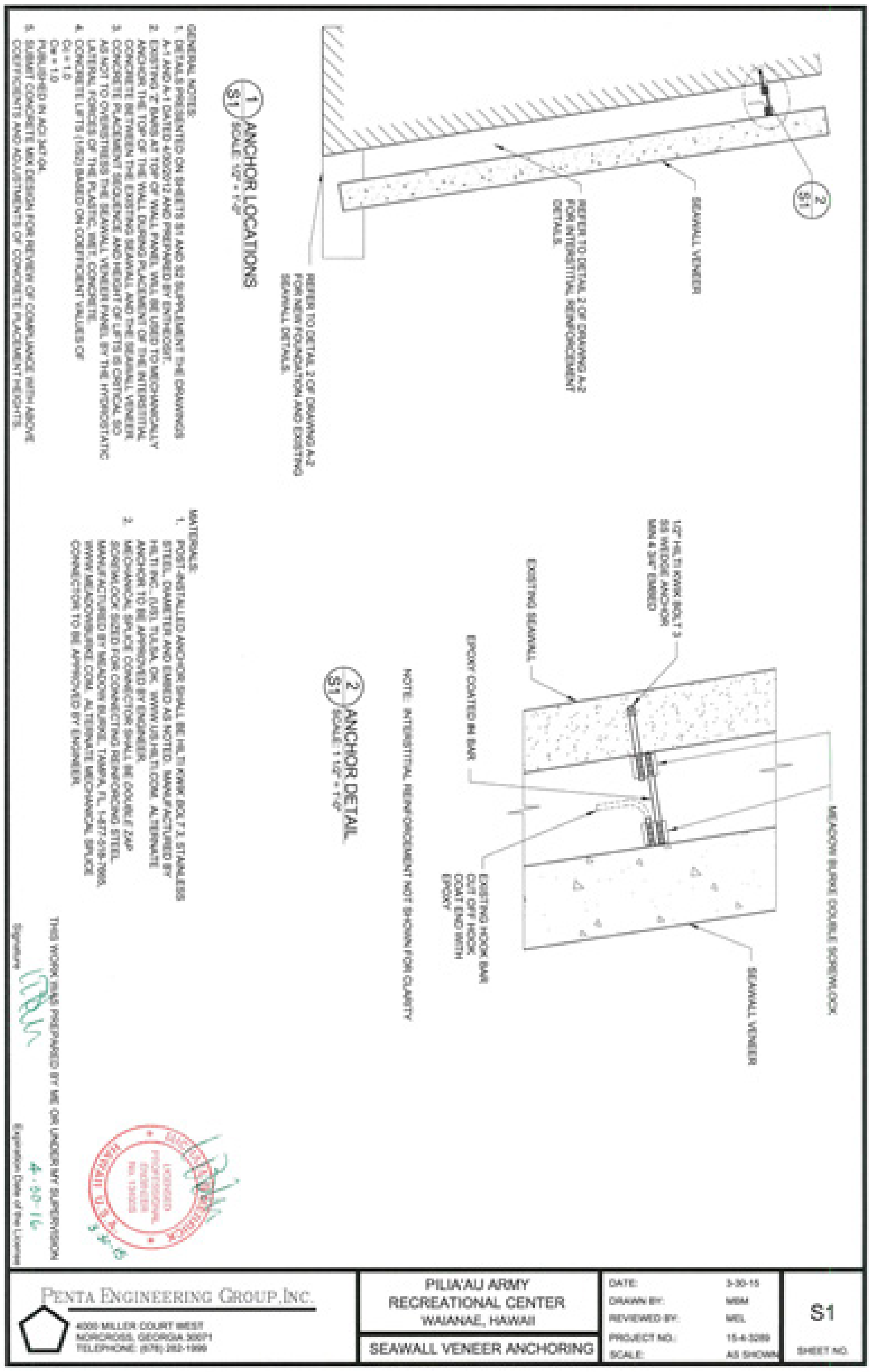
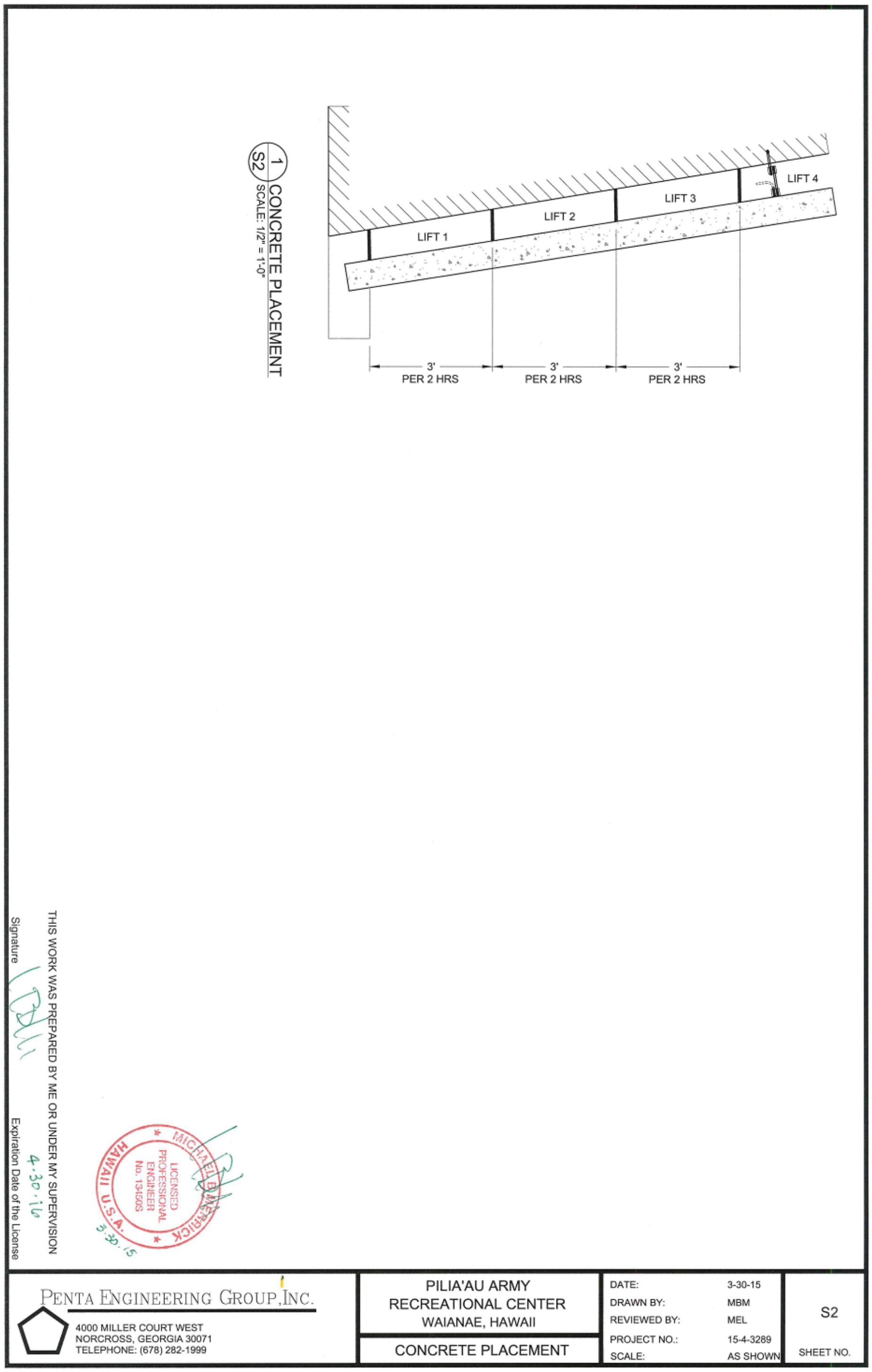


Figure B2. Engineer drawing for concrete placement.



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14. ABSTRACT

This Office of the Under Secretary of Defense Corrosion Prevention and Control Program project was to demonstrate the long-term performance of an ultrahydrophobic concrete additive that blocks water intrusion and chloride penetration into concrete. The proprietary additive was to be used to repair the seawall in a highly corrosive environment at Pililaau Army Recreation Center (PARC) in Waianae, Hawaii. The deteriorating stone seawall at PARC was to be covered in a concrete veneer with a new stair access to the beach, both using the waterproofing additive. Chloride, humidity, and corrosion rate sensors were placed in the concrete veneer panels and were to be monitored for two years.

Unfortunately, while the seawall veneer panels were completed, the government was unable to obtain necessary permits to allow excavation of the beach at the base of the seawall for construction of the footing. Even after it became clear that the work could not be completed under the contract for this project, the Corps of Engineers Honolulu District in Hawaii initiated their own project to complete the work by using the prepared veneer panels, but they also were unable to do so because of the permitting and environmental study requirements.

15. SUBJECT TERMS
Concrete—Corrosion, Seawater corrosion, Corrosion and anti-corrosives, Concrete—Additives, Waterproofing, Seawall, U.S. Army Garrison Hawaii, Corrosion Prevention and Control Program

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